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1968
WIHG

Annual Report

2011-2012

WADIA INSTITUTE OF HIMALAYAN GEOLOGY

(An Autonomous Institute of Department of Science & Technology, Govt. of India)

Dehradun

ANNUAL REPORT
2011-12

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RESEARCH ACTIVITIES

RESEARCH GROUPS

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

MISSION PROJECTS

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

UNITS ANCILLARY TO RESEARCH

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

ADMINISTRATION

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

EXECUTIVE SUMMARY

The Wadia Institute of Himalayan Geology (WIHG), named after late Dr D.N. Wadia, the doyen of Indian Geology, is a premier research Institution with the mandate of carrying out basic research to unravel the geological truth related to building and evolution of the majestic Himalaya, and improve upon the understandings of geodynamic processes, climate-tectonic interactions, evolution and extinction of life, processes of ore formations, glacier melt water contribution to river systems as well as providing ways to connect with natural hazards and foster sustainable and secured living in the Himalayan region. The contributions made by the Institute are widely recognized and as such has acclaimed reputation of internationally known center of excellence for researches aimed to unfold the orogeny of the world's youngest and loftiest mountain system of the Himalaya. The major scientific programmes being pursued under the 11th Five Year Plan are focussed to address special scientific themes in the form of Mission Mode Projects (MMP). The scientific activities during the Plan are centered on the following Mission Mode Projects:

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

The work carried out in each mission mode projects during the year 2011-12 are discussed in detail in subsequent sections, the salient achievements made in respective themes are summarized below.

Himtransects

Geo-electric model beneath the Bijnaur-Malari profile is developed using MT method. The study reveals mid-crustal ramp structure and identified presence of fluid/partial melt at shallow depth (10-15 km) which steeply dips beneath MCT zone up to a depth of 20 km.

The 3-D variation of shear wave velocity is investigated in the western Himalaya and adjoining Tibetan plateau through seismic tomography indicating a broad mid-crustal low velocity zone on the boundary of Himalaya and Tibet. The study also indicates increasing depth of Moho from south to north direction in this part.

Receiver function analysis at 17 broadband stations across NW Himalaya shows northward deepening of the Moho from ~45 km beneath Nahan to ~80 km beneath Ladakh region with prominent mid crustal low velocity layer (LVL) at 10-35 km depth beneath Ladakh. The LVL and high Poisson's ratio in Ladakh indicated the presence of fluid/ partial melt.

The existing stress regimes beneath the NW Himalaya are studied by stress tensor inversion of focal mechanism solution. The study reveals variation of stress pattern in different tectonic units of NW Himalaya.

The Mesoscopic and AMS studies carried out in the eastern part of Ladakh (Darbuk Pluton) reveal that the deformation/re-mobilization of the diorite and felsic magmatism is synchronous and orthogneiss show magnetic fabric. U-Pb geochronology of zircons from the diorotic gneiss gives a crystallization age of 63.8 ± 1.5 Ma and also shows younger zircon growth at ~50 Ma, ~30 Ma and down to ~13 Ma. Two-mica leucogranite sample from the Darbuk Pluton gives a common Pb chord lower intercept of 22.7 ± 0.5 Ma (MSWD = 1.8) with the five youngest concordant analyses yielding a $^{206}Pb/^{238}U$ age of 20.2 ± 0.4 Ma (MSWD = 1.14) that is interpreted as the age of crystallization of the Pluton. These findings imply that, contrary to previously believed ~15 Ma age of initiation for the Karakoram Fault Zone (KFZ), non-coaxial deformation in the KFZ continued throughout the Cenozoic (early Paleocene to mid-Miocene) until ~13 Ma.

Tangtse mylonites of KFZ show the significant role of the host minerals regarding fluid immiscibility. The compositional differences between these fluids and the associated metamorphic system indicate the presence of considerable amounts of salinity and CO_2, drives the immiscibility in fluids. This study shows that the dominance of two phases of fluid could coexist and widespread throughout the process of exhumation at the KFZ.

The xenoliths occurring in ~ 500 Ma old Kinnaur Kailash Granite in the Baspa valley record pre-Himalayan regional metamorphism ranging from amphibolite to granulite facies. The key evidence of granulite metamorphism is xenolith of twopyroxene mafic granulite with peak metamorphic condition of ~840ºC.

Climate-Tectonics Interaction

The evolution history of late Quaternary alluvial fans in the Soan Dun shows that in the southeastern part of the dun the aggradation phase initiated well before 55 ka and terminated around 29 ka, whereas in the northwestern part the aggradation phase continued till 10 ka due to continuous creation of accommodation space resulting from tectonic activity. In both the cases, the termination of sedimentation occurred under increased monsoon phases.

The reconstructions of late Cenozoic basin fill stratal architecture of the Siwalik succession in the Ravi re-entrant is used to understand the relative roll of tectonic, climate and geomorphic base-level changes. Large scale cyclicity of expansion and contraction of floodplain facies (ASD) tract which caused axial river facies (ARD) tract avulse to and fro to the basin margin and reflect systematic rise and fall of geomorphic base level. During base level rise (decrease accommodation space), ARD facies tract migrated toward farther edge of the basin in the area occupied by ASD facies tract. Considering these changes and two separate sediment supplied, source area suggest interplay of tectonic and climate within the Ravi-entrant.

An age-depth model has been developed for the Chandra Lake using new and previous ages. Based on these dates and various proxies including major and trace elements, Magnetic Susceptibility, Anhyreretic Remnant Magnetization, Saturated Isothermal Remnant Magnetization (SIRM) and Loss of Ignition (LOI), the paleomonsoon and winter and summer wind circulation for last 11 ka BP has been reconstructed.

Biostratigraphy & Biodiversity-Environment Linkage

The Bryozoan fauna from Pin area of the Spiti Basin section indicates Late Ordovician to Late Silurian age. It is equally present in Thango as well as in the Takche formations. The presence of brachiopods, bryozoans and calcified green algae in this succession suggest shallow marine to near shore environmental conditions. Based on the faunal elements from these formational units, Middle to Late Ordovician age can be assigned to Thango Formation and Late Ordovician to Silurian to the Takche Formation.

The present day distribution of modern taxa comparable to the fossil assemblage recorded from the Vagadkhol (western India) area indicate mostly terrestrial lowland environment. Low frequency of pollen of two highland temperate taxa (Pinaceae) in the assemblage suggests that they might have transported from a distant source. The wood and leaf taxa in the fossil assemblage are suggestive of tropical moist or wet forest with some deciduousness during the Paleoceneearly Eocene. The presence of many fungal taxa further suggests the prevalence of substantial humidity at the time of sedimentation. The recovery of reasonably well preserved plant remains from Vagadkhol has raised the hopes of finding Paleocene vertebrate remains.

Occurrence of structures resembling 'heterocyst' in cyanobacteria from slates of Narainnager Member of Krol Formation shows that aerobic conditions prevailed during deposition of the Krol Formation.

The andesites and rhyolites discovered recently between Precambrian Sirban Limestone and Early Paleogene Subathu Formation in Jammu region of J & K are important in understanding a) the timing of primordial collision of India with Eurasia, b) hiatus between Subathu and Sirban Limestone and c) their economic potential.

Sustainable Natural Resources

Fluid inclusion and Laser Micro Raman Spectroscopy on phosphate mineral lazulite from the Main Central Thrust (MCT) Zone show disparity between high pressure during inclusion entrapment and later low pressure conditions during exhumation, and infers rapid uplift along the MCT. The derived TP estimate for lazulite formation in the MCT Zone is 520°C, 3.7 kb.

Recent fluid inclusion and Raman Spectroscopy on the fluids trapped in the gangue and sphalerite at Askot favour an interpretation that these are 'massive sulfide ores' related to a primary depositional submarine-volcanic-hydrothermal activity and overprinted by the synorogenic Himalayan event.

The relatively well defined geochemical trends obtained for the felsic volcanics (Siang window of the Eastern Himalaya), the progressive increase in REE concentrations, pronounced negative Eu anomalies, combined with results of the petrogenetic modelling support the idea that fractional crystallization process has played a major role during the evolution of these felsic volcanics. Geochemical characteristics of the felsic volcanics in conjunction with the geochemical data of the associated mafic volcanics strongly suggest that they were emplaced in an extensional tectonic environment.

The Manipur ophiolites hosts both refractory grade high-Al chromitites (0.46 < Cr# < 0.59) and metallurgical grade high-Cr chromitites (0.77 < Cr# < 0.79). The chromite compositions in the high-Al chromitites are characterized by low Cr_2O_3 content (39.42-44.64 wt.%), high contents of Al_2O_3 (20.80-30.23 wt.%), FeO (11.15-16.97 wt.%) and MgO (11.48-16.18 wt.%). Their chromite compositions in conjunction with the calculated $(Al_2O_3)_{melt}$ (14.00-16.34 wt.%) and the $(FeO/MgO)_{melt}$ (0.72-1.35 wt.%) values indicate that they were derived from the tholeiitic melt that formed at the mid-ocean ridge centre through low-degree partial melting.

The chemical data of Chorabari Glacier shows diurnal variation in Ca, Mg, Na, K, HCO_3, SO_4, pH and electrical conductivity. The diurnal variations in the magnitude and pattern of discharge, suspended sediment concentration, Ca, Mg, Na, K, HCO_3, SO_4, pH and electrical conductivity are indicative of timing of the meltwater transmission through the subglacial drainage. The major ions chemistry of the glacier melts suggest two major flow components i) A widespread distributed drainage system and ii) A more discrete channelised system incised either upwards into the basal ice layer or engraved into the underlying bedrock which transports meltwaters rapidly through the glacier.

Real Time Geology for Society: Coping with Natural Hazards

In a quest to document and understand the nature of earthquake precursors in the Himalaya, the Multi-parametric geophysical observations are recorded at Ghuttu in the Garhwal Himalaya. Through most modern and sophisticated eleven equipments, high quality data is generated at remote site in the seismically active region of the Garhwal Himalaya. The continuous data for the last four years (2007 2011) indicates feeble precursors in few parameters, however the co-seismic variations are recorded many times, which are only in case of moderate magnitude earthquakes occurred within 200 km distance.

The Himalayan Frontal Thrust (HFT) has been widely considered to be the southernmost active tectonic mountain front of the Himalaya. To understand the ongoing tectonics further, paleoseismological investigations carried out in the vicinity of the HFT system along the Himalayan front near Kala Amb, Himachal Pradesh have provided unambiguous evidences of at least two large magnitude earthquakes occurred in this region. An earthquake with 12 m or larger surface displacement and magnitude 7.6 or greater occurred in this region between 34.1 ka and 17 ka in the Late Pleistocene and another great earthquake recurred with 26 m or more surface displacement and magnitude of 8, 8.5 or greater between 5.78 ka and 2 ka in the Holocene.

Presence of large-sized coseismically induced sand-injection feature and its disposition recognized in the trench also suggests occurrence of large magnitude earthquakes in this region. The long term slip rate of the abandoned terraces due to the activity of the HFT is estimated to be 3.59±1.01 mm/yr or greater since Late Holocene. The present study is the first time report of explicit evidences for multiple large magnitude paleoearthquakes in the northwestern part of the Frontal Himalaya during Late Pleistocene and Holocene. The repeated reactivation of HFT substantiates high seismic potential of the Frontal Himalaya and calls for more extensive study of paleoearthquakes of this vastly populous mountainous region.

The seismicity of two earthquake swarms, occurring within 50 km across the Main Central Thrust (MCT) in Garhwal Himalayan region in a time interval of nearly one month during April and May 2009, has been revisited to look for precursory phenomenon before main event. Evidences like spatio-temporal pattern of background seismicity, stress development pattern, b-value, stress drop and prevailing seismotectonic environment has been considered to relate the swarm activity to be as precursory phenomenon to a bigger event. A preparation zone of 100x100 km^2 has been demarcated recognizing these swarms as precursors to moderate to great earthquake in the Garhwal Himalaya which lies in a seismic gap. The study recommends the usefulness of precursory phenomenon such as swarm activity to be used for future seismic hazard assessment of high seismicity area like Garhwal Himalaya.

Academic Pursuits

Under the on-going research programs pursued during the year, the Institute has published 67 research papers both in international and national journals and about 77 research papers are in press/communicated. In addition to this, 34 papers were presented in national and international seminar/symposia/workshop by the Institute scientists. Under human resource development more than 75 students (M.Sc./M.Tech.) from various universities were provided training on different aspects of Geology/Geophysics/ Instrumentation. Further, four Ph.D. theses have been awarded while three theses have been submitted for the award. The Institute continued to provide laboratory facilities to sister organizations and academic institutions, particularly to the students.

The significant contributions in the fields of Indian monsoon variability and Quaternary Geology led to the award/honour of 'Fellow of the Indian National Science Academy (INSA)', 'M.S. Krishnan Gold Medal' from the Indian Geophysical Union and the 'Young Researcher Award' by the Ministry of Mines.

The Institute brings out regular Himalayan Geology publications. During the year volumes 33(2) 2011 and 33(1) 2012 were brought out along with volume 17 of Hindi magazine Ashmika. To promote geoscience research in the Himalaya, the Institute organized, Workshop on the Himalayan Glaciers and the Community Responsibility (September 26 - 27, 2011), Indo Iceland workshop (October, 21 - 22, 2011) and International Conference on Indian Monsoon and Himalayan Geodynamics (IMHG 2011), November 2 - 5, 2011.

Other Highlights

In order to promote 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. 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. The Annual Report of the Institute for the year 2010-2011 was translated in Hindi and published in bilingual form. Hindi Pakhwara was celebrated from 14 to 28 September 2011 during which various competitions like essay and debate were organized.

Anil K. Gupta
Director

PROGRESS IN MISSION MODE PROJECTS

MMP -1 : HIMTRANSECTS

Component 1.1 : Multiple Geophysical studies for imaging deep Lithospheric structure Investigation beneath Himalaya

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

Subsurface resistivity characterization using magnetotelluric method

Recognizing that high resolution imaging of crustal structure is useful in establishing seismicity-tectonic linkage, the natural source magnetotelluric (MT) method is used for mapping deep structures of the Garhwal Himalaya in terms of electrical resistivity distribution. Knowledge of deep structure is critical in this area as the accumulated strain rates are adequate to drive the next great earthquake in this section of the Himalayan arc. Electrical resistivity by virtue of its sensitivity to interconnected fluids and temperature has proved potential marker of active dynamics and stress build up.

Joint inversion of TM and Tipper in the regional co-ordinate frame (N45W) provides subsurface image (Fig. 1) which correlate well with the observed geological and structural feature along the Bijnaur-Malari profile. Approximately 10 km wide MCT zone is seen as low resistivity steeply dipping structure, which flattens out further north to merge with the IC-LRL somewhere in the depth range of 20 km. Near surface high conductive feature in the MCT zone may be associated with the occurrence of conductive mineral phases like graphite and carbonates. The most dominant feature of the crustal-section is the inter-crustal low resistivity layer (IC-LRL). Trapping of low fractions of fluids, released by metamorphic dehydration reactions and/or tectonically induced neutral buoyancy are advanced as a mechanism for the formation of fluid-filled horizons at mid-crustal depths which can be detected as low resistivity as well as low velocity layer. The top of the IC-LRL in depth, dip and extent excellently traces the geometry of the seismically active detachment, defined as a boundary separating the top of the down-going Indian Plate with the overriding wedge of the Himalaya. Such fluid-filled porosities influence the rheological properties of the crust and, thus, resistivity sections deduced from MT surveys have become a useful proxy to map the brittle-ductile transition and provide an estimate of thickness of overlying brittle seismogenic layer. The presence of fluids in the mid-crust has strong influence on the rheological properties and dramatically reduce the shear strength of brittle-ductile transition, causing focusing of tectonic forces on such a plane. The alignment of hypocenters of large earthquakes on a planar surface is explained by this hypothesis. The alignment of 1999-Chamoli earthquake on the upper surface of IC-LRL along this profile is a further testimony to this hypothesis. The mapped geometry of IC-LRL shows discontinuous jump in depth coinciding with the Lesser Himalaya and Higher Himalayan Crystalline, which structurally can be visualized as ramp structure. The presence of such a ramp has been often invoked to explain concentration of low magnitude earthquakes to a narrow belt straddling the Main Central Thrust (MCT). In conclusion, it can be summarised that the imaged electrical resistivity distribution by MT survey

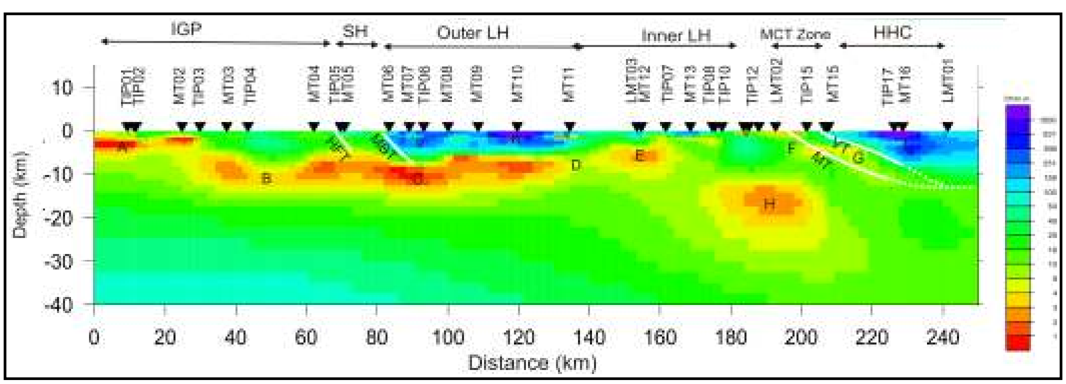


Fig. 1: Subsurface resistivity distribution along Bijnaur-Malari profile obtained after joint inversion of TM and tipper. RMS misfit is 2.1

in the dynamically active Himalaya, like many other parts of the world, has proved useful in constraining the tectonic evolution model of the orogen and more significantly it has imaged inter-connected fluidized zones beneath the seismogenic depths. Incorporation of the role of fluids on the rheology of crustal rocks, propagation of fluids to over pressurized shear zone can be a useful guide to understand the processes of seismogenesis, e.g. nucleation, rupture and triggering earthquakes and it thus helps in constraining the seismotectonic model of the Himalayan seismicity. It is suggested that future studies such as mapping and comparing the resistivity structure along different sectors may be able to provide new insight on the along-strike segmentation of seismicity and the structural diversity along the Himalayan arc. Further, monitoring temporal changes in measured MT responses from the large fluidized regions of the crust and their extension upward into the brittle crust could reveal measurable potential earthquake precursors.

Investigation of lithosphere structure in western part of Himalaya-Tibet tectonic zone

The 3-D variation of shear wave velocity in the lithosphere of western Himalaya and adjoining Tibetan plateau is investigated using Rayleigh wave tomography. The group velocity dispersion curves are obtained for more than 200 earthquakes (M4.5) originated in the Himalaya and Karakoram region. The seismic data of these earthquakes recorded by the broadband seismic instruments of the Wadia Institute of Himalayan Geology (WIHG) and some instruments of the Incorporated Research Institutions for Seismology (IRIS) network are used. The results reveal significant variations in the crustal velocity structure. Fundamental mode Rayleigh wave group velocities in the period range of 6-60 sec were measured using the Frequency-Time Analysis (FTAN) method. In the first step a 2D tomography methodology is used to examine the lateral variation of group velocities for different periods of waves selected between 6 and 60 sec. Very dense path coverage of dispersion curves is used for the earthquakes recorded at 35 broad band seismic stations. The average dispersion curves are inverted to obtain the shear wave velocity structure for the uppermost 85 km of the lithosphere of study region. In the upper part of the crust, low velocities are evident in the south-western and north-eastern parts of the study region in correspondence with the Northern Indo-Gangetic plain and the Tarim basin. Higher velocities are reported in the collision zone. South of the Karakoram Fault the upper crust is coupled with a very high velocity under-thrusting Indian plate. North of the Karakoram Fault, a thick mid-crustal low velocity layer is detected that is reaching up to a depth of 45 km with a lateral extent to the North up to the southern limit of the Tarim basin. This low velocity layer is sandwiched between a strong Indian lithosphere and a less strong Tarim block and extends to depths larger than 80 km. The in-depth extent of the low velocity zone beneath Tibet is interpreted as the broken part of subducting Indian plate. These results will shed new lights on the long-lasting debates regarding processes governing continental deformation of mountain ranges and the formation of the Tibetan plateau.

We inverted the average dispersion curves computed for 1°x1° cells using the Herrmann and Ammon (2002) methodology to obtain shear-wave velocity models for the crust and the uppermost mantle, corresponding to the first 85 km. The obtained shear

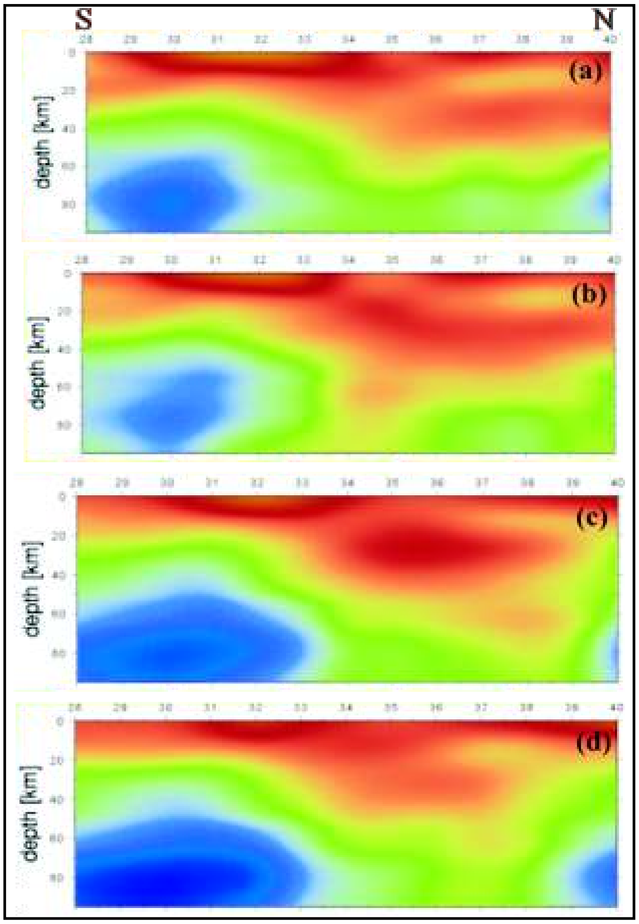


Fig. 2: Shear wave velocity structures obtained at (a) 73° (b) 74° (c) 75° and (d) 76° longitude cross-sections between 28° and 40° latitude passing through western part of the Himalaya and Tibet collision zone

wave velocity structure at different longitudes between 28° and 40° latitude are shown in figure 2. These maps clearly depict the northward dipping of the Indian Moho boundary starting from Indo-Gangetic plains.

Stress field in the Kangra-Chamba region of Northwest Himalaya

Fault plane solutions of 68 local events (for the period 2004-2009) and harvard CMT solutions for 50 earthquakes (1963-2011) were determined from northwestern part of the Himalaya to study the stress pattern and stress regime. Majority of fault plane solutions show thrust type of faulting with small amount of strike-slip motions. 15 fault plane solutions (FPSs) are showing normal faulting nature. The pressure and tension axes are determined from the Fault plane solutions and they are projected on the tectonic map. It is observed that the P-axes orientations are in NE-direction and the nodal planes are trending in NW-SE direction having conformity with the trend of major thrust/lineaments of the northwest Himalaya. The normal faults are concentrated in Kinnaur and northeastern corner of` Kumaun Himalaya bordering Nepal and Tibet. The nodal planes of Normal faulting events are trending in N-S direction with T-axes trending in E-W direction. This indicates the effect of E-W extension in these two regions. The stress tensor inversion study shows compressional

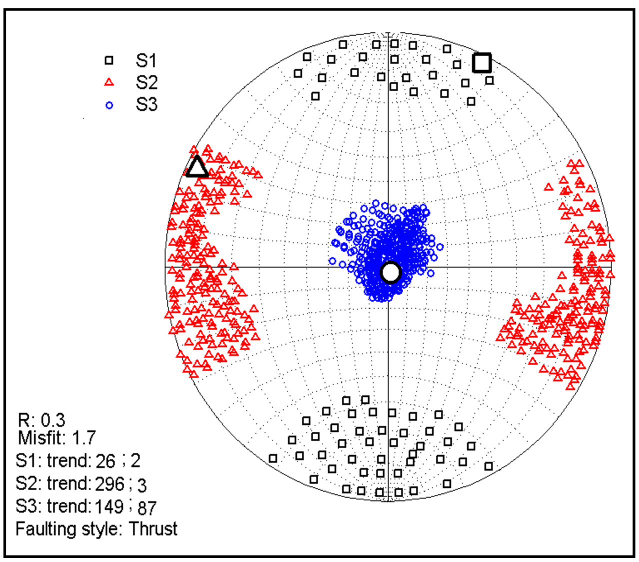


Fig. 3: The Stress Tensor Inversion result obtained using fault plane solutions for Garhwal-Kumaun region. The 95 percent confidence limits are defined by the black, red and the blue dots for the greatest (S1=σ1), intermediate (S2=σ2) and least (S3=σ3) principal stresses, respectively. The resultant maximum compressional axis orientation for this region is NNE-directed

regime for Kangra-Chamba and Garhwal-Kumaun region and extensional regime for Kinnaur region in the northwestern sector of Himalayan Arc. The stress tensor inversion result obtained from USGS fault plane solutions for Kumaun-Garhwal region is shown in the figure 3.

Crustal structure across a profile from HFT to Ladakh, NW Himalaya

During the period under review, the work is mainly focused on a ~450 km long profile of seismological stations starting from Nahan, Himachal Pradesh to Ladakh region (Fig. 4). Moho discontinuity and intra crustal layers beneath 6 seismological stations in Himachal Pradesh and 10 stations in Ladakh region have been mapped using P-wave receiver function (RF) method incorporating additional teleseismic data recorded till July 2011. Integration of the additional data set enhanced the confidence in results reported earlier and helped in critical examination of azimuthal variation of crustal structure. The data from Ladakh stations shows strong azimuthal variation in crustal structure. The waves piercing the region from NW show weak P-to-S Moho converted

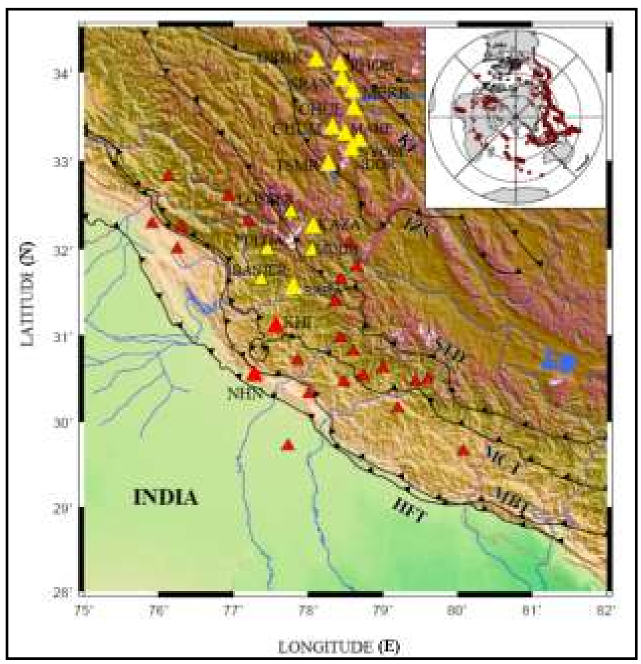


Fig. 4: Topographic map of NW Himalaya with major tectonic features e.g. Himalayan Frontal Thrust (HFT), Main Boundary Thrust (MBT), Main Central Thrust (MCT), South Tibet Detachment (STD), Indus Zangbo Suture (IZS), Karakoram Fault (KF) with locations of seismological stations (Triangles). The yellow triangles indicate completion of receiver function data analysis till 2011

phase (Ps), compared to the earthquakes arriving from other directions. The RF image of Tso-Morari station is complicated where Ps phase is ambiguous for the earthquakes arriving from all back azimuths. The inversion of RF data suggests dipping nature of Moho from ~45 km near HFT to 80 km near Pangong Lake (Ladakh). The Intra Crustal Low Velocity Layer (ICLVL) is prominent in Ladakh region within ~10-35 km depth. The Poisson's ratios are recalculated incorporating additional data and observed that it is higher in Ladakh (2.7-0.34) compared to Himachal and Garhwal Himalayas (0.25-0.26). The existence of low velocity mid-crustal layer and high Poisson's ratio of crust suggest presence melts or aqueous fluids.

Crustal anisotropy beneath Ladakh Seismological stations

Broadband seismograms of teleseismic earthquakes (M $\geq$ 5.5, epicentral distance: 30°-90°) from 10 seismic stations located in Ladakh, were analyzed to determine the anisotropy characteristics of the underlying crust, orientation of the axes of symmetry and the degree of anisotropy. Radial and transverse receiver functions of about 50 earthquakes are analyzed to find splitting parameters using cross-correlation technique (Bowman et al., 1987, *Astron. Soc.* 88, 25-41). Analysis of the split measured in the deconvolved radial and transverse *P*-to-*S* converted components from the Moho discontinuity indicates that the anisotropic axis lies approximately NW-SE with a split-time within the range 0.34-0.45 s (Fig. 5). Observed directions of the vertically averaged anisotropy are in reasonably good agreement with the geologic features of the region, although not necessarily conforming to the plate velocity, indicating that their sources lie in the stress/strain fields accumulated in the crust.

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)

Synchronous deformation and magmatism in the Pangong Transpression Zone, Eastern Ladakh, India: Implications for age of initiation of the Karakoram Fault Zone

In the eastern part of Ladakh, the dextral strike-slip Karakoram Fault Zone (KFZ) bifurcates into two

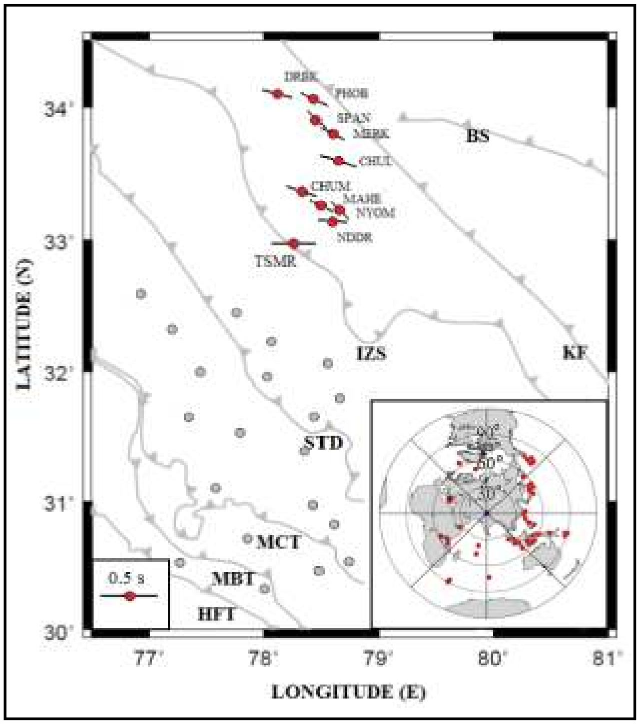


Fig. 5 : Tectonic features of the study region with broadband seismological stations operated by WIHG, Dehra Dun (circles). The red filled circles indicate the seismological stations at Ladakh region used for crustal anisotropy study, the orientation and bar (black) indicate average fast polarization direction and splitting delay time respectively. The inset map (right bottom) shows locations of earthquakes used in this study

strands called as Pangong Strand and Tangtse Strand. The region bounded by these two strands is called the Pangong Transpression Zone (PTZ) and it consists of diorites, which have transformed to migmatite, orthogneiss and a pluton of two-mica leucogranite called as the Darbuk Pluton. Mesoscopic foliation of gneisses is steeply dipping to near vertical with a strike (~140° -150°) parallel to the regional trend of the KFZ. Mylonites indicate a dextral, top-to-the south sense of shear. Mesoscopic evidences also suggest that deformation/remobilization of the diorite and felsic magmatism is synchronous. Anisotropy of Magnetic Susceptibility (AMS) reveals concordant mesoscopic and magnetic fabric for the orthogneiss. However, the magnetic fabric of the two-mica leucogranites at the centre of the Darbuk Pluton is oriented at a high angle to the regional trend of the KFZ. U-Pb geochronology of zircons from the diorotic gneiss gives a crystallization age of 63.8 ± 1.5 Ma and also shows younger zircon growth at ~50 Ma, ~30 Ma and down to ~13 Ma. One two-mica leucogranite sample from the

Darbuk Pluton gives a common Pb chord lower intercept of 22.7 ± 0.5 Ma (MSWD = 1.8) with the five youngest concordant analyses yielding a $^{206}Pb/^{238}U$ age of 20.2 ± 0.4 Ma (MSWD = 1.14) that is interpreted as the age of crystallization of the pluton. These findings imply that, contrary to previously believed ~15 Ma age of initiation for the KFZ, non-coaxial deformation in the KFZ continued throughout the Cenozoic (early Paleocene to mid-Miocene) until ~13 Ma. The Darbuk Pluton is syntectonic with this deformation event and was emplaced in a dilational zone within the PTZ.

Signature of fluid immiscibility and deformation textures in Karakoram Fault Zone mylonites

In nature, certain fluid system rich in volatile components behave immiscible (heterogeneous or multiple coexisting fluids) and other show completely miscible (a single homogeneous phase) at varying temperature and pressure condition. Such complex behavior of fluids has recently been examined in Tangtse mylonites of KFZ. Tangtse mylonites show the significant role of the host minerals regarding fluid immiscibility. These immiscible fluids are preserved within plagioclase and quartz grains. The plagioclase grains preserve magmatic fabric in the form of oscillatory zoning, and this possibly formed during crystallization at a temperature of ~650°C. The compositional differences between these fluids and the associated metamorphic system indicate the presence of considerable amounts of salinity and CO_2 drives the immiscibility in fluids. This study shows, the dominance of two phases of fluid coexists and are widespread throught the process of exhumation at KFZ. Consequently, the late entrapment of saline aqueous mixture became the most dominant fluid system, when the KFZ mylonites had undergone greenchist metamorphism. At this stage, the saline aqueous fluid system behaves miscible. Though, presumed trapping condition of brine and carbonic - rich inclusions implies that the fluid system was immiscible at elevated pressure-temperature condition. Tangtse mylonites yielded a low argon mica fluid partition coefficient and this applied to explain the sudden drop in pressure in the system. This favors the production of reequilibrated texture e.g. satellite, decrepitation, stretching. These microstructures have commonly been observed in regards to the volume changes of fluid inclusions due to differential pressure and are controlled by the mechanical strength of the host mineral. The differential pressure is built up when the pressure-temperature path of the host rock does not follow the isochore. Result irreversible deformation takes place, and the force at the inclusion wall created by this differential pressure exceeds the strength of the enclosing crystal. In KFZ rocks, two patterns of failure of the fluid inclusions are noticed: (i) at lower temperatures, yielding can take place by brittle failure, generally referred to as 'decrepitation' and (ii) at comparatively higher temperatures, yielding can occur by plastic creep of the enclosing crystal referred to as 'stretching' as 'reequilibration'. Decrepitation can be inferred from the presence of characteristic microstructures. Diagnostic features are highly irregular shapes of inclusion, radial cracks originating from the inclusion and healed fractures outlined by small 'satellite' inclusions. The studied microstructure criteria of fluid inclusions in the KFZ mylonites have shown considerable difference in densities at lower temperature. And this later favors the appearance of second stage of immiscibility can thus be partly explained at KFZ.

The ophiolitic mélange representing unavoidable circumtances the Neo-Tethyan ocean floor in the Ladakh region is the characteristic feature of sutured Plate junction define the southern limit of the Indus Suture Zone (ISZ), was considered to form as the result of a single eastward progressing collision event initiated in late Paleocene to early Eocene time. The ISZ is a welded plate junction between the Indian and Tibetan-Karakoram blocks. The different episodes of ophiolitic mélange within the ISZ of NW Himalaya were emplaced as a result of India - Eurasian plate convergence and eastward progressing collision boundary initiated in Late Cretaceous. The study exhibits that the ophiolitic mélange obducted on to the surface at least in three stages; Initially as the Sapi-Shergol Ophiolitic Melange (S-SOM) in western Ladakh during latest Cretaceous to early Paleocene time and then Khalsi Ophiolitic Melange (KOM) in Central Ladakh during early Eocene and finally as the Zildat Ophiolitic Melange (ZOM) in southeastern Ladakh during late Eocene to Oligocene time respectively in space and time, indicates diachronous nature of ISZ between the Indian and Tibetan-Karakoram blocks from west to east. The re-aligned collision boundary generated due to anticlockwise rotation of the Indian Plate and simultaneous eastward welding of India-Asian plates. The Nidar Ophiolitic Complex (NOC) to the north of the ZOM exhumed at a faster rate between the Mahe Thrust and Chulse Thrust along with arc trench gap sediments of the Indus Formation of the Ladakh Group during Miocene time in the terminal stage of the India - Asia collision in NW Himalaya. Western extention of NOC obliquely cross cut the flysch and mollasse of the Indus Formation of Ladakh Group indicate its late Eocene-Oligocene emplacement.

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)

Composite mesoscopic and magnetic fabrics of the Paleo-Proterozoic Wangtu Gneissic Complex, Himachal Himalaya, India: Implications for ductile deformation and superposed folding of the Himalayan basement rocks

The study demonstrates how the Paleo-Proterozoic Wangtu Gneissic Complex (WGC) of the Lesser Himalayan Crystalline sequence experienced superposed folding and doming prior to its exhumation, with the help of integrated field, microstructural, magnetic fabric anisotropy and geochronological studies. The WGC forms basement of the Lesser Himalaya and is bounded by Vaikrita Thrust (VT) to the northeast and Munsiari Thrust (MT) to the southwest. The regional structure consists of upright large scale early folds (D1) trending NW-SE. The mesoscopic fabric is related to axial plane foliation of the D1 folds and, to a lesser extent, late D2 folds. The axes of maximum compression for D1 and D2 folds are mutually orthogonal. The D1 folds have formed simultaneously with the major Himalayan thrusts, whereas the D2 folds have developed during a later deformation event. The magnetic lineation at the hanging wall of the VT is sub-horizontal indicating stretching along the strike of the thrust. In the interior parts of the WGC, the magnetic fabric are of two types: (i) magnetic lineation demarks the intersection of mesoscopic and magnetic foliation indicating superposed deformation and (ii) scattered distribution of magnetic lineations due to D2 folding on initially curved and non-cylindrical D1 surface (Fig. 6). ^{40}Ar-^{39}Ar dating of biotite from one sample from the core of WGC gives an age of 9.3 ± 0.3 (2σ) Ma. It is inferred that the doming of the WGC took place at ~9 Ma and instead of large scale thrusting, it is characterized by superposed folding and strike-parallel stretching along the VT zone. It is suggested that the effect of superposed folding and ductile deformation of the Himalayan basement rocks has to be taken into account before cross-section balancing or any estimation of crustal shortening is attempted.

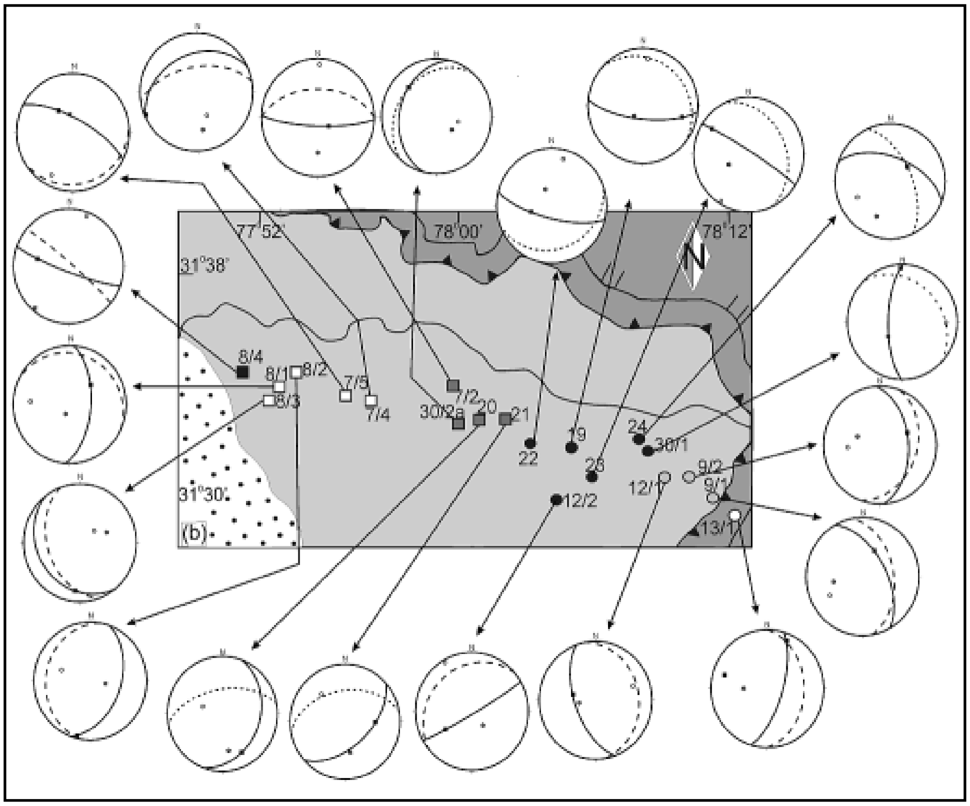


Fig. 6: Map showing composite mesoscopic (broken line) and magnetic foliation (solid line) and magnetic lineation ('star') of the WGC. Open circles are pole to mesoscopic foliation and filled squares are pole to magnetic foliation. Different symbols of sample locations are for different zones

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)

Extensive geological research during the last three decades makes the Lesser Himalayan belt one of the well-documented Proterozoic sedimentary basins. The Lesser Himalayan (LH) is a terrane, documented a complex tectonic history for a span from Palaeoproterozoic era to Tertiary period. The Lesser Himalaya bounded in the north by Main Central Thrust (MCT) and Main Boundary Thrust (MBT) in the south. This sequence consists of Proterozoic sedimentary to meta-sedimentary (low-grade metamorphics), metavolcanic rocks and crystalline klippe which were deposited on the northern margin of the Indian craton. Uniqueness of the Lesser Himalayan domain lies from the other Proterozoic basins of Indian sub-continent as being suffered the Tertiary Himalayan Orogeny and thus the basin genesis aspects of these sedimentary packages is convoluted. In spite of the severe deformation, the sediments still have preserved the signatures of numerous geo-tectonic events and different phases of basin genesis. The basinal evolutionary history of the Lesser Himalaya is masked by green schist to upper amphibolite facies metamorphism particularly the thrust sheet covering the autochthonous and para autochthonous units and structures that formed during intense shortening of the Tertiary Himalayan Orogeny. Structural and stratigraphic relations of the Lesser Himalayan gneisses (Crystalline Klippen) of the Garhwal Himalaya indicate that it represent(s) an older basement sliver, which is tectonically emplaced within the cover sequence as wedges at different structural level. In totality, Ediacaran (between 650-542 Ma) part of the Lesser Himalaya is relatively fairly constrained and understood in terms of litho- and bio-stratigraphy, sedimentology, structure, tectonics and isotopic constrains. However, pre- Ediacaran part is least attended owing to some inherited geological problems.

During the period, the work is mainly focused on the basin genesis aspect of Proterozoic clastic and associated volcanic succession of the Lesser Himalaya using sedimentological, petrographical and geochemical data sets. In the current year, we have focussed our work on the compilation of the data sets generated during last four years 2007-11. The study led us to some significant understanding of the Lesser Himalayan basin aspects which are coined below:

- The Palaeoproterozoic Damtha Group of the Garhwal Lesser Himalaya, an argillite - siliciclastic shallow marine succession associated with mafic volcanics possibly represents the oldest sedimentary rocks exposed in the Himalayan orogen. The widespread occurrence of seismites in the comparable sections over large spatial distances (~150 km) and association with syn-sedimentary Palaeoproterozoic mafic volcanics point towards a regional triggering agent like frequent earthquakes. The gradual change from argillite dominated to siliciclastic dominated succession with sub-aerially erupted syn-sedimentary volcanism and the occurrence of seismites and pebble bed at the upper part of succession suggestive of deposition in unstable shallowing upward basins. The occurrence of rift related volcanics coupled with non-steady state weathering condition indicate active tectonism during Paleoproterozoic time.
- Comparing the petrographic data of the siliciclastics of both the zones suggests that the Outer Lesser Himalaya (OLH) siliciclastics are relatively rich in rock fragments, whereas Inner Lesser Himalaya (ILH) is rich in feldspar. The decrease in grain size towards north favors southerly source and therefore ILH may possibly be a part of the distal end of the shallow sea.
- The geochemistry of the Lesser Himalayan sediments shows illite control that gets diluted with increasing quartz content. Majority of the arenaceous sedimentary rocks exhibit presence of plagioclase, K-feldspar and clay minerals, but lack ferromagnesium minerals which indicate decomposition of feldspar but greater decomposition of ferromagnesium minerals. High Zr and Th contents and Th/Ni, La/Sc and $(La/Yb)_N$ ratios as well as Sc vs Th/Sc relationship indicate a dominant felsic source for these rocks.
- The basic volcanic rocks are mainly associated with Nagthat Formation of Outer Lesser Himalaya and Rudraprayag Formation/ Rautgara Formation of Inner Lesser Himalaya. These basic volcanic rocks range in composition from sub-alkaline

basalt through andesite to andesitic basalt. Chondrite normalized REE plot of Nagthat (OLH), Rudraprayag (ILH) and dykes (Pithoragarh) exhibit remarkable similarities and are enriched in LREE and relatively flat HREE pattern along with a weak negative Eu anomalies.

- Structural and stratigraphic relations of the Lesser Himalayan gneisses (Crystalline klippe) of the Himalaya indicate that it represent(s) an older basement sliver, which is tectonically emplaced within the cover sequence as wedges at different structural level.
- Until recently, geochronological constraints of the Blaini Formation of the Lesser Himalaya have remained poor, but new detrital zircon ages from diamictite samples provide a maximum age limit of 692 ±18 Ma (^{207}Pb/^{206}Pb).
- The Proterozoic Lesser Himalayan basin genesis visualizes that the early rifting episode in Bundelkhand block is preserved as penecontemporaneously deposited volcanic and siliciclastic sequence in Lesser Himalaya.

Component 1.4b :
Geochemical and isotopic studies of source rocks and riverine phases in the head waters of the Indus and Ganga: Implications for weathering and erosion in the North West Himalaya

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

Geochemical and Isotopic studies of hydrothermal springs in the NW Himalaya have been conducted to address the questions including: (1) how the Himalayan orogeny influences the long term CO_2 concentration of atmosphere through its degassing during the processes of metamorphism (2) whether it is significant in comparison to the weathering of silicate rocks in the Himalaya. About 40 water samples from geothermal springs and 46 from nearby rivers were collected from the Main Central Thrust (MCT) zone of the Himalaya (Garhwal, J&K, Himachal Pradesh) and were measured for their isotopic (^{13}C of DIC, ^{18}O) and geochemical compositions (major ions and trace elements) to estimate the CO_2 flux originated due to Himalayan metamorphism. This process acts as source of CO_2 and has important bearing on the past climatic variation and will be helpful to compare with other processes which act as a CO_2 sink like silicate weathering. The ^{13}C of Dissolved Inorganic Carbon (DIC) and ^{18}O of these springs were determined in the Isotope Ratio Mass Spectrometer (IRMS) Laboratory at Wadia Institute of Himalayan Geology, Dehra Dun. Preliminary results show that there is a strong variation (-8.5‰ to +4.0‰ $_{(PDB)}$) indicating the varied sources of their origin. The higher ^{13}C of DIC indicate a deeper origin for these springs.

Component 1.5 :
Geological and geophysical characteristics of Malari and Lower Palaeozoic Kinnaur Kailash Granites

(S.S. Thakur, Santosh K. Rai, Koushik Sen and Gautam Rawat)

Component 1.5a :
Analysis of geological and geophysical characteristics of the Malari Leucogranite, Garhwal Higher Himalaya: Evaluating the effect of Channel Flow along the South Tibetan Detachment

(S.S. Thakur, Santosh K. Rai, Koushik Sen and Gautam Rawat)

Metamorphism of MCT Zone

The Main Central Thrust (MCT) which separates the Higher Himalayan Crystalline Sequence (HHCS) from the Lesser Himalayan Sequence (LHS) occurs in the form of shear zone in the Alaknanda valley and is commonly referred to as MCT shear zone. The shear zone consists of mica schist and pelitic schist with minor quartzite bands. Within the MCT zone metamorphic grade gradually increases from chlorite-biotite grade at lower structural level to garnet grade at higher structural level. Brittle shearing has been observed in the rocks at the lower structural level, whereas rocks at higher structural level have deformed by ductile shearing. Field observations and petrographic study show that rocks have deformed with top-to-southwest shear sense. At higher structural level, garnets occur as porphyroblast with curved or spiral inclusion trails. These commonly contain inclusions of ilmenite, quartz, biotite and chlorite. Most of the garnets show chemical zoning of spessartine content which decreases from core to rim. P-T calculation shows that garnets are prograde in nature and attained the peak metamorphic temperature at about 550ºC and pressure of ~8 Kbar.

Geophysical Observations

In order to understand geophysical characteristics of the Malari granites Magnetotelluric (MT) transfer function at five places namely Tapovan, Lata, Jumma, Malari and Farkyan are obtained utilizing Welch overlapped section averaging with robust approach based on Huber regression M-estimation. Dimensionality analysis indicates that out of five sites, four sites can be considered for 2-d regional electric resistivity distribution for period band 1000 Hz to 100 sec, whereas the fifth site namely Farkyan and all sites for periods greater than 100 sec show higher order resistivity distribution. Computation feasibility and observational limitation do not allow MT transfer function modeling for three dimensionality or anisotropic behavior at this juncture.

Component 1.5b :
Study of Himalayan metamorphism in the Satluj River valley of Himachal Himalaya

(S.S. Thakur)

The xenoliths occurring within the early Palaeozoic Kinnaur Kailash Granite (KKG) in the Baspa river valley, NW Himalaya record pre-Himalayan regional metamorphism at range of pressure (P)-temperature (T) conditions that span amphibolite to granulite facies. The key evidence of granulite metamorphism is a xenolith of two-pyroxene mafic granulite in which orthopyroxene occurs as both discrete grains and microscopic needles exsolved parallel to prismatic cleavage of the clinopyroxene host. The rock records the peak metamorphic temperature of ~840ºC. Garnetiferous mafic xenoliths display coronae of garnet around plagioclase and clinopyroxene and of sphene around ilmenite. These coronae were developed by near isobaric cooling after peak metamorphism at ~730ºC and 8 Kbar. Pelitic xenoliths have the assemblage biotite-plagioclase-quartz± garnet± K-feldspar± muscovite and record P-T ranges of 7.0-9.0 kbar and 500-700ºC which indicate lower to middle amphibolite facies metamorphism of these rocks. Quartz, feldspar and mica in the pelitic xenoliths commonly show optical evidences of crystalloplastic deformation which indicate that the rocks were sheared before being engulfed as xenoliths in the KKG. The findings of this study imply that the present day metamorphic assemblages and shear fabrics in HHCS rocks need not be attributed solely to the Himalayan orogeny.

Component 1.6 :
Thrust zone geochemistry, fluid-rock interaction and mineralogical studies - implications for tectonic evolution in Uttaranchal Himalaya

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

Data generated on the Ramgarh Granite gneisses were synthesized during the year. It was observed that the granitic rocks on the hanging wall of the Ramgarh Thrust were sheared and phyllonitized with minimal mass transfer (volume reduction -10-15%), in contrast, the Nagthat quartzite on the foot wall were sheared and phyllonitized through extensive mass transfer (60-80% volume loss) mainly by dissolution of silica under presence of plentiful of fluids.

The REE chemistry of the quartzite and granitic gneisses and their derivative mylonites and phyllonites are nearly indistinguishable. Further, presence of euhedral zircons as inclusions in detrital quartz and the trace element characteristics of zircon grains suggest a purely igneous provenance. In view of the recent hypothesis that the northern tip of the Indian plate represents an active margin set-up of a paleo-Proterozoic Arc and the entire Lesser Himalayan rocks seem to be volcano-sedimentary in nature and probably suggestive of paleo Proterozoic Arc tectonic set-up. The geochemistry of meta-sedimentary sequence of the Lesser Himalaya realised through geochemical study of the low order stream sediments earlier, were revisited in above context.

The trace elemental abundances and ratios are similar to arc magmatic signatures. Abnormally high Cr (median: 271 ppm as against 185 ppm in bulk crust) and strongly depleted Sr (median 62 ppm as against >300 ppm in the bulk crust) strongly refute a continental crust derived provenance for LHSS. Y-Nb plot illustrates strong positive correlation, with a very monotonous Y/Nb ratio of 0.49 (± 0.14), also comparable to arc magmatic trend. Together with high LILE, low Ti & Nb, the stream sediment compositions mostly cluster within or near the boundary of arc related fields in the tectonic discrimination diagrams. Negative Nb anomalies signature has so far been attributed only to subduction-related magmas and the continental crust. Trace element characteristics differ markedly from typical pelitic compositions and resemble more closely to a subduction related continental arc magmatic source (volcano-clastic sedimentary) that are not expected in sediments derived from continental crust. Present study, therefore, supports an active margin set-up for deposition of LHSS and coeval igneous rocks rather than a passive margin believed hitherto.

Field work was also carried out in the Uttarkashi-Gangotri-Barkot area (Bhagirathi and Yamuna valleys) with the aim to understand the mineral chemistry of granites and P-T estimates of the Higher Himalayan Crystallines. Computations of errors in P-T estimates by the Monte Carlo Method, Numerical error propagation technique and High-Precision Relative Thermobarometry (ΔPT) approach is carried out. An important limitation of Monte Carlo technique is that correlation of errors is not accounted. Numerical error propagation technique can be applied to complex problems, as in geothermobarometry, where analytical procedures are difficult due to complex mathematical relations, and is faster and more informative than a Monte Carlo method. Since we are interested in calculating pressure and temperature variations, or differences in P-T (ΔPT), therefore, the contribution of systematic uncertainties e.g. those associated with a-x models and thermodynamic data can be minimized by the High-Precision Relative Thermobarometry (ΔPT) approach. Computations on estimation of uncertainties on P-T estimates from Higher Himalayan Crystalline zone of the Garhwal Himalaya was done using Monte Carlo method and numerical error analysis. Application of rigorous error analysis in geothermobarometry will provide a better appreciation of the uncertainties in P-T estimates and thus will lead to a better understanding of tectonic processes.

Component 1.7 :

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

(Keser Singh)

The crystalline rocks of the Himalaya, in general, (High Himalayan Crystallines, Central Crystallines etc.) are bounded above by the Zanskar Shear Zone/Trans Himadri Fault System and below by the Main Central Thrust (MCT). South and tectonically below the MCT lies the Lesser Himalaya comprises the low grade meta-sedimentary succession and the crystallines klippen. North and tectonically over the Zanskar Shear Zone lies the sedimentary succession of the Tethys Himalaya.

Defying this normal set-up, however, a different geological setup to the northwest of Beas valley, where the Tethyan rocks, to a large extent, placed either in contact with the Lesser Himalayan thrust sheets or surrounding the Higher Himalayan Crystallines (HHC). This is documented around areas comprising Chamba, Kishtwar and Zanskar regions in the northwest Himalaya. The geometric relationship of the regional-scale SW-vergent Chamba syncline and the NE-vergent Tandi syncline occurring within the Tethyan rocks, south of the HHC, remains unexplained so far. Till now no satisfactory account has been put forward to explain the NE vergent Tandi syncline in the context of dominantly SW-directed, synmetamorphic folding and nappe thrusting in the Himalaya. Of late, a new deformation event i.e. the NE directed deformation was introduced which was thought to precede the main SW directed Himalayan deformation to explain such structure. Lack of definitive evidences of such a deformation phase prior to the main SW-directed deformation renders this proposition debatable. Attempt has been made to explain such regional folds with vergent in opposite direction in the realm of the SW directed Himalayan deformation.

MMP - 2 : CLIMATE-TECTONIC INTERACTION

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

(M.P. Sah and A.K.L. Asthana)

During the year emphasis was given to synthesize the data on the evolution of the Quaternary sequences in the Ladakh-Lahaul-Spiti. Tsokar basin in Ladakh is the single largest basin in which Quaternary sedimentation occurred. The Spiti basin has traces that witnessed the lacustrine deposition during this period. The age of the Tsokar basin estimated from uniform sedimentation rate, available radiocarbon date and depth profile works out to be around 0.65 million years. In contrast, the age of 50,000 years BP or so although this seems to be at variance considering reported TL date at around 10,000 year BP for the Kioto lake sequence as against 45,000 years BP or so earlier based on varve count for the timing of the development of this lake.

The sediment build up exposed in non-lacustrine environment in the upper Spiti valley has revealed periodic changes in facies development like fluvial, swampy, aeolian etc. The swampy facies rich in radiocarbon material have been dated and also studied for the pollen assemblages. In general, environmental change in the region is visible which has further been augmented by human colonization of the area. According to field observations collected earlier the alluvial fan pockets in the Spiti valley in particular were adequately vegetated but have been decimated since the dawn of inhabitation several centuries ago. The removal of forest cover in the alluvial fan terrain has led to depletion of water resources in otherwise cold and dry region. The temperature in the Spiti valley is showing changes with the minimum temperature reflecting diminishing trend. This may be due to the changes in the system at both the regional and global levels.

The main Spiti valley was carved by the advancement of the glacier between Kaza to Sijling as indicated by its wide-open and straight outline in this section and the presence of till-like deposits upstream of Sijling. Once the glacial retreat reached its present position tectonic activities led to the impoundment of the valley bottom to eventually convert it into long time ranging lacustrine sedimentation. The fluvial and lacustrine sediments are in abundance upstream of Sijling without exposing the bedrock in the thalweg while downstream of this point, Spiti has carved a deep gorge in the parent country rock following a transverse fault development. The geomorphic record indicates that Late Quaternary tectonics has been responsible for the migration of river courses in the Ladakh-Lahaul-Spiti region. Evolution of alluvial fans along the tributary streams of the Spiti river as also the overlooking hills slopes indicates a revealing environmental change during the Quaternary period in terms of recession of snow/glacial cover to pave way for the vigorous frost action and fluvial erosion and deposition.

Thematic maps like drainage, geomorphology, slope and longitudinal profiles for the Spiti river and its tributaries and compiled geological data have yielded interesting information in regard to the development of this valley. The longitudinal profile shows sixteen knick points which coincides with the river terraces and fan terraces in the valley. Major breaks in the longitudinal profile are at 4050 m near Losar (upstream), 3840 m at Gompa, 3600 m near Kaza, 3320 m near Tabo and 3200 m near Sumra. In general, 3 to 4 levels of fluvial and fan terraces are observed and represent the manifestation of tectonic activity, besides the fluvial action in the area.

Component 2.2 :
Environmental magnetic study of selected paleo- and present day glacial lakes in Central Higher Himalaya, India

(Narendra Kumar Meena)

Sediment profiles from Chandra and Renuka lakes were studied. Several palaeoclimatic proxies were utilized to reconstruct past climatic variations that enabled us to understand the structure of Holocene climate.

Chandra Lake

Almost, all the studies that relate the temperature with monsoon dynamics agree that a substantial cooling and heating of the Northern Hemisphere during glacial and interglacial periods cause weakening and strengthening of Indian summer monsoon (ISM). However, a convincing mechanism of persistent monsoon failure and strengthening in these extreme climates is still elusive. This may be due to ignorance of factors like past large scale change in cross-equatorial wind circulations and their time lags, the role of Himalaya Tibetan plateau and ITCZ. To address these questions, the poorly constrained

Chandra Lake sediments were dated. A total of 9 dates were obtained from NOSAM-AMS facility, USA. An age-depth model was developed for the Chandra Lake using new and previously done ages. Based on these dates and various proxies including major and trace elements, Magnetic Susceptibility, Anhyreretic Remnant Magnetization, Saturated Isothermal Remnant Magnetization (SIRM) and Loss of Ignition (LOI), paleomonsoon, winter and summer wind circulation for last 11 ka BP were reconstructed. Using these proxies a new mechanism of ISM circulation in which the Himalaya and Tibet plateau play a significant role in monsoon dynamics was inferred. The variation in monsoon rain during the glacial and interglacial time can be explained by the large scale cross equatorial pressure gradient re-distribution with three conditions.

i) The consistent failure of ISM in the extreme cold climate is associated with strength of winter winds which crossed the Higher Himalaya and converged south to the equator. As a consequence the summer monsoon winds are not able to enter on the Indian continental that resulted as failure of the ISM. The timing of this ISM failure in our data is 11 to 10 ka BP and 3 to 1 ka BP.

ii) The second condition is opposite to it, during the extreme warm conditions, the SW monsoon winds cross north to Himalaya and convergence takes place somewhere in north of the Tibetan plateau. This extended circulation of the winds strengthen summer monsoon precipitation in rain deficient Tibetan plateau. The timing of strengthen of monsoon in our data corresponds with Holocene Optimum 10 to 6 ka BP.

iii) In third condition, during transition times the orographic barrier of the Himalaya accumulates the convergence trough that resulted as gradual change in monsoon *e.g.* 6 to 3 ka and 1 ka BP to modern in Chandra lake.

Renuka Lake

The main purpose to choose the Renuka lake in this project was to establish the correlation between low altitude monsoon dominated regions and Higher altitude glacial and fluvio-glacial lakes. After a successful coring in the lake, a resolution of 2.5 mm and 1 cm from corresponding levels was achieved. About 500 samples have been analyzed for the bulk magnetic susceptibility and around 150 samples have been geochemically analyzed. The preliminary and undated results of top two meter core samples indicate a considerable fluctuation in the magnetic susceptibility. The combination of the magnetic susceptibility and lithology of lake suggest that monsoon driven climate is responsible for higher values of the magnetic susceptibility in the lake. The lake core needs to be dated and accordingly a set of samples for ^{14}C, AMS dating were prepared.

Component 2.3 :
Tectono-climatic evolution of Alaknanda-Bhagirathi river system in NW Himalaya

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

This year we studied a 4.9 m thick lake sequence, formed due to landslide damming of a stream in semi arid Garhwal Himalaya. The Optically Stimulated Luminescence (OSL) chronology indicated the existence of this lake between 12 and 7 ka before the Present (BP). Chronologically constrained trends of Organic Bound Phosphorus (OP), Apatite Bound Inorganic Phosphorus (AIP) as well as mineral susceptibility, measured for the first time in any palaeolake profile in the Himalaya, indicate that the Indian summer monsoon ameliorated following 12 ka cooling. In the younger interval, four phases of wetter climate are recognized during ~11.8-11.3 ka BP, 10.5-11 ka BP, 9.2-10.1 ka BP and 8.3-7.4 ka BP. These phases were characterized by high magnetic susceptibility, increased OP and reduced AIP. These results are in broader conformity with the Holocene records of Indian summer monsoon from ocean, cave, loess and lake sediments.

Component 2.4 :
Paleoclimatic and Tectonic study of the Quaternary-Holocene Speleothems from NW and NE Himalaya

(V.C. Tewari)

Field work was carried out in the Shillong Plateau region with special reference to the study of speleothems. Speleothems were investigated from the Mawmluh, Mawsmai and Mustos caves for paleomonsoon records. The relationship between the climate, monsoon and tectonics in the Shillong Plateau has been studied.

The stalagmites and stalactities collected from Chulerasim in Kumaun region and Mastosh cave in the Meghalaya have been studied in detail in the laboratory. Laboratory studies include petrography, microfacies analysis, major and trace element variation in the speleothems and their carbon and oxygen ratio variation etc. (Fig. 7). The studied speleothems are 10 to 15 cm long stalagmite from Chulerasim (29°53′08″ N and 79°21′06″ E) and Mastosh caves. δ^{18}O varies from - 2.4 to - 5.6 ‰ (PDB) and δ^{13}C varies from - 5.0 to - 7.6 ‰ (PDB) in the Chulerasim cave. Isotope data is consistent with the previous data from Sahastradhara, Prakateshwar in Garhwal and Mawmlu and Mawsmai caves in Meghalaya. Drip water δ^{18}O from cave is between -3.4 and -4.6‰ SMOW. Calcite is the main mineralogy of the stalagmite from Chulerasim cave. Growth rings are very well developed without any break and shows continuity of the growth. The vegetation outside the cave includes (Oak, and Pinus roxburghii). Annual precipitation around the cave is 1050-1250 mm and the region, in general, is characterized by warmer summers and cooler winters (sub tropical). Since speleothems are the most ideal continental records to

Fig.7: Polished slab of the Stalagmite from the Mawmluh cave in Meghalaya showing light and dark laminae analysed for the high resolution oxygen and carbon isotopic ratios and sedimentological studies

Fig.8: Highly disturbed speleothem from the Shillong Plateau, Meghalaya showing the displacement and irregular growth of stalagmite due to impact of the earthquake (seismo-tectonic activity) in the area

reconstruct the past climate change and best continental archives and provide absolute environmental time series. The dating of stalagmite by U/Th offers the very reliable time of the stalagmite formation and more dates are required from the Lesser Himalayan stalagmites as well as Meghalaya for reconstruction of the paleomonsoon history. The disturbed or discontinuous growth rings recorded from the Mastosh cave in Meghalaya indicate short time hiatus/break in stalagmite development and may also be due to the combined effect of the paleoseismic events in the Shillong Plateau, heavy precipitation and motion of the Indian Plate (Fig. 8).

Component 2.5:
Late Cenozoic fluvial deposits in the sub-Himalaya between Ravi and Satluj Rivers-interaction of tectonics and climate

(Rohtash Kumar and N. Suresh)

Late Cenozoic successions of the Himalayan foreland basin between Ravi and Satluj rivers, is represented by both Siwalik and post Siwalik (late Quaternary) deposits. Siwaliks are one of the best-studied foreland deposits, however the interfluve sequences within the Siwalik stratigraphy have potential to understand the aggradation and degradation history and their relationship with hinterland tectonics and climate in space and time at millennial scale. On the other hand the Quaternary succession, with better time constrains provides the aggradation and degradation history vis-à-vis climate and tectonics at kilo year scale. A sedimentary succession records at least three possible conditions: deposition, bypass or erosion and are controlled by topographic uplift and/or variation in climate which causes change in aggragation and degradation phases in the depositional basin. The main focus of the study was to understand the variability in the sedimentation pattern in the Kangra sub-basin (KSB). In this basin, the Middle Miocene to Pliocene deposits belong to the Siwalik formations and is tectonically deformed, whereas the younger post-Siwalik deposits (late Pleistocene-Holocene) are comparatively undeformed and are deposited in the Soan Dun, by Beas and Satluj rivers and their tributaries.

Evolution of Late Quaternary deposits in the Soan Dun

Soan Dun, a longitudinal structural valley in the sub-Himalaya, is spanned between Satluj River in the east and Beas River in the west and is bordered by Siwalik mountains in the north and south (detached Siwalik

Hills). Studies carried out in the Soan Dun exhibit various landforms in the form of alluvial fans deposited by the ephemeral streams draining the surrounding Siwalik mountains (Middle and Upper Siwalik formations). These alluvial fans are deposited transverse to the valley axis, with their apexes at the foot of the Siwalik mountains in the north or south and their toes terminating at the axial river-Soan. Based on quartz optically stimulated luminescence (OSL) dating, the alluvial fans deposited to the north of the axial river show two distinctive phases of aggradation. The deposit on the southeastern part of the Dun is older, whereas the deposit on the northwestern part is younger. The four alluvial fans from the southeastern part of the Dun show that the aggradation phase initiated well before 55 ka and terminated around 29 ka. On the other hand, four alluvial fans from the northwestern part of the dun show that the aggradation phase is much younger and is continued till 10 ka. These younger alluvial fans are observed in front of the Soan Thrust. Along the Soan Thrust, the Middle Siwalik rock is riding over the fan sequence with uplifted late Pleistocene deposit (29 ka) observed on the hanging wall. This suggests that tectonic activity along the Soan Thrust resulted continuous creation of accommodation space in the northwestern part of the dun. The termination phase of sedimentation in the older and younger alluvial fans has occurred in the reported increased monsoon phases and can be correlated to variation in climate change which exerts a profound control on fluvial transport processes and hence on landscape development. The alluvial fans are also observed to the south of the axial river, i.e. from the detached Siwalik hills. These fans show high angle depositional slope and are time equivalent to younger alluvial fans. In addition, late Quaternary deposits are also observed on top of the anticlinally folded Siwalik formations (Janauri Anticline) and also in the paleo-gorge in the detached Siwalik Hills. The fluvial successions in the paleo-gorge are dominated by gravel and sandy facies and the architecture suggests its deposition by a major river, probably by Satluj River. However, the Bhaddi Anticline in the southeastern part of the detached hill, southern boarder of the Soan Dun, earlier documented as Middle and Upper Siwalik, is not showing any characteristics features of the Siwalik sequence. The thick fluvial deposits forming the Bhaddi Anticline are represented by multistory, mica rich, grey coloured medium to fine sandy facies and are very loose with low induration (Fig. 9). The litho units are anticlinaly folded and show low dip towards north or south. Based on quartz OSL ages, the oldest age obtained at the exposed bottom is 69 ka and the top is

Fig. 9: The anticlinally folded late Pleistocene fluvial deposits (post Siwalik), showing low angle dip, forming the detached Hill (Bhaddi Anticline) in the southern margin of the Soan Dun. Earlier workers have documented this sequence as the Middle Siwalik Formation. A) Thick fluvial deposits, showing low angle dip towards north, and represented by multistory, medium to fine grained, mica rich grey coloured sand B) trough cross-stratified sand body with low induration

50 ka. This grey sand bearing detached hill is probably formed due to tectonic uplift which resulted in the channel shifting of the Satluj River.

Siwalik Rocks

Reconstruction of late Cenozoic basin fill stratal architecture of the Siwalik succession, Ravi re-entrant of the Himalayan foreland basin, is used to understand the relative roll of tectonic, climate and geomorphic base-level changes. This record systematic expansion and contraction of floodplain facies between 12.77 and 5.71 Ma resulted migration of easterly flowing axial river towards basin margin and away from it, and capped by alluvial fan facies after 5.71 Ma. The floodplain facies (ASD), which constitute the southerly flowing (transverse) sheet flood deposit in the form of paleosol bound mudstone, levee, crevasse splay, lacustrine and ribbon sandstone, expand time to time toward the basin and occupies the broad area close to basin margin. The axial river facies (ARD) represent by multistorey grey sandstone occupies the basin center. The axial river deposit remains at a deposition site in the order of $1x10^4$ to $2x10^4$ years and reoccupies almost the same geomorphic site after $8x10^3$ to $12x10^5$ years. The ASD and ARD differ in term of architecture, paleoflow pattern and source area. These cycles conform broadly to the aggradation/degradation pattern in which an aggradation phase consists of thick package of mudstone-paleosol bound ribbon channels and degradation phase comprises erosional based multistory-multilateral sheet sandstone.

This large scale cyclicity of expansion and contraction of ASD facies tract caused ARD tract avulse to and fro to the basin margin and reflect systematic rise and fall of geomorphic base level. During base level rise (decrease accommodation space), ARD facies tract migrate toward feather edge of the basin and area occupied by ASD facies tract. On the other hand during base level fall (increase accommodation space), ARD facies tract advance toward basin margin resulting contraction of ASD facies. Large-scale cycle stacking patterns show significant change in basin-fill architecture through time, including deformation along basin margin, permanent change from ARD to ASD and finally capped by alluvial fan facies (ARD) with increase basin slope, sediment flux and grain-size. Considering these changes and two separate sediment supplied source area suggest interplay of tectonic and climate within the Ravi-entrant.

Component 2.6 :

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

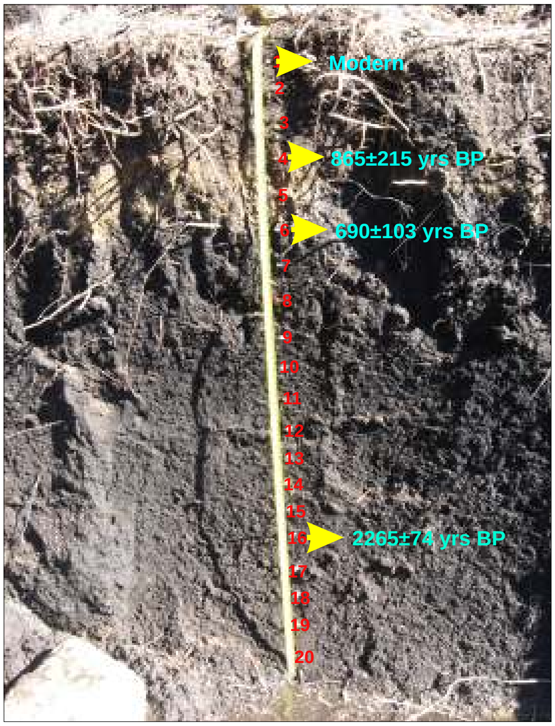
(D.K. Misra, Pradeep Srivastava and B.K. Choudhuri)

Fieldwork was carried out in the Siang and Siyom valleys of Arunachal Pradesh. The rivers flowing from north to south cut through Proterozoic to Cenozoic rocks that occur in the form of eight distinct thrust bound litho-tectonic units. From SW to NE, in ascending structural order these are: 1. the Siwalik Group, 2. the Gondwana Group, 3. the Yinkiong Group, 4. the Miri Group, 5. the Bomdila Group, 6. the Sela Group, 7. the Tidding Formation and 8. the Lohit Plutonic Complex. The Sub-Himalayan Zone (Siwalik Group) overrides the Brahmaputra Alluvium along the Himalayan Frontal Fault (HFT) and is over thrust by the rocks of the Lesser Himalaya (Gondwana, Yinkiong, Miri and Bomdila groups) along the Main Boundary Thrust (MBT). High-grade metamorphics of the Central Crystalline Complex of the Higher Himalayan Zone (Sela Group) overlay the Bomdila Group of rocks along the Main Central Thrust (MCT) and is over thrust by the rocks of the Tidding Formation of Trans Himalaya along the Tidding Thrust. The Lohit Plutonic Complex is of batholithic dimension and has been thrusted over the rocks of the Tidding Formation along the Lohit Thrust. Field studies coupled with interpretation of topographic maps resulted in identification and delineation of a large number of NNW-SSE to WNW-ESE, N-S, NNE-SSW to NE- SW and E-W trending active faults which post-date the 'boundary thrusts' that define the boundaries of lithotectonic terranes and shear zones. Recent movements on the faults have caused not only pronounced deflection of rivers and streams but also formed hairpin geometry, loops and present-day ponding. Movements along faults are also responsible for abrupt rise of mountain front, occurrence of a planar scarp and triangular facets devoid of gullies or with a few straight furrows, huge landslides, debris fan, abrupt narrowing down of wide meandering rivers and uplifted fluvial terraces.

A soil profile in the Higher NE Himalaya was studied that provides an opportunity to understand the elemental behavior in the highly eroded and humid region, where rainfall is as high as ~2600 mm/a. This soil profile is developed on a granodioritic base rock at Anini of Arunachal Pradesh, at an altitude of 1644 m. A 2.5 m thick soil profile was studied and 10 samples, along the vertical profile, were collected for geochemical analysis of the pedogenic processes. The profile being devoid of protolith confirms it as soil profile. The exposed base rock is noted with high fractures indicating the play of physical weathering, which further promotes chemical weathering due to water-rock interaction which is substantiated by increase of LOI percentage from base rock to top soil. With the advancement of weathering, pH in the profile goes acidic in nature as the rain water interacted with alkaline base rock. Immobile major elements like Ti, and Al gradually enhances upward in the profile. The advances of weathering also show enrichment of Rb, Zr, Ba and depletion of Sr from base rock to the top soil. With the progressive weathering, the LREE shows enhancement from base rock to top soil, whereas HREE retains uniform characteristic throughout the profile. We observed slight negative

Ce anomaly in the base and sap rock indicating the reducing environment, however positive Ce anomaly is noted in saprolite, saprolith and regolith showing oxidation effect during the progressive weathering. The base rock shows no of minor Eu anomaly, however weathered rocks have significant negative Eu anomalies. This observation concludes that the negative Eu anomaly can be produced during chemical weathering of granodioritic rock. We suggest the relative enrichments of other REE's and partial loss of Eu during the breaking down of plagioclase as a plausible explanation.

The surface of the soil profile hosts a meter thick peat deposits (Fig. 10). The deposit was dated using ^{14}C technique on the bulk organic carbon at Physical Research Laboratory. The top of the profile yielded modern age and the sample towards the base yielded an age of 2265±74 years BP. Mineral susceptibility results on this profile indicated initial increase that lowered at ~800 years BP. The details on the mineral susceptibility will be assimilated after stable isotope analysis of these samples. The samples are submitted to the Stable Isotope Laboratory of the Institute.



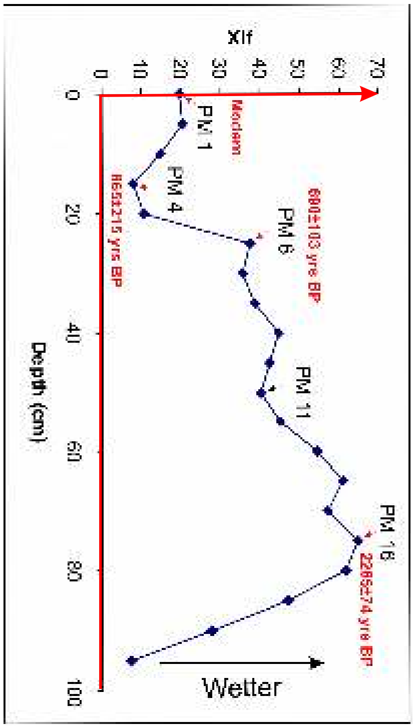


Fig. 10: One meter thick peat profile at Anini, Arunachal Pradesh, NE Himalaya. Note the bulk organic carbon ages and mineral susceptibility data (left panel). 1-20 (in red) are the sample positions

MMP - 3 : BIOSTRATIGRAPHY & BIODIVERSITY-ENVIRONMENT LINKAGE

Component 3.1 :

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

(S.K. Parcha)

The Spiti Basin together with the Zanskar basin is the largest basin among the Himalayan Tethyan basins. The basin exposes exceptionally well preserved Palaeozoic-Mesozoic successions. The Cambrian successions of the Spiti basin contain well preserved ichnofossils as well as trilobite assemblages. The ichnofossil assemblage reported from the Debsakhad Member and the Parahio Member of Kunzum La Formation includes various ichnogenera. The ichnofossils collected from the Cambrian successions of the Spiti Basin are important in deciphering the age of pre-trilobite bearing beds. The distribution pattern shows that there is no record of body fossils from the basal part of Kunzum La Formation in the Parahio valley. The distribution pattern of ichnofossils shows increase in taxonomic and morphological diversity up in the section. The distribution of ichnofossils in the Lower Cambrian succession reflects the paleoecological condition like availability of oxygen and nutrient influx. The studied ichnofossils from the section suggest that the availability of nutrients strongly increased their distribution as well as abundance. The ichnofossils reported from this section provide evidence regarding the development patterns during the early phase of life. The present assemblages of ichnofossil are very much significant in assigning the age of the Debsakhad Member. The abundance of ichnofossils in sandstone, siltstone and shale and rarely in quartzite indicates important change in the benthic conditions. The change in the fossil assemblages is also noticeable in the Parahio Member of the Kunzum La Formation. The body fossils in the basal part of Parahio Member indicate an early Middle Cambrian age. Due to the scantiness of body fossil, as well as microbiota in the lowermost beds of the Debsakhad Member, the Precambrian-Cambrian boundary can not be demarcated. It indicates that the boundary could be below the ichnofossil horizon. However, the presence of *Treptichnus* and *Phycodes* can be considered as a horizon marker for the beginning of Lower Cambrian in this section.

The Cambrian biostratigraphy of the Tethyan Himalayan regions in general and Middle Cambrian in particular is based on the trilobite faunal assemblages. In the Spiti Basin trilobites were reported from the Parahio section as well as from the Pin section. The trilobite fauna has been preserved in shale, sandstone and limestone. The Middle Cambrian trilobite bearing limestone beds represent thin transgressive systems tract deposits developed over marine flooding surface. The fauna collected from the Kunzum La Formation of the Spiti region particularly in the Parahio valley has been assigned to various species. New faunal collections were recovered from the shale as well as from the carbonate beds. The collection of well-preserved eodiscidae fauna from the Parahio section seems very much useful to understand the developmental stages of the eodiscidae. At present, the morphometric analysis of *Pagetia* and *Opsidiscus* was carried out to understand their growth stages and ontogenic developments. In addition to this, the studies are going on to study the different species of *Oryctocephalus* collected from the Parahio and Pin sections.

The Ordovician - Silurian successions is exposed in the Pin and Parahio valleys and in the Takche section. In the Spiti Basin, the Ordovician succession is separated from the underlying Cambrian successions by a break in the deposition, which is denoted by angular unconformity. This unconformity is significant in the Pin and Parahio sections. The middle part of the formation comprises of thin layers of carbonate beds in alteration with the sandstone beds. The Ordovician succession of this area thus comprises of medium to thick-bedded purple red, current bedded quartzites with minor grits and occasional intraformational conglomerates. The Takche Formation overlying the Thango Formation exposes calcareous dolomite and argillo-arenaceous successions. The lateral facies variation is also noted in the upper part of this formation. The presence of sporadic reefal complexes, assign a late Ordovician to Silurian age to this formation. The present studies show that both the formational units contain a rich assemblage of the microfossils along with other body fossils. In the present study, the carbonate beds in Ordovician and Silurian successions have yielded a number of microfossils, among which are the calcareous algae (Dasycladaceae), bryozoans, crinoids stems, broken fragments of cephalopods, lamellibranches, Hyolithids together with the brachiopods; fragmentary remains of arthropods and trace fossils. A variety of calcareous algae were found in association in the same thin sections. It seems that calcareous algae were little developed during the Cambrian, but their diversification might have taken place from the Middle Ordovician onwards. The Pin area of the Spiti Basin might have colonized by calcareous algae during Middle and Upper Ordovician which extends up to the Early Silurian succession in this region. The Bryozoan fauna reported from this section indicate Late Ordovician to Late Silurian age. It is equally present in Thango as well as in the Takche formations. The presence of brachiopods, bryozoans and calcified green algae in this succession indicates shallow marine to near shore environmental conditions. Based on the faunal elements from these formational units, Middle to Late Ordovician age can be assigned to Thango Formation and Late Ordovician to Silurian to the Takche Formation.

The Muth Formation is underlain by the Takche Formation of upper Ordovician to lower Silurian age. The Muth Formation is devoid of age-diagnostic fossils, but well constrained arthropod ichnofauna of the Muth Formation broadly indicate an early Devonian age. The Muth Quartzite forms a marker horizon in Spiti and other parts of the Tibetan Zone. The formation consists of thick-bedded to massive, white or slightly greenish, fine- to medium-grained quartzites. The rocks exhibit current bedding, ripple marks and burrows. In the uppermost thirty meter of the formation, carbonate and dolomite are intercalated with the quartzites. There is an increase of sand towards the top of the Silurian succession indicating a regression but a major gap below the Muth Quartzite is very much probable.

Component 3.2:
Inner Lesser Himalayan Carbonate Belt: Biostratigraphy, Biodiversity and Time-Space-Environment relationship with the Krol Belt

(Meera Tiwari)

Cyanobacteria are ancient and morphologically diverse group of photosynthetic prokaryotes are one of the main components in the cyclic alteration of carbon and oxygen and thus in the maintenance of the gaseous composition of the atmosphere. One of the major roles of cyanobacteria is to fix nitrogen from the atmosphere. The release of free oxygen was one of the most significant events in the planet's history and has caused the gradual transformation of the primitive reducing atmosphere to an oxidizing one, thus enabling the development of the aerobic mode of heterotrophic metabolism in the living world. The increasing levels of oxygen in the atmosphere created a problem for bacteria capable of nitrogen fixation, because the enzyme nitrogenase, responsible for nitrogen fixation is highly sensitive to oxygen. Many filamentous cyanobacteria vegetative cells are differentiated into morphologically and ultrastructurally distinct cells called 'heterocysts', which specialize in nitrogen fixation under aerobic conditions. Occurrence of structures resembling 'heterocyst' in cyanobacteria from slates of Narainnager Member of the Krol Formation (Fig. 11) shows that aerobic conditions prevailed during that time.

Heterocysts are large, thick-walled, apparently empty specialized cells, found between normal cells. Heterocysts are formed by cyanobacteria of subsections IV (order Nostocales) and V (order Stigonematales), which are all filamentous. Single heterocyst develop about every 9-15 cells, producing a one-dimensional pattern along the filament. The interval between heterocysts remains approximately constant even though the cells in the filament are dividing. The filament possessing heterocyst can be treated as a multicellular organism with two distinct yet interdependent cell types. These specialized cells fix nitrogen (N_2) in the air using the enzyme nitrogenase. Since nitrogenase is inactivated by oxygen, these cells create a microanaerobic environment, in order to keep oxygen out of the cell. This requires several changes in the cell, including formation of three additional cell walls. These additional layers, permit the atmospheric nitrogen to diffuse inside, whereas on the other hand

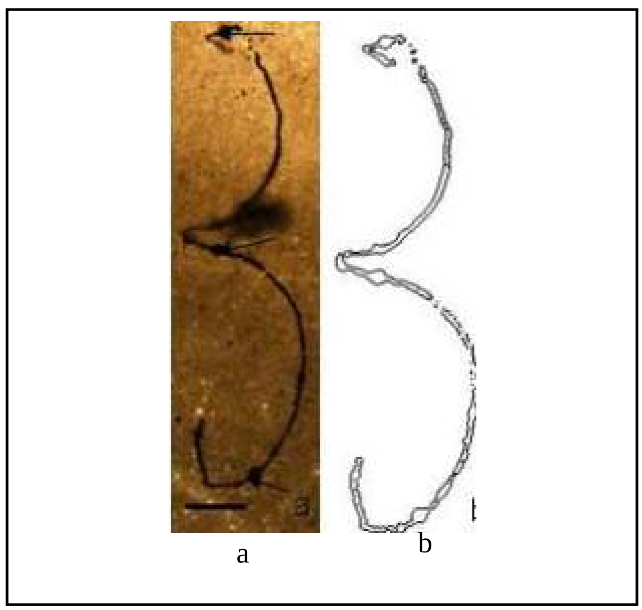


Fig. 11: a. Heterocyst bearing cyanobacteria, b. Diagrammatic sketch of figure a. Scale bar = 250 m

they stop the atmospheric oxygen to come inside and so help to maintain a microaerobic interior. This is a damage-control mechanism for the enzyme nitrogenase, as the nitrogenase is sensitive to O_2 and cold, and can not function in the presence of O_2. Moreover the Photosystem II (PS II) is also absent from the Heterocyst, because PS (II) does the photolysis of water and generates free O_2 gas. That is why only Photosystem (I) is present here, which generates assimilatory powers ATP, which helps in nitrogen fixation. How different forms of cells and organisms emerged during evolution remains a challenging question in biology. In view of the fact, that heterocyst development is under arrest in anaerobic conditions and that the rate of heterocyst differentiation is enhanced by increases in atmospheric oxygen, the evolution of heterocysts may have accompanied the initial appearance of oxygen-rich environments in Earth's history. Cyanobacterial heterocysts appeared, when oxygen first reached levels that inhibit nitrogenase activity. Heterocysts are, therefore, interesting for evolutionary developmental studies.

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

(B. N. Tiwari)

In the perspective of lost Saraswati river, microscopic cyprinid fish fossils from Miocene horizons of Kutch and the Kangra valley of the Himachal Himalaya provide us a basis to reinvent geological and paleontological aspects of Himalayan link in the region. It is known that the cyprinids are characteristically obligate freshwater weberian-apparatus-equipped ostariophysian teleost fishes and were confined to Asia, their native place, till Eocene. Obviously they reached Indian subcontinent following its Cainozoic suturing with Asia, a preamble of evolution of the Himalaya. Their dispersal from Asian inland water streams to distal regions like Kutch bordering Arabian Sea in Miocene via Indus Suture Zone and proto-Himalayan region in the subcontinent reveal so far unknown deeper insights of concomitant geodynamical and related paleoclimatic developments. Most plausibly suture zone was imparted altitude through the compressional Himalayan tectonics which gave rise catchment/s to the antecedent set of rivers emanating from the Himalaya and reaching far off regions on the southern side of the orogen.

Through dedicated field and lab work, we find definite presence of sparking delicate pharyngeals of exotic cyprinid fish in the macerated residue of the bulk samples from several sections of Kutch; in combination with their occurrence in other Miocene Outer and Trans- Himalayan sections and presence of paleo-river channels ascribed to lost mighty Saraswati river. Further, analysis of their occurrences too is indicative of waxing and waning inland river system/s fed by Himalayan catchments and the history does not go older than Miocene, an interval when thrusting came into being in the Himalayan region.

Non-marine fossil evidences are known to be important in reconstructing successive stages of the Himalayan evolution but perhaps it is unusual to find a clue in this regard from such a far off region as Kutch.

Neogene freshwater beds on the southern side of the Himalaya are rather continuous feature all along the length of the orogen and chronicle orogenic pulses in the hinterland. Fossil content of these sedimentary archives that are now exhumed and exposed due to sustained thrusting is immensely useful in reconstructing geological past and in calibrating spatial and temporal evolution of the extant clades. Juvenile gastropod fossil shells ascribed to *Brotia*, a genus of Pachychilidae, from different Siwalik and pre-Siwalik sections in the western Outer Himalaya are in focus of the present study. From Upper Dharamshala Formation, we have small but fairly noteworthy gastropods from two localities associated with mega and microfossils consisting of ostracods, crocodiles, snakes, cyprinid fishes, rodents, and a deinothere. Besides Dharamshala juvenile *Brotia* shells in large number from a recently explored Siwalik locality yielding otoliths, ostracods, fish remains, rodents, etc.

These records are interesting in the milieu of the facts that i) ancestors of Indian pachychilids hailed from Southeast Asia, and ii) out of two Indian extant pachychilid taxa namely, *Brotia* and *Paracrostoma*, earlier one is confined to the Ganga-Brahmputra river basin of northern India, whereas the later one is known from south Indian freshwater bodies. Elaborate biogeographic account of extant *Brotia* forms based on molecular studies by Kohler et al. (2010) gets geologic dimension through our records from Siwalik and Dharamshala beds exposed in Doon and Kangra valleys in western Himalayan domain. Exotic pachychilid fossil gastropods in our collection and published account on extant and fossil occurrences from other areas offer us an opportunity to see them in the context of the Himalayan tectonics. This is prudent as evolution of this Himalaya gave rise to a new dynamic regime of inland water system in the Indian Subcontinent for long distance dispersal of freshwater aquatic life forms. We intend to demonstrate that presence of *Brotia* in our collection and its published record from Nepal, Kasauli, Ladakh and Southeast Asia together is a palaeobiogeographical reflection of the geological events of the subcontinent.

Component 3.4 :

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

(Kapesa Lokho)

The Assam-Arakan basin in the Northeast India is one of the largest sedimentary basins covering 70% of the total land by the Cenozoic sediments. The basin is significant in the context of Indian Geology because of its polyhistory type basin. The basin evolution is largely influenced by the movement of the Indian Plate in relation to the Eurasian and Burmese Plates. As such, the stratigraphy and tectonic history is very complex. The basin so far, has the least explored macro-and micro-plaeontological data to date age and paleoenvironment. Therefore, as part of the ongoing research programme aimed to explore signatures of early life, a field work was carried out as reconnaissance survey in parts of Manipur and Nagaland. Field work was also conducted in parts of Kohima and Dimapur districts in Nagaland where Disang Formation of Eocene age and Surma Group of rocks of Miocene age were exposed. A traverse was also carried out in parts of Senapati district in Manipur where Disang and Barail formations of Eocene and Oligocene age, respectively were exposed. The micropaleontological investigations are going on in the laboratory for the recovery of microfossils. Varieties of acids and methods are tried in the processing of the collected rock samples for the extraction of microfossils.

Micropaleontological investigations were carried out on the rock samples collected in the previous year from the Bhuban Formation, Mizoram, for the recovery of nannofossil, where foraminifers were reported. The recovered nannoplanktons are in the process of identification. The recovered nannoplanktons will have an impact in deciphering in dating of age and paleoenvironment of the studied formation and in large will help to understand the tectonic evolution of the basin.

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

(K. Kumar and N. Siva Siddaiah)

Volcanic rock of andesitic composition (53-57 wt% SiO_2) is discovered between Precambrian Sirban Limestone and Paleogene Subathu Formation in the Jammu region of Jammu & Kashmir state. It is 1 to 2 m thick, maroon to greenish grey flow unit occurring in association with rhyolitic breccia within the Jangalgali Formation. It is porphyritic with 20-30 volume percent phenocrysts. It consists of plagioclase feldspar, hornblende, quartz, magnetite, potash feldspar, biotite, with minor amounts of sphene and zircon. Zircons are euhedral, pinkish and fairly abundant.

The plagioclase phenocrysts are euhedral to subhedral and range from 0.5 to 6 mm in grain size. Twinning is widespread among the plagioclase phenocrysts with the albite-type most abundant. The groundmass consists of microlites of plagioclase, orthopyroxene and clinopyroxene, and with minute granules of magnetite and/or Fe-Ti oxides. It is relatively Fe-rich (15-24 wt % Fe_2O_3) and alkali poor (K_2O=0.12-0.9 wt %; Na_2O=0.02 wt %). The relatively high loss on ignition values of the samples (LOI=3.75 to 5.5 wt %) is probably due to the presence of alteration derived clays. Regarding its origin some form of hybridization between basaltic and acidic magmas, possibly followed by fractional crystallization is being considered. Understanding the age and petrogenesis of this volcanic rock would help in exploring their significance in Himalayan orogeny and mineral potential.

The higher vertebrate faunal groups that received focus during the reporting year include chiropterans and creodonts (Mammalia), while among the lower vertebrates frogs (Amphibia) were studied. Some of the important non-vertebrate biotic remains studied included plant fossils from a newly sampled Late Paleocene-lower Eocene section.

Early Eocene chiropterans (bats) are the most abundant and diversified mammals of western India, which may locally represent a mangrove environment. They are not older than the earliest bats known from the other continents but are certainly more diversified compared to those from the continents of North America, Europe, Africa, and Australia. New bat fossils under study include jaws and limb bones. A new species of a relatively large archaeonycterid bat has been identified. In all, eight species belonging to five genera and four families are present. Resemblances of Indian bats to European taxa suggest a biotic contact between India and Europe prior to Indian-Asian collision. This is consistent with affinities of other mammal groups in the fauna. An assemblage of Early Eocene frogs based on diverse ilia, vertebrae and limb bones was also studied.

Biota from the continental Paleocene of South Asia is crucial in understanding biotic affinities on the drifting Indian Plate with regard to its Gondwanan association with Africa, Madagascar, and South America on the one hand and Eurasia on the other. Unfortunately, the continental Paleocene has limited exposures in India and generally occurs with the lower Eocene lignite/coal sequences in Rajasthan and Gujarat along its western margin and in Meghalaya in the northeastern region and as a result little data is available on this important interval. The Paleocene sections mapped so far in the northwestern Himalayan region are all shallow marine deposits. Pollen-bearing continental sediments associated with the Late Cretaceous Deccan volcanics have been reported at a few places. Their pollen content shows affinity to the best described Paleocene pollen assemblage from the classic Matanomadh Formation of Kachchh (Gujarat) in western India. In general, there is a large gap in our knowledge of terrestrial biotas between the terminal Cretaceous and the lower Eocene (Ypresian) sediments, well illustrated by the Vastan mine section (Cambay Shale Formation) close to Vagadkhol in western India. Macro- and micro-floral remains comprising fossil leaf impressions, silicified wood, spores, and pollen grains is reported from the Paleocene-lower Eocene Vagadkhol Formation (=Olpad Formation) exposed around Vagadkhol village in the Bharuch district of Gujarat, western India. The fossil leaves are represented by five genera and six species, namely, *Polyalthia palaeosimiarum* (Annonaceae), *Acronychia siwalica (Rutaceae)*, *Terminalia palaeocatapa* and *T. panandhroensis* (Combretaceae), *Lagerstroemia patelii* (Lythraceae), and a new species, *Gardenia vagadkholia* (Rubiaceae) (Figs. 12, 13 and 14). The lone fossil wood has been attributed to a new species, *Schleicheroxylon bharuchense* (Sapindaceae). The palynological assemblage, consisting of pollen grains and spores, comprises eleven taxa with more

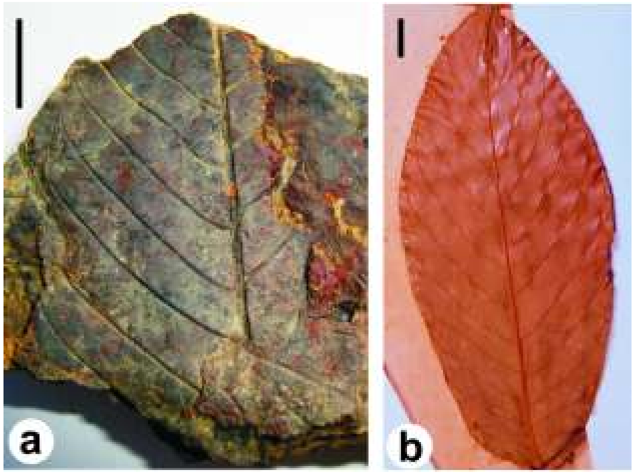


Fig. 12 : a. *Polyalthia palaeosimiarum* fragment of fossil leaf; b. *Polyalthia simiarum comparable* modern leaf. Scale bars equal 10 mm

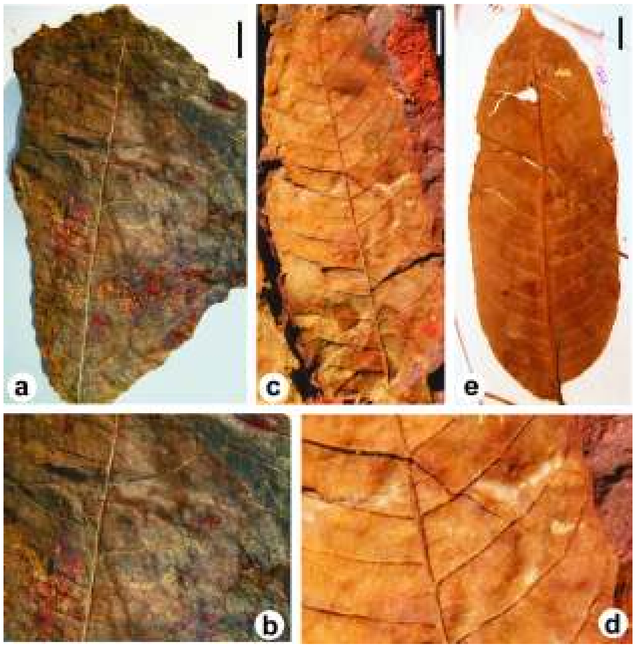


Fig. 13: a, b. *Terminalia palaeocatapa*, a ,fossil leaf; b, part of fossil leaf showing details of venation pattern; c, d. *T. panandhroensis*, c, fossil leaf d, a part of fossil leaf magnified to show details of venation pattern; e, *T. coriacea* modern leaf showing similarity in shape, size, and venation pattern with fossil leaves in a-d. Scale bars equal 10 mm

PROGRESS IN MISSION MODE PROJECTS

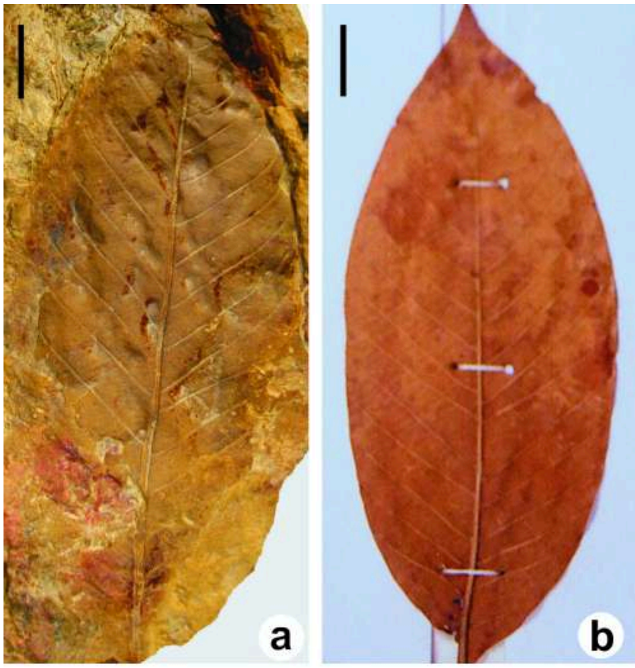


Fig. 14: a. *Gardenia vagadkholia* n. sp., fossil leaf; b, *G. resinifera* modern leaf showing similarity with fossil leaf. Scale bars equal 10 mm

or less equal representation of pteridophytes gymnosperms and angiosperms. Angiospermous pollen include a new species *Palmidites magnus*. Spores are mostly pteridophytic but some fungal spores were also recovered. All the fossil species have been identified in the extant genera. The present day distribution of modern taxa comparable to the fossil assemblage recorded from the Vagadkhol area mostly indicate terrestrial lowland environment. Low frequency of pollen of two highland temperate taxa (Pinaceae) in the assemblage suggests that they may have been transported from a distant source. The wood and leaf taxa in the fossil assemblage are suggestive of tropical moist or wet forest with some deciduousness during the Paleocene-early Eocene. The presence of many fungal taxa further suggests the prevalence of enough humidity at the time of sedimentation. The recovery of reasonably well preserved plant remains from Vagadkhol has raised the hopes of finding Paleocene vertebrate remains.

Field work was also carried out in the Late Paleocene-Middle Eocene sections of Subathu stratotype area in Himachal Pradesh. In one of the sections exposed near Kurla, an unconformable contact between the Simla Slates and the Subathu succession was delineated and right at the contact about half a meter thick bed of tonstein (altered volcanic ash) was also seen. This section apparently has the best exposures of the basal part of the Subathu succession and it is important not only for the dating of the tonstein bed but also for recognition of PETM zone. Apart from this richly fossiliferous grayish black recrystallized limestone, a pebbly limestone horizon was delineated along the Kuthar river.

Field work was carried out in the Paleocene and Early Eocene sections of western India for prospecting of vertebrates and associated biotic remains. The new collection includes isolated teeth of creodonts, primates, artiodactyls, tillodonts and indobunids among mammals and frogs and agamid lizards among amphibians and reptilians, respectively and numerous postcranial elements comprising vertebrae and limb bones of mammals, frogs and snakes. Teeth of ziphodont crocodilians were recovered for the first time. These have important palaeobiogeographic implications.

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)

India was part of the Gondwanaland supercontinent till early Cretaceous. It was a period of intense plate tectonics leading to the development of new sedimentary basins and major episodes of the flood basalt extrusion. Further anti clockwise movement (northward flight) of India caused emergence of passive margin setting.

Indian Plate completely got detached from Antarctica in early Albian. The passive margin setting from Late Cretaceous to Oligocene continued untill the collision of the Indian Plate with Eurasian and Burmese Plates in the NE. The largest Mesozoic-Tertiary sedimentary basins of the Northeastern India includes the Assam-Arakan region, covering northeastern states of Assam, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Surma valley, South Cachar and Mikir hills as well as in subsurface sections of upper Assam. The thick sedimentary pile was deposited in Late Mesozoic to Cenozoic in shallow shelf, inner and outer ramps to basinal facies. Deeper marine deposits are also found in some parts of Dishang and Bhuban formations. Two distinct shelf and basin sedimentation have been recognized. The sediments of the inner and outer shelf are well developed in the Garo, Khasi and Jaintia hills of the Shillong Plateau, Meghalaya. The paleogeography and the paleoclimatic changes in the northeastern region during Late Mesozoic to Tertiary period have been reconstructed with special reference to basin architecture, depositional facies, foraminifera-algae records, organic and inorganic carbon isotope ratios and thermal events (hydrocarbon potential) of these basins. New stable isotope data of the limestones from the exotic blocks of the Manipur Ophiolitic belt is being recorded. The carbon isotope from Ukhrul, Mova cave and Kankhui shows $\delta^{13}C$ values range from + 0.44‰ (V-PDB) in Ukhrul to + 2.08‰ (V-PDB) in Kankhui. $\delta^{18}O$ values range between -6.47‰ (V-PDB) to -10.23‰ (V- PDB) indicating shallow marine environment.

The calcareous fossil algae has been studied in detail in laboratory form the Lakadong and the Praang Limestone from the Um Sohryngkew river section. In addition to this organic carbon isotope ratios of the Plaeocene-Eocene Lakadong Limestone suggest a thermal event at the P/E boundary. This is the first

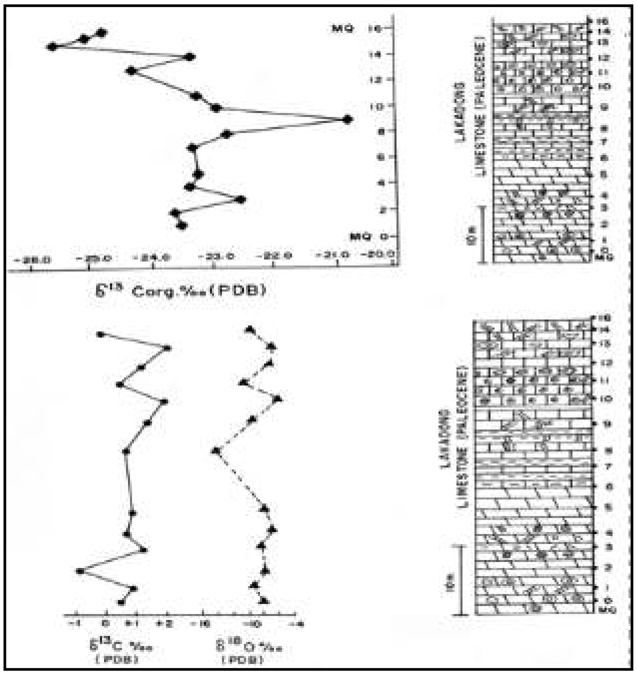


Fig. 15: Organic carbon isotopic changes across Paleocene-Eocene succession in the Shillong Plateau, Meghalaya

study of the organic carbon isotope ratio from this section (Fig. 15). Glauconite pellets with algal fossils (Fig. 16) have been observed in the Mahadeo Formation (Late Cretaceous). Microstructure of the dinosaur bone (Fig. 17) studied from the Mahadeo Formation suggest that the dinosaur fossil may be of Sauropod.

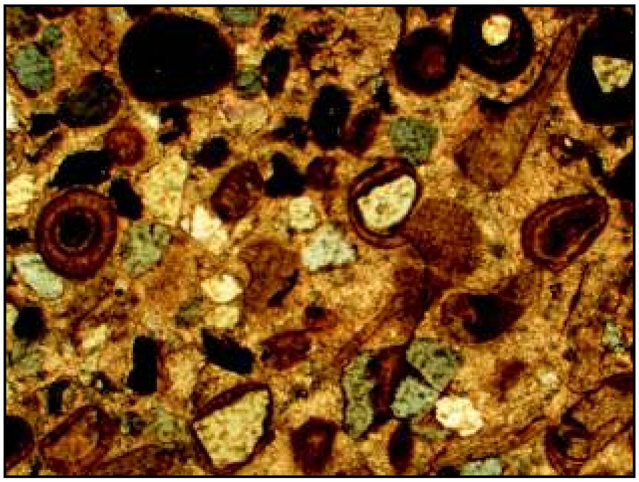


Fig. 16: Petrographic thin section of the Mahadeo Formation (Late Cretaceous) showing glauconite pellets (greenish) with the algal microfossils near the Cretaceous-Tertiary boundary in the Um Shryngkew River section in Meghalaya

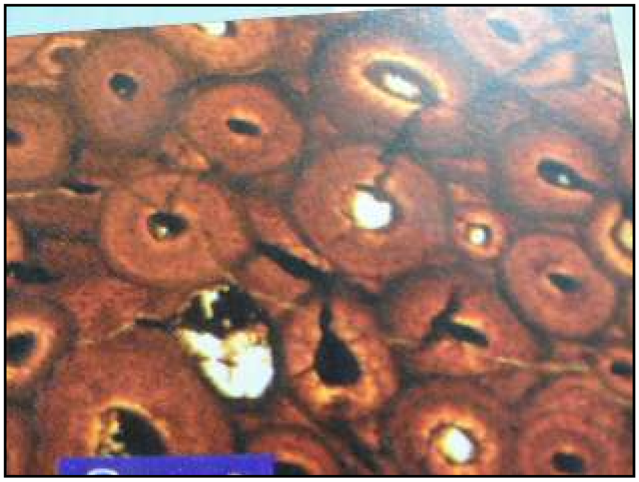


Fig. 17: Microphotograph of the Dinosaur bone collected from the Mahadeo Formation (Upper Cretaceous), East Khasi Hills, Meghalaya

MMP - 4 : SUSTAINABLE NATURAL RESOURCES

Component 4.1:
Mineralisation and metallogeny in space and time in context of diagenesis, magmatism, metamorphism and tectonism: special emphasis on the role of complex fluids in the genesis and evolution of host rocks and ores

(R.S. Rawat)

22 samples collected previously from the Proterozoic, Palaeozoic and Tertiary granitic bodies i.e. of Ghutu-Barkot-Bhatwari, Bhaironghati and Yamontri-Gangotri were subjected for their melt temperature determinations through the homogenization experimental studies. The studied granites range in space and time. It has been observed that the melt temperatures for these granites range from 700 to 800^0C and there is structural state transformation in the alkali feldspars after the experiments i.e. from microcline to orthoclase.

Field work was carried out in the Uttarkashi district to study the volcano-sedimentary sequences between the rivers Bhagirathi and Yamuna for their litho-tectonic contacts as well as mineralization in them. Pillow structures in a gabbroic rock were observed before crossing the Yamuna and Ganga (Bhagirathi) near its water divide. This is a unusual occurrence of the pillow structures in the gabbroic sill in the area and is attributed to the intrusion of the sill (gabbroic magma) in the water saturated fine grained sediments in a shallow marine or shallow shelf condition. The rocks in the area do indicate fluctuation in their depositional environment i.e. shallowing and deepening of the depositional basin for the Garhwal Group sediments during Middle Proterozoic to Middle Devonian times. This fluctuation in the basin is attributed to the presence of sub-surface Delhi- Haridwar- Harshil Ridge (DHHR) - an extension of the Aravalli Basement beneath the Himalaya to facilitate the formation of pillow structures in the water saturated sediments by the gabbroic magma. The pillows might also be present under similar conditions in other localities of Lesser Himalayan zone from east to west, which needs a detailed study.

Also along Varuna river section in the Uttarkashi, two types of basic rocks have been observed i.e. earlier fine grained pene-contemporaneous within silsiclastic sediments, which later on intruded by the coarser doleritic/gabbroic sills and dykes and contain disseminated specks of polymetallic Pb-Zn-Cu-Fe sulphides mineralization. Genesis of the mineralization is being worked out.

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 (Pinjaur - Una Dun) of Himachal Himalaya

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

54 samples of active stream sediments were collected from the Pinjaur - Una Dun, H.P section and were processed in the laboratory. All these samples were dried at 60°C and sieved. In order to assess the degree of contamination resulting from increasing urbanization and various industrialization activities in the study area, the finer fraction of the sediment samples that represent the soil derived from the area were chosen for chemical analysis. To observe the effect of grain size, different fractions (<173 micron and <63 microns) of each sample were separated and analyzed for major, trace and rare earth element concentrations using XRF and ICP-MS. A brief summary of the observed relationship in concentration vs fineness of the analyzed samples is given in Table 1.

Table 1.

Const.	**Na_2O**	**K_2O**	**MgO**	**CaO**	**SiO_2**	**Al_2O_3**	**MnO**	**Fe_2O_3**	**Ba**	**V**	**Sc**
FF/CF	0.92	1.29	1.34	1.74	0.83	1.63	1.14	1.43	1.47	1.45	1.43
Const.	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Pb**	**Th**	**Rb**	**Sr**	**Y**	**Zr**
FF/CF	1.61	1.24	1.38	1.37	1.47	1.06	1.05	1.26	1.51	1.03	1.72

FF: Finer fraction (<63 micron); CF: Coarser fraction (<173 micron)

The finer fraction was found to contain higher concentration of heavy metals because of their incorporation in phylosilicate or clay minerals by adsorption.

Thus in total 150 stream sediment samples were collected from Pinjaur-Una Dun covering approximately the entire project area (~1000 km^2). Sampling locations are depicted in figure 18. Summary of all major and trace elements with their minimum, maximum, average and median values are shown in a Table 2a,2b and figure 19. Values of some of the important trace elements have also been compared with global average crustal value and are shown in figure 20.

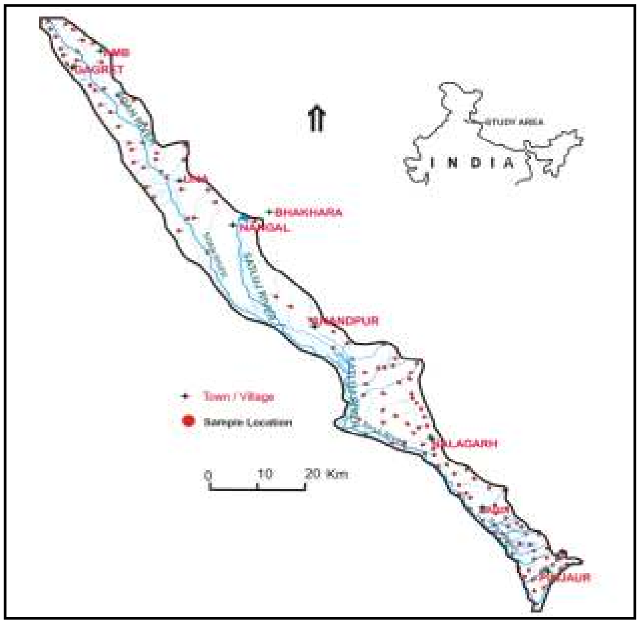


Fig. 18: Sample location and drainage map of Pinjaur - Una Dun

Table 2a: Summary statistics of major oxides abundances in Pinjaur-Una Dun stream sediments

MAJOR OXIDES	MIN	MAX	AVG	MED
Na_2O	0.42	2.25	1.20	1.04
MgO	0.64	1.98	1.26	1.26
Al_2O_3	3.70	14.69	9.63	9.42
SiO_2	63.84	90.15	77.95	77.94
P_2O_5	0.04	0.28	0.10	0.08
K_2O	0.72	2.76	1.87	1.82
CaO	0.28	6.04	1.46	1.33
TiO_2	0.38	1.29	0.62	0.59
MnO	0.04	0.30	0.08	0.07
Fe_2O_3 (T)	1.59	6.99	3.37	3.20

Table 2b: Summary statistics of trace element abundances in Pinjaur-Una Dun stream sediments

TRACE ELEMENTS	MIN	MAX	AVG	MED
Ba	18	749	365	387
Cr	1	1188	238	189
V	29	112	64	62
Co	0	388	36	9
Ni	2	133	18	16
Cu	5	3063	72	29
Zn	33	328	62	49
Ga	3.4	14	9	8.35
Pb	11.3	2284	59	17
Th	4.9	50	17	13.6
Rb	28	132	79	78
U	0.39	5.6	2.9	2.97
Sr	22	108	49	46
Y	17.8	57	30	28
Zr	122	1988	433	332
Nb	7	20	13	12.6

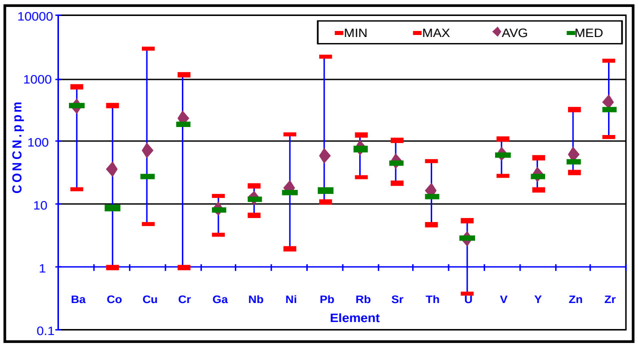


Fig. 19. Range of elemental abundances in Pinjaur-Una Dun

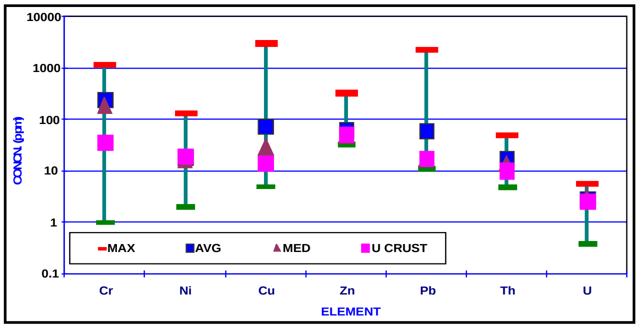


Fig. 20. Range of trace elements abundances in the Pinjaur-Una Dun and their comparison with the crustal abundance

The heavy metal concentrations in Pinjaur-Una Dun sediments vary in the ranges of <1-388 for Co, 2-133 for Ni, 5-3063 for Cu, 33-328 for Zn, 11.3-2284 for Pb and 15900-69900 ppm for Fe. Considerable variation in heavy metal concentrations has been observed between Jhajra and Sirsa catchments. The higher concentration of heavy metals (particularly Pb, Zn, Cu, and to some extent Ni and Co) has mainly been observed along Jhajra catchment and around highly populated areas, such as Kalka, Pinjaur and Parwanoo. The spatial distribution of different elements has been portrayed in the form of geochemical maps (Figs. 21, 22, 23).

Preparation of reference materials

The data collected from various contributors for our two proposed reference samples: DGH and AMH was

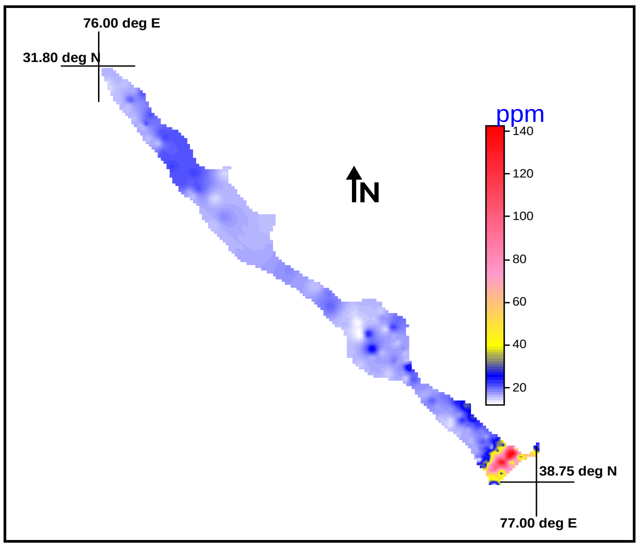


Fig. 21: Geochemical map portraying spatial concentration of Pb in Pinjaur Una-Dun

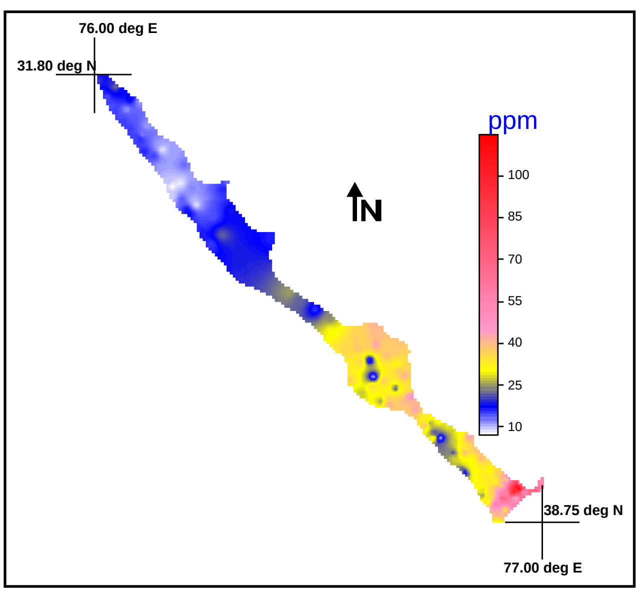


Fig. 22: Geochemical map portraying spatial concentration of Cu in Pinjaur-Una Dun

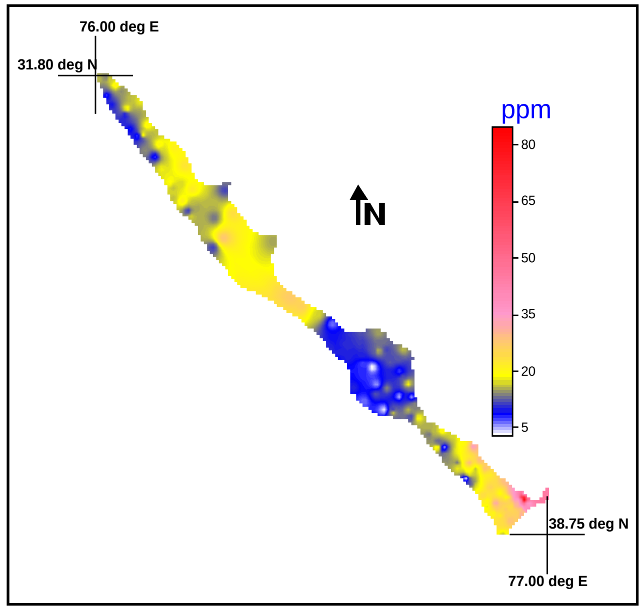


Fig. 23: Geochemical map portraying spatial concentration of Ni in Pinjaur Una-Dun

statistically evaluated for upgrading the derived values for DGH and proposing new working values for AMH.

Component 4.2b :
Mineralization, Metallogeny and the petrological investigations of host rocks in Kumaun Region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao)

The fluid inclusion and Micro Raman Spectroscopy on the fluids trapped in the gangue and sphalerite at Askot attribute that ore forming fluids are C-O-H with low salt contents. Significant CH_4 is present together with CO_2 and the evidences of aqueous fluid boiling are also discernible. The CH_4 in high temperature magmatic fluids may be derived from sediments in subvolcanic hydrothermal system or from an inorganic reaction between deep CO_2 and H_2. The occurrence of the hydrothermal fluids resulting sulphides near the thrusts is interesting, but disseminated sulphides in schists and gneisses are also crucial. Overall, the fluid inclusions favour an interpretation, wherein we appraise that these are 'massive sulfide ores' related to a primary depositional submarine-volcanic-hydrothermal activity, and overprinted by the synorogenic Himalayan event.

Lazulite, a phosphate of magnesium and aluminium, is significant as index minerals and also for its rarity, gem quality and the decorative uses. In continuation of earlier work on lazulite bearing veins occurring adjacent to the Main Central Thrust in Kumaun Himalaya, fluid inclusions studies are carried out on the lazulite-quartz association. Both microthermometry and Micro Raman spectroscopy of the fluids in lazulite and vein quartz have been conducted to evaluate lazulite formation, depositional environment adjacent to major thrust and post depositional changes, if any. A rich population of the fluid inclusions is hosted within the lazulite grains. Much of the inclusion population is trapped in the trails in lazulite crystals with <20% inclusions occurring as isolated random distribution. The Laser Micro Raman Spectra for bubble in aqueous-carbonic inclusions show that the band positions are at 1387.49 and 1284.15 cm^{-1} confirming that the carbonic fluid is CO_2, and a clear band for methane or nitrogen is not discernable. CO_2 always homogenized to the gas phase presenting a low estimated density: 0.31 to 0.38 g/cm^3 for the CO_2 trapped in lazulite. The fluid inclusion trails in lazulite essentially terminate within lazulite grains without traversing to the adjacent quartz suggesting that the quartz recrystallisation occurred after their entrapment. The excess internal pressure shown by some isolated inclusions features in lazulite develops as a result of the disparity between high pressure during inclusion entrapment and later low pressure conditions after exhumation of the host. This probably infers rapid uplift along the MCT. Large scale continued fluid flux along this thrust can not be invoked in the absence of any secondary fluid inclusion trail that crosscut the lazulite-quartz boundary. Since lazulite is capable in sustaining the records of upto amphibolite grade, the derived TP estimate: 520°C, 3.7 kb from fluid inclusions in lazulite can be explained by the mineral formation in the pre peak metamorphic conditions when compared with the metamorphic conditions estimated for the MCT zone rocks.

Raman spectroscopy is an important tool for categorizing the different carbonaceous material through their studies in the low-grade metamorphic sequences to high grade of metamorphics. Graphite formation temperatures are significant in understanding the conversion of carbonaceous material to graphite and metamorphism in the area as graphitization process is significant for their irreversible property. The first order spectrum with G-band at 1580 cm^{-1} and the presence and position of defect bands are useful in defining the crystal structure of graphite and the defects. Extensive Raman spectroscopy is carried out on graphite and further work on estimating graphite temperatures are underway.

The Higher Himalayan Metamorphic Zone (HHMZ) and its cover rocks are exposed through tectonic zones within the hinterland of Kumaun Himalaya. These rocks are studied along Kali valley along Mangti to Garbyang section. The HHMZ is considered to be the Proterozoic basement rocks, which is bounded by the Lesser Himalayan sequence (LHS) and the Tethyan Sedimentary Zone (TSZ) rocks on both sides. The HHMZ is mainly composed of amphibolite to lower granulite facies paragneisses, migmatitic gneisses, orthogneisses, and subordinate calcareous gneisses and metabasites. The gniesses comprise quartz-plagiocalse foliae that define the foliation and are locally folded. Garnet forms skeletal to poikiloblastic porphyroblasts that contain inclusion of biotite, quartz, plagioclase which show rotation. Syn-tectonic poikiloblastic garnet in the gneiss is found in different shapes (e.g., skeletal, elongated, irregular, s-shaped and eqidimensional) and sizes. The variation in garnet shape is the result of growth in mineralogically and texturally different environments. It has been observed that garnet is deformed and occurs as stretched elongated grains in a quartz matrix, but nearly undeformed in a feldspar matrix. This could be because of the relative flow strength of garnet being greater in a matrix of feldspar than it is in a matrix of quartz, as a result of which equidimensional crystals occur where the matrix is more micaceous, whereas elongate crystals occur in more quartz-rich areas. It has also been observed that the micas indicate variable levels of internal strain caused by localized deformation, including kink banding and undulose extinction. Plagioclase is fine- to coarse- grained subidiomorphic to idiomorphic, and locally poikilitic (inclusions of muscovite and quartz). It occurs both in the matrix and as texturally zone poikioblastic porphyroblasts that contain quartz, micas and tourmaline. Quartz and feldspar display signs of internal deformation and dynamic recrystallization related to mylonitic deformation. Sometime they also show mortar texture around garnet prophyroblasts. Kyanites are elongated parallel to the foliation and the stretching lineation. They are generally fractured, bent and partially altered into fine-grained muscovite. The P-T evolution has been inferred for samples from different strategically located structural levels of the HHMZ in the Kali valley along the Mangti to Garbyang section. The interpreted results suggest that in the lower structural levels within the garnet-staurolite zones the P-T conditions varies from 5-7 kbars and 530-600°C respectively, while in the middle crustal levels of Ky-Sil zones it varies from 7-11 kbars and 600-750°C respectively. Preliminary field and petrographic observations suggest that pressures and temperatures further decrease upward in higher structural levels between Bundhi and Tethyan sequence. The former suggest the inverted metamorphic sequence in lower and middle structural levels of HHMZ, and the latter in the higher structural levels it is a normal metamorphic sequence. The lower and middle structural levels of the HHMZ along the Kali valley record a nearly isothermal P-T path during exhumation, while the upper structural levels record a near-isobaric path. The lower structural levels record burial depths of 16-23 km with a thermal gradient of 26-33°C/km, while in middle structural levels the burial depth recorded is 23-36 km, with a thermal gradient of 21-26°C/km.

Further, the geochemistry of the gneisses in the lower structure levels of HHMZ show that they are much evolved rocks (mg#: 8-34), with subalkaline and high-K calc-alkaline nature. They are metaluminous to peraluminous with mol. A/CNK ratios in the range of 0.92 - 1.32. The geochemical variation trends exhibited by these rocks suggest that, fractional crystallization may have been an important process in the evolution of these rocks. Accessory minerals such as apatite and zircon may be more important than major phases in controlling the concentrations of some elements, e.g., Ti, Y, Sr and Zr. The REE in these rocks show highly fractionated trends with some appreciable amount of Eu anomalies. The chemistry of gneisses on the tectonic discrimination diagrams show that they are post-orogenic granites. The high Rb content and the relatively low Nb+Y content and their multication values are predicting the tectonic evolution of collisional orogens.

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 mafic volcanics of the Siang window of Eastern Himalaya comprise voluminous mafic volcanics and minor amount of felsic volcanics (rhyodacite and rhyolite with minor amounts of dacite and welded tuff). The relatively well defined geochemical trends obtained for the felsic volcanics, the progressive increase in REE concentrations, pronounced negative Eu anomalies, combined with results of the petrogenetic modelling, support the idea that a fractional crystallization process has played a major role during the evolution of these felsic volcanics. They have been produced by a two-stage process involving partial melting and fractional crystallization, and the data suggest that significant contamination is involved during their evolution. The less siliceous dacite rock could have been formed after a low degree (<15%) of partial melting of a mafic parental magma source (Fig. 24a). The silica-rich rhyodacites and rhyolites may have been derived from a dacitic magma source by a higher degree (>45%) fractional

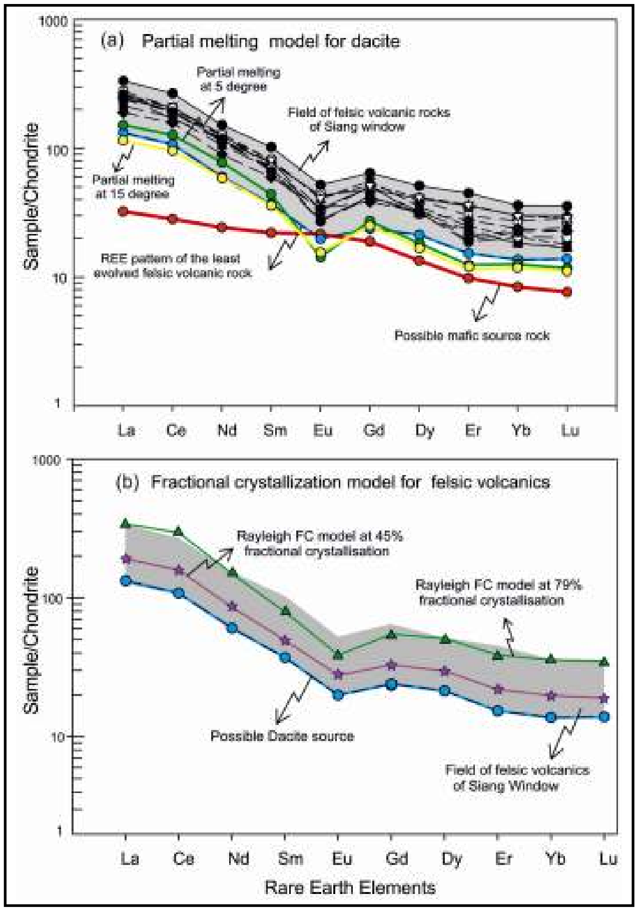


Fig. 24: (a) Chondrite-normalized Rare earth elements (REE) plot shows the zone for felsic volcanics of the Siang window, Eastern Himalaya and their calculated source. REE patterns of this model source were calculated using the batch melting equation, assuming a basaltic mantle source leaving a residue with 55% plagioclase; 14% orthoclase; 18% clinopyroxene; 3% orthopyroxene and 10% amphibole. (b) Rayleigh fractional crystallization (FC) model for the production of rhyodacite at 45% FC and high-silica rhyolite at 79% FC from the dacitic source using the percentages of fractionating phases of 70% plagioclase, 12% clinopyroxene, 7% amphibole and 11% magnetite

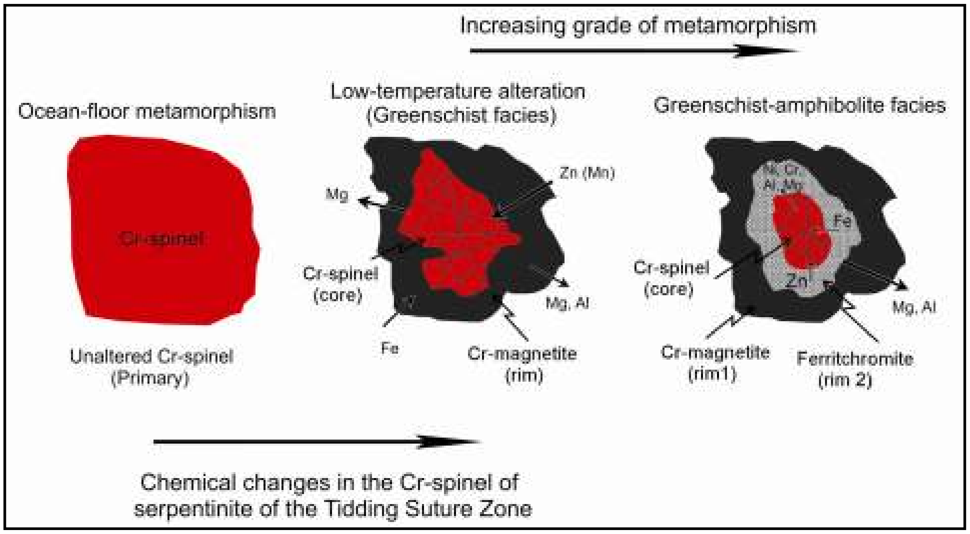


Fig. 25: Schematic illustrations of textural and chemical changes in Cr-spinel in serpentinite of the Tidding Suture Zone, Eastern Himalaya during progressive alteration and metamorphism

crystallization (Fig. 24b). Geochemical characteristics of the felsic volcanics in conjunction with the geochemical data of the associated mafic volcanics strongly suggest they were emplaced in an extensional tectonic environment.

Metamorphosed serpentinites of the Tidding Suture Zone (TSZ), eastern Himalaya, contain variably altered Cr-spinels that are concentrically zoned from high-Cr, low-Fe^{3+} spinel at the core to Cr-magnetite at rim. Zn and Mn enrichment in the core zone of the Cr-spinel is due to the substitution of Mg^{2+} and in part of Fe^{2+}, by Zn and Mn. These elements were probably supplied from olivine upon serpentinization during and after obduction of the ophiolitic mélange along the Tidding Suture Zone in the eastern Himalaya, northeast India. A schematic illustration of the processes of alteration and metamorphic reconstitution of Cr-spinel of the TSZ is shown in figure 25. This simplified phase diagram shows the extent of the spinel miscibility gap appropriate to that stage of the process. During ocean-floor metamorphism, low temperature serpentinization probably did not produce any change in Cr-spinel composition as it took place under highly reducing conditions. With an increase in temperature during the earlier stages of greenschist facies metamorphism, MgO- and SiO_2 rich fluids (derived from low temperature serpentinization of olivine and pyroxenes) reacted with Cr-spinel to form chlorite; as a consequence, chromite became altered to a FeO- and Cr_2O_3-rich, Al_2O_3-poor Cr-spinel. A further increase in the degree of metamorphism around sub-greenschist to lower-greenschist facies stops the serpentinization of olivine and pyroxene, promoting the creation of a relatively more oxidizing environment. Subsequently, the reaction of serpentines with the pre-existing Cr-spinel (both altered and unaltered) results in the formation of a thin Cr-magnetite rim, often incomplete, and has a sharp contact with the chromite core. With more extensive fluid interaction during mid-greenschist facies, the Cr-magnetite zone widens around the margins of chromite, and develops along Cr-spinel fractures. Around the transition from greenschist-amphibolite to lower amphibolite facies conditions, higher amounts of serpentine react with Cr-spinel, producing Cr-rich, Al-poor ferritchromite zones at the inner contact with the Cr-spinel cores (Fig. 25). On the basis of these observations, the textural and chemical characteristics of the investigated Cr-spinel present in the TSZ serpentinites match those of the greenschist facies metamorphism.

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

(S.K. Bartarya and P.S. Negi)

The climate change and its impact on the Himalayan glaciers has been studied on the basis of landforms formed by the Chorabari and Dokriani glaciers, and dating of various cycles of advance and retreat of the glaciers by lichenometry in the Garhwal Himalaya. Based on lichenometric dating four stages of Advance and

Retreat of the glaciers are 258 (173/1 + 85), 240, 170 & 128 yr respectively. The overall average rate of retreat of the glacier is 14.53 m/yr (3750 m / 258 yr). In addition to Chorabari Glacier, a comprehensive study of multi-temporal glacier fluctuation record has been undertaken for the upper Bhagirathi and Saraswati/Alaknanda basins of the Garhwal Himalaya from 1968 to 2006 using Corona and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite images acquired in 1968 and 2006, respectively. The study revealed that retreat rates for the Garhwal Himalayan glacier are lower than previously reported. More recently (1990-2006), recession rates have increased. The number of glaciers in the study region increased from 82 in 1968 to 88 in 2006 due to fragmentation of glaciers. Smaller glaciers (<1 km^2) lost 19.42. ±5% (0.51±0.07% a^{-1}) of their ice, significantly more than the larger glaciers (>50 km^2). From 1968 to 2006, the debris-covered glacier area increased by 17.8±3.1% (0.46±0.08% a^{-1}) in the Saraswati/Alaknanda basin and 11.8±3.0% (0.31±0.08% a^{-1}) in the upper Bhagirathi basin. Climate records from Mukhim (1900 m asl) and Bhojbasa (3780 m asl) meteorological stations were used to analyze climate conditions and trends, but the data are too limited to make firm conclusions regarding glacier-climate interactions.

Meltwater chemistry

Meltwater chemistry, undertaken to understand ionic sources and flow pathways, revealed that the ionic composition in meltwater of Chorabari Glacier may be explained on the basis of chemical weathering of different rocks present in the glacier catchment and atmospheric contribution. The analysis of acid alkali associations indicates the dominance of alkaline earths and weak acid ions in the melt water. 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 data shows that carbonate derived calcium and magnesium are the major contributors of the total cations in all samples. The higher (0.91) Ca+ Mg and TZ^+ and low Na+K and TZ^+ equivalent ratios indicates that the carbonate weathering of granites could be the major source of dissolved ions in the melt water with very small contribution from silicate weathering. High equivalent ratio of $(Ca^{2+} + Mg^{2+})/(Na+K+)$ ranging from 2.3 to 38.4 (mean = 11.2) and high $(Ca^{2+})/(Na^+)$ ratio ranging from 3.7 to 24.2 (mean = 11.6) also confirmed that carbonate weathering of granite rocks was the major source of dissolved ions in the Chorabari Glacier.

The chemical data of Chorabari Glacier shows diurnal variation in Ca, Mg, Na, K, HCO_3, SO_4, pH and electrical conductivity. The diurnal variations in the magnitude and pattern of discharge, suspended sediment concentration, Ca, Mg, Na, K, HCO_3, SO_4, pH and electrical conductivity are indicative of timing of the meltwater transmission through the subglacial drainage. Glacier drainage systems consist of a mix of supraglacial, englacial, and subglacial components and chemical weathering rates can vary among these components. The major ions chemistry of the glacier melts suggests two major flow components; i) A widespread distributed drainage system, and ii) A more discrete channelised system incised either upwards into the basal ice layer or engraved into the underlying bedrock which transports meltwaters rapidly through the glacier. As ablation season progresses, this channelised system expands headwards, following the retreat of seasonal snow cover.

Under the objectives of water quality assessment of city and townships of Himalayan region, study of Tehri reservoir and its surrounding area indicate that, in general, water is almost neutral to mildly alkaline in nature but surface water of reservoir is highly alkaline. The Ca, Mg, and HCO_3 are dominant ions and the water belongs to Ca-Mg- HCO_3 hydrochemical facies. Dolomite and limestone bearing Deoban Formation present in the area are their major sources. Mass balance approach along with graphical interpretation shows that rock weathering is controlling the major ion composition of the waters of the Tehri area. The higher concentrations of HCO_3 indicate intense chemical weathering from carbonate source. The ternary and X-Y diagrams also reflect the ionic contribution mainly from carbonate rocks and partly from silicate rocks. The relatively higher ionic concentrations in groundwater (springs and handpumps) in comparison to stream water indicate longer contact time of water with aquifer material. Factor analysis represents two factors to be most important in affecting the water chemistry of area. They are naturally occurring lithological processes indicated by strong correlation of calcium, magnesium, bicarbonates, total hardness and total dissolved solids and other one is anthropogenic processes associated with sulphate, nitrate, chloride and potassium. No major temporal variation in major ion composition of Bhagirathi is observed before and after damming of river. Based on the water quality indices, water is excellent to good for irrigation in general and also good for drinking purpose.

Further, water and sediment samples were collected from the Ramganga and Ganga rivers in the months of June, August and February to understand the intensity and nature of weathering in non-glacial fed river and also impact of anthropogenic activities in river and groundwater. Samples were also collected under campaign mode from the hot springs and river water of Himachal and Ladakh Himalayas. The analysis of major ions and stable isotopes is in progress.

Treeline dynamics in relation to climate change

Amongst the various natural features of alpine region, the treeline and lichens are the two important climate markers that response to the climate change by their characteristics and hence identified and studied. The dynamic characteristics of altitudinal treeline has been used to examine the climate change response in upper most micro-watersheds of Alaknanda and Bhagirathi rivers in the proximity of Dokriani and Chorabari glaciers. The base line data was obtained from 1962 Survey of India topographic map, relevant floristic records and their at-the-spot validation while present status is delineated by detailed ground checks. Field work has been carried-out in the month of October to cover more sampling sites and to establish permanent reference points for future monitoring. It is observed that within the valley, altitudinal treeline is at relatively lower elevation in proximity to the glacial snout rather than distant area (downstream) from the snout. It is attributed that atmospheric energy in the vicinity of glacial snout is utilized during melting of snow/glacier which generate energy deficit (low temperature) and create deterrent effect to treeline dynamics. While areas away from the glacial snout do not face this deterrent effect and hence bear treeline at higher elevation. It is also investigated that moisture ridden north-facing slopes have encouraged growth of broad leaved *Betula utilis, Rhododendron companulatum, Sorbus acuparia* species while species such as *Taxus baccata*, *Juniperus squamata*, *Abies spectabilis* flourished on the drier south facing slopes. Present and earlier investigations revealed that in the proximity of glacial snout, treeline increased towards higher altitudes.

The treeline advance to the erstwhile snow-ice boundaries, replacement of dominant *Quercus semicarpifolia* by *Rhododendron companulatum, Betula utilis and Sorbus acuparia in Dokriani glacier valley is* bound to invite ecological implication such as increased carbon sink area and decreased *frozen water resource which consequently alter* carbon sequestration potential, radiative energy balance and hydrological regime in alpine ecosystem. Present study with earlier interdisciplinary studies collectively also suggests that treeline rise and loss of snow-ice cover in alpine ecosystem is more related to the deflected snow precipitation system than the global warming impact in Himalayan region.

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

(D.P. Dobhal)

During the period 2010-11, mass balance, snout retreat and hydro-meteorological observations were carried out for the Dokriani and Chorabari glaciers under the ongoing long term glacier monitoring programme on the Himalayan Glaciers.

Annual Mass Balance and Snout Retreat

The dynamics of mass balance and its components of the Dokriani (7.5 km^2) and Chorabari (6.6 km^2) glaciers, located in the Central Himalaya were measured and analyzed for hydrological year 2010-11. The data have been acquired by employing glaciological method, including weekly ablation measurement of stakes and fixed date accumulation measurement for calculation of annual net mass balance. The results are summarized as follows: i) during the period 2010-11, net annual balance was negative with net balance of (-) $4.45x10^6 m^3$ w.e. ii) The ELA found at an altitude of 5090 m compared to ELA altitude of 5085 m in 2010. Calculated mass balance was negative with specific balance 0.40 m w.e. for the Dokriani Glacier and 0.73 m w.e. for the Chorabari Glacier. However, the annual mass balance calculated was negative but magnitude of balance was lower in Dokriani Glacier compared to Chorabari Glacier. It is also observed that variations in annual summer melting are not different but winter accumulation varies year to year. The winter accumulation is the controlling factor in present mass balance scenario. The snout dynamics are another component to determine the changes in length, aerial extent as well as altitudinal alteration of the glacier surface over the period. In order to obtain the detailed and thorough estimation of changes in length, the snouts of both the glaciers have been mapped and measured for the annual retreat. The snout retreat was *ca*. 9 m and 20 m for Chorabari and Dokriani glaciers, respectively. The results reveal that there is no uniform rate of snout retreat; this may be due to the geometry, the temperature variations of the local region and elevation of the snout. The Dokriani Glacier has a narrow and steep sloped terminus area, whereas Chorabari Glacier has broad, gentle sloped and thickly debris covered. The thick debris on the glacier surface protects the glacier ice from the solar radiation and reduced melting. Chorabari Glacier is one of the example in the Himalayan region having thick debris covered ablation area, laying over the southern slope which made it more important and it is well established fact that the southern slope facing glaciers are more prone to melting as the area receives higher amount of solar radiation compared to north facing slope. Therefore, the Chorabari Glacier has slower frontal retreat rate but total annual mass loss rate is higher than the Dokriani Glacier.

Hydro-meteorology

Three Automatic Weather Stations (AWS) were installed at Dokriani Glacier in the Bhagirathi basin and three at Chorabari Glacier in the Alaknanda basin at different altitudes in June and October 2011. Air temperature, humidity, solar radiation, albedo, sunshine duration, wind speed & direction and precipitations were recorded on hourly basis. The data collected during the study period (June-November, at Dokriani Glacier) showed that the total rainfall recorded was 1452 mm, whereas the mean monthly temperature was 9.8°C in June and 9.5°C in September at Base Camp (3812 m asl) and maximum mean air temperature recorded was 14.2°C. The temperature recorded in three observatories at Dokriani glacier basin is shown in figure 26. The winter precipitation generally occurs between the month of December and March when the western disturbances are dominant in the area as they move eastward over Northern India and maximum snowfall occurs during this period. There is no instrumental data on winter snowfall, however, during the study period a total of 80 - 175 cm thick snow packs were measured in snow pits and by probing snow pack in accessible area in the accumulation zone (4000 - 5000 m) in the early spring to estimate winter accumulation. In the lower reaches (3800 - 4000 m), 30 to 55 cm snow depth was measured in the months of April and May, which melted before the commencement of monsoon in mid June. Discharge measurement in the Chorabari and Dokriani glaciers were carried out for the period of June - October. Unfortunately, due to heavy rainfall (flash flood), the discharge site washed and the discharge measurement were not made properly in the Dokriani Glacier. In Chorabari Glacier, discharge measurements have been carried out for the entire ablation period (June - October). The area-velocity method was used to estimate the daily discharge. The mean monthly discharge observed during study period i.e. June, July, August, September and October is 0.7, 1.1, 1.2, 0.9 and 0.7 m^3/s. The mean monthly total discharge calculated was $10.80 \times 10^6 m^3$.

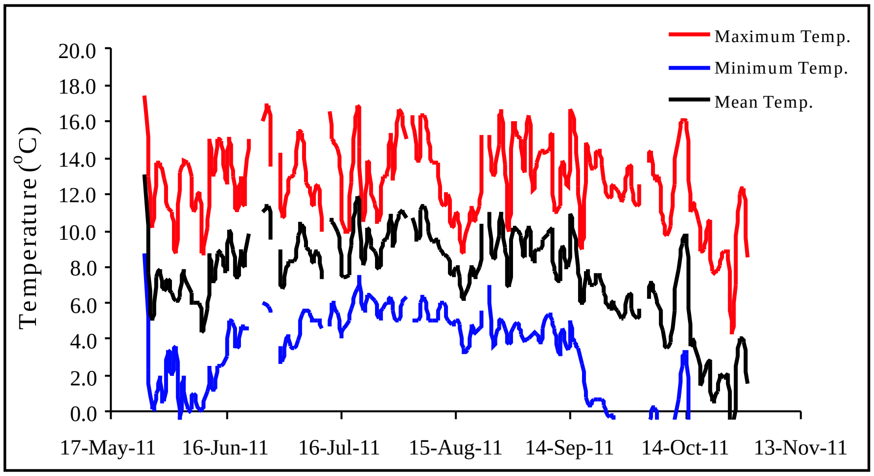


Fig. 26: Daily maximum, minimum and mean temperature during ablation period (2011) at base camp (3862 m asl), Dokriani Glacier

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

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

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

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

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

During the reporting year our study has been continued in the Himalayan Frontal Thrust (HFT) region where we had excavated a trench in the previous year. The HFT is manifested in the Quaternary, rather in the younger alluvium, in the form of discontinuous range-front scarps that truncate the Quaternary fluvial terraces and alluvial fans. The two faults recognised in the trench wall at Singhauli, where the Middle Siwaliks have thrust over the Quaternary alluvium is very significant as far as the repeated reactivations of the HFT in the Frontal Himalaya is concerned. These two faults, Fault-I and Fault-II, have not only uplifted the younger fluvial terraces but also generated induced secondary features and soft-sediment deformation structures, mainly the sand injection and water escape structures. The OSL ages of the samples collected from two different spots within the induced sand injection structure show ages of 79.3 and 63.4 ka respectively. The sand injection structure has cut across a younger litho-unit (OSL age of 34.1 ka) suggesting the injection occurred after the deposition of this unit. The dismembered litho-units suggest that during heavy shaking the water escape structures have also altered the thickness of the sedimentary units by upward and lateral injection of fine grained materials. The Fault-I demonstrates the Late Pleistocene activity of the HFT by thrusting of Siwalik rocks over the Late Pleistocene alluvium. The hanging wall of the Fault-I, comprising Middle Siwaliks and younger litho units is again thrust over by the Middle Siwaliks along another parallel fault, the Fault-II. The fault plane dips 30^0 N, which is also parallel to average dip of the HFT in this region, suggesting it to be yet another reactivation of the HFT in the Late Holocene. The faulting has also uplifted the Holocene terrace in the hanging wall and truncated across the HFT. The OSL sample collected 1m below the surface of the Holocene terrace shows an age of 5.8 ka. The scarp face of the Fault-II is presently being degraded and covered by the colluvium derived from Siwaliks and the up thrown terrace. Based on the above observation, we report here for the first time explicit evidences for multiple paleoearthquakes during Late Pleistocene and Holocene in the Kala Amb area (Himachal Pradesh) of the northwestern part of the Frontal Himalaya. The topographical profiles in the present site suggest that the distribution of T2 terrace (2.1 ka) along the river is not affected by the movement or offset by the HFT indicating the latest activity. This suggests that after Mid Holocene no tectonic activity is observed or identified in this locality.

In the present study, the strath terrace is used to calculate the slip and the uplift rate of the HFT at Singhauli. The strath terrace, which is 3-5 m thick and resting over 15 m Siwalik rocks, shows a long term slip to be 3.59±1.01 mm/yr and has generated a slip of 7.18±2.02 mm/yr along the 30^0 dipping Fault-II. However the uplift rate calculated for the Fault-II, considering the vertical relief of strath terrace and the youngest litho-unit, is 2.87±0.63 mm/yr. The large slip of 30m along the Fault-II might also be due to multiple reactivations along the fault: the earlier faulting event occurred between 5.8 ka and 4.3 ka and the latest event occurred between 4.3 ka and 2 ka.

Empirical formulae are being employed to calculate the parameters of paleoearthquakes. Based on the measurements made in the trench, we estimated that a large earthquake with ~ 12 to 16 m of slip with a magnitude 7.3 or greater hit this region in the period between 34 ka and 17 ka. With regard to Fault-II, considering the comparative elevation difference of 13 m of the exposed Siwaliks, both in the hanging wall and footwall, show a minimum displacement of 26 m along the 30^0 dipping fault. On the other hand, the present day disposition of 15 m between the marker units across the Fault-II exhibits a maximum displacement of 30 m. We therefore believe that a huge earthquake of magnitude 7.6 or greater might have occurred in this region. Based on the above empirical relationship, an earthquake of M ~7.6 with a maximum surface rupture length (SRL) of about 150 km has been estimated. However, the observable SRL might vary depending on lithology and rates of erosion. In the present study the observed length of the subdued fault scarp is limited owing to fast modification of the landform for agricultural and industrial development. Considering the two empirical equations suggested by Matsuda (1975) and Wells and Coppersmith (1994), we are of the opinion that the reactivation of the HFT has generated large paleoearthquakes of >7.5 to 8.5M during Late Pleistocene and Late Holocene. Repeated reactivation of the HFT substantiates high seismic potential of the Frontal Himalaya and calls for more extensive study of paleoearthquakes of this vastly populous mountainous region. The present observation in the Kala Amb trench and the reports of earlier workers strongly indicates that the HFT will produce large magnitude earthquakes greater than those events that took place in the historical past.

Based on the analysis of drainage pattern and neotectonic studies, a tectonic model has been proposed for the evolution of the frontal part of southwestern Arunachal Himalaya. A transverse fault existed before the initiation of sedimentation in the Neogene foreland basin. Later, during tectonic evolution of the Sub-Himalayan mountain range, this fault was reactivated which persisted till recently and has controlled the development of present-day drainage pattern, and the Quaternary basins, formed between Himalayan Frontal Thrust (HFT) and Intra-Siwalik Thrust (IST). Further towards southwest, the Sub Himalaya is traversed by a transverse fault that has cut a regional fault propagation fold located towards north. Later this fault propagated across the HFT towards south into the Brahmaputra alluvium plain. Recent dextral strike-slip faulting is recognized within IST zone along which river course has been deflected. Along hinge zone of the fold the river course has been deflected and recurrence of landslides takes place. Thus recent active out-of-sequence faulting took place along the IST in mountain frontal part of Arunachal Himalaya. Soft-sediment deformation structures or seismites are also recognized in the Middle Siwaliks in Arunachal Himalaya and have been interpreted to be related with the reactivation of the Bomdila Thrust or the MCT. The structural study and analysis of the Quaternary landforms at Siang river exit indicate that the mountain front in the frontal Arunachal Himalaya has been active at least during the Late Pleistocene-Holocene between 56 ka and 8 ka.The Quaternary Medziphema intermontane basin, covered with fan and terrace deposits was studied to understand its tectonic and geomorphic evolution. The basin is situated between the Naga and Sanis-Chongliyimsen thrusts of the frontal Naga-Patkai-Mizo Hills forming schuppen belt of Nagaland, northeast India. On the basis of field evidence and morphometric parameters the evolution of the basin has been attributed to the successive westward younging activation of thrusts in the schuppen belt. Thrusting of Neogene rocks over the Quaternary Brahmaputra alluvium along the Naga Thrust has uplifted the frontal range resulting in the development of the intermontane valley. Upliftment along the Naga Thrust has tilted the Early Pleistocene Dihing rocks occupying the core of the intermontane valley towards the SE. In the hinterland region, based upon the field observation along with structural and geomorphological analyses it is revealed that middle part of the Arunachal Lesser Himalaya shows neotectonic activities along a fault that is parallel to the Himalayan orographic trend. Recent tectonic activities have resulted in re-moulding the landscape morphology along this fault, which is associated with regional-scale active fault that suggests the locking of the detachment below the Lesser Himalaya.

In Kathgodam and Tanakpur areas, the truncation of fans, fault scarps, tilting of terrace deposit, and formation of lakes and lakelets along normal faults indicate neotectonic activities in the MBT zone and mountain front. Morphometric indices have also been analysed to assess tectonic activities along the HFT. The ratio of valley floor to valley height (V_f) of 44 transverse rivers and streams have low V_f values. This suggests active incising across the mountain front due to a consequent of uplift along the HFT. Longitudinal profile drawn for streams flowing across Bastia Thrust and HFT shows perturbation in the profile indicating tectonic activities along these thrusts. Stream Length-Gradient index (SL) shows high values suggesting rapid uplift of the area. The Basin shape index (Bs) analyzed for the sub-basins perpendicular to mountain front are elongated suggesting uplift along the mountain front. Mountain-front sinuosity index (S_{mf}) calculated for mountain front of length of ~73 km gives an average low value of 1.44 suggesting uplift along the mountain front defined by the HFT.

Field and Anisotropy of Magnetic Susceptibility studies along a transverse active fault passing across the North Almora Thrust reveal that a continued progressive deformation resulted oblate type of deformation in central part and prolate to oblate types of deformation in terminal parts.

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)

During the year 2011-12, fieldwork in the Alaknanda and Bhagirathi valleys has been carried out. Data on joints / discontinuities present in all the lithounits along a transportation corridor between Chamoli and Badrinath have been collected and analyzed stereographically. It has been observed that all along the transportation corridor, Lesser and Higher Himalayan in-situ rocks are exposed at 23 localities. Of these 23 localities, 12 localities are located in the Higher Himalaya and 13 in the Lesser Himalaya. These rocks contain numerous joints and owing to their orientation, blocks of rock of varying sizes are susceptible to fall, thus endangering the vehicular traffic and the settlements. The kinematic rockfall hazard analysis was carried out for all these 23 localities where in-situ rocks are observed. The results of the analyses were evaluated and the areas delineated as susceptible to rockfall hazard are highlighted. It has been noted that the rocks of the Higher Himalaya falls dominantly either in low hazard or moderate hazard. The area has been classified as 'low hazard' potential having upto two joints or the intersection of joints, susceptible to fail, 'moderate hazard' potential having 2-4 joints or the intersection of joints, susceptible to fail and 'high hazard' potential having > 4 joints or the intersection of joints, susceptible to fail. Contrarily, all the area falling in the Lesser Himalaya falls in the 'moderate to high hazard' potential. Further various lithounits have been characterized on the basis of Rock Mass Rating (RMR) as well as Q-value characeteristics.

The quantification of various textural parameters and petrophysical & mechanical properties of quartzites of the Lesser and Higher Himalayas has also been done. A dimensionless quantity 'Texture Coefficient' (TC) representing rock texture incorporates various textural parameters like grain shape, orientation, degree of grain interlocking and relative proportion of grain and matrix (packing density) has been measured, besides shape preferred orientation and grain boundary suturing (fractal dimension). These have been correlated with the seismic properties like P- and S- wave velocities and attenuation characteristics and unconfined compressive strength. It has been concluded that seismic velocity in rocks is a function of various textural parameters, like with the increase of aspect ratio, grain size and shape preferred orientation, velocity increases and with the increase of suturing (fractal dimension) the velocity decreases. The TC is noted to be inversely proportion to the velocity and there exits strong positive relationships (R = 0.71) between TC and the unconfined compressive strength. However the relation between the velocity and the UCS is meaningless.

Component 5.2 :

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

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

Component 5.2a :

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

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

The understanding of earthquake source processes and the medium characteristics provides the basic tools for the assessment, mitigation and reduction of seismic hazards. To obtain these objectives WIHG is operating a regional seismic network in the NW Himalaya to address seismotectonics, and the evolution of stress pattern of the region in better way. Accurate assessment of the earthquake hazard is critical step for earthquake risk mitigation.

Observations noted from the analyses of local earthquakes

WIHG is operating a seismic array consisting 41 seismographs. Eleven broadband seismographs are connected through V- sat and getting data at Dehra Dun in real time mode. During January 2011 to March 2012, we have recorded about 378 local earthquakes. The focal depths of these local events range between 7 km to 38 km, but large number are confined to upper ~20 km. The local magnitude ranged between 1.5 and 4.9.

Evaluation and implications of seismic events in Garhwal-Kumaun region of Himalaya

The Garhwal-Kumaun region continues to accumulate the built-up of strain energy like the other regions of the Himalaya. But this sector unlike the other sectors is yet to release this accumulated strain energy which can be in the form of major to great earthquake. The region has sufficient strain energy to generate earthquake of M>8 .The analysis of four hundred sixty seven local events recorded by ten station broadband network between July 2007 to February 2012 shows that most of the seismic events recorded in this region continue to occur at shallow depth (< 25 km). The evaluation of source parameters from p-wave spectral analysis indicates that the events have low stress drop values. The region continues to release energy in the form of smaller magnitude earthquakes. The epicentral location map indicates that the Munsiari Thrust, which is located south of the Main Central Thrust is more active.

A harmonic potential well based particle swarm optimization applied as optimization technique in earthquake locations

Particle swarm optimization (PSO) is preponderantly used to find solution for continuous optimization problems and has the advantage of being cheaper and quicker. Here state-of-the-art new particle swarm optimization algorithm is used to solve the complex optimization problems. The availability of the introduced algorithms is validated statistically on several benchmark problems and also compared with the existing versions of PSO.

Novel sorting technique for large database

Sorting is frequently used in a large variety of important applications used by Earth Scientists. Here state-of-the-art novel sorting technique named "Position Sort" is used. This sorting technique provides the correct position to an element by only one swapping operation. It is an improved sorting algorithm with lesser running time and number of swapping operations in comparison to some other existing techniques like Bubble sort and Selection sort.

Stress patterns of different seismic regimes of the Northwest Himalaya

The stress patterns of different seismic regimes of the northwest Himalaya are investigated using focal mechanisms of =3.0 magnitude earthquakes. Fault plane solutions of 68 events are selected from earlier published work during 1974-2009. The data set contains the earthquakes of magnitude more than 3.0 mainly occurred in the regions of Lesser and Higher Himalayas. In addition the focal mechanisms of 50 events are from USGS CMT solutions during 1963-2011 having magnitude >5.0 and mainly occurred in higher Himalayan region, Trans Himalaya and south Tibetan plateau zone. Except few earthquakes of magnitude >6.0, the mechanisms are oblique in nature with higher proportion of reverse/thrust mechanisms. The mechanisms of higher magnitude are available with pure thrust mechanisms except one event of Kinnaur region which has caused deformation purely through normal mechanism. Based on this data set the pressure and tension axes are determined from the fault plane solutions and are projected on the tectonic map to evaluate the linkage of stress pattern with tectonic elements. It is observed that most of the P-axes orientations are in NE-direction and nodal planes are in NW-SE direction that shows the conformity of ongoing stress with the trend of major thrust/lineaments of NW Himalaya. The normal fault mechanisms are concentrated in Kinnaur and northeastern corner of Kumaun Himalaya bordering Nepal and Tibet. The nodal planes of most of the events of normal fault mechanism are trending in N-S direction with T-axes trend in E-W direction. This indicates the effect of E-W extension in these two regions which is the part of South Tibetan Detachment zone. The stress tensor inversion study shows compressional stress regime for the Kangra-Chamba and the Garhwal-Kumaun regions and extensional regime for the Kinnaur region and other portion in the eastern part of study zone comprising the strata of south Tibet plateau.

Aftershock study of September 18, 2011 Sikkim earthquake (Mw 6.8)

A new seismological network consisting of 8 broadband seismographs were installed in Sikkim Himalaya during September 2011 to study aftershock activity of recent Sikkim earthquake 2011.

Component 5.2b :

Multi-parametric Geophysical Observations for earthquake precursory research

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

The opening of cracks and influx of fluids in the dilatant zone of impending earthquake is expected to perturb the mass distribution during earthquake build up cycle, which should be reflected in time-varying geophysical field. The continuous time series of different geophysical parameters such as superconducting gravimeter (SG), overhauser magnetometer, tri-axial fluxgate magnetometer, ULF band search coil magnetometer, radon, water level recorder, seismometer, accelerometer and GPS are being collected at one site to observe unusual behavior during the occurrence of nearby big size earthquake. Along with this the WIHG has been operating dense networks of broadband (BB) seismographs and GPS in NW Himalaya and the data of these stations is also being utilized for earthquake precursory study. The critical analysis of various geophysical time series indicates anomalous behavior at few occasions, however the data is also influenced by many external parameters which has to be removed for observing true signals related to earthquake deformation. The geomagnetic field changes are sensitive to solar-terrestrial dynamics where as the flux of radon emission is strongly dependent on environmental factors like temperature and hydrology. The gravity data of SG is influenced by tidal forces, atmospheric pressure, changes in water table, moisture etc. These influences are the major deterrent in the isolation of weak precursory signals and it is observed that if effects of environmental and hydrology are not recognized and corrected, some anomalies will be falsely viewed as earthquake precursors. On the other extreme, some precursory signals would be masked by factors other than stress-induced changes. Although any significant earthquake is not reported close to the observatory during observation period however some weak precursory signals and co-seismic changes have been identified in few parameters related to the occurrence of moderate and strong earthquakes.

Seismic activity of the Garhwal Himalaya

The Multi Parametric Geophysical Observatory (MPGO) is the central part of active seismic zone, corroborated by a close network of BB seismic and GPS stations of the Wadia Institute of Himalayan Geology. After the installation of MPGO, as a part of independent project of the Ministry of Earth Sciences (MoES), we strengthened seismic network in the Garhwal Himalaya that lowered down the earthquake detection threshold to nearly M 2.0 compared to its initial level of M2.5 in 2007. In this network 10 BBS stations are being operated in real mode through VSAT sponsored project of MPGO for analysis of seismicity in real time at Dehra Dun. Subsequently, the seismic network of other regions of the NW Himalaya are installed and strengthened. The recent data of all earthquakes of M=2.0 have highlighted a high seismic activity over MCT zone around MPGO stations. The recent and past seismicity around MPGO is analysed to search earthquake precursory signatures in the time and spatial variability of earthquake occurrence. We are adopting different techniques such as seismic quiescence, enhancement of seismic activity, RTL (Region-Time-Length) algorithm for the change in the behavior of seismic activation to get any signal of zone preparing for large earthquake around MPGO and other adjoining parts of the Himalaya. Using these techniques, we have detected some seismic precursory signals in the past data in Garhwal Himalaya and methodologies are being adopted for present data analysis.

Co-Seismic Variation observed in Gravity using Superconducting Gravimeter

It is observed that sudden offset in the gravity residual from the average level is due to occurrence of local and regional large magnitude earthquakes. A moderate magnitude (M4.9) earthquake occurred on 22nd July 2007 with its epicentre just 60 km away from the SG instrument site. Wide spread data analysis has been done to trace the unusual gravity variation before the occurrence of this earthquake after taking the residual record of 15 days before and 15 days after this earthquake. Although there is gradual change before the occurrence of the earthquake but that is related with heavy rainfall occurred during this period in the region. The residual data of one sec sampling indicates sudden shift in the average level of gravity after the occurrence of this earthquake which has been obtained after removing the hydrological effect. This is a well preserved co-seismic change observed through SG data at this high seismic zone of the Himalaya. Taking this into consideration, we processed and analysed the data related to other earthquakes that have magnitude more than 4.5 and occurred close to the SG site. Based on the analysis it has been observed that co-seismic change in gravity is identified whenever any earthquake having magnitude more than 4.5 occurred within a distance of 100 km. Recently an earthquake of M5.7 occurred in the Darchula region (India-Nepal Border) on April 4, 2011 and the co-seismic changes also have been observed during its occurrence having epicentre distance of 200 km.

Geomagnetic and Electromagnetic Observations

Stress changes, associated with the process of earthquake generation, perturb various physical properties of subsurface rocks. These changes may cause time dependent local magnetic anomalies either due to piezomagnetic effects or from electro kinetic effects. In order to detect these changes, Overhauser Magnetometer, and ULF band Induction coil magnetometer are continuously registering total magnetic field and variation in magnetic field in three components at Bhatwari and Adibadri.

For ULF band (0.01-10 Hz) electromagnetic emission polarization analysis has been done using the ratio of vertical and horizontal magnetic field components (S_Z/S_H) in the selected frequency band. EM signals originating due to tectonomagnetic effect violates plane wave approximation and therefore the dominance of these tectonomagnetic origin signal would result in high non-zero S_Z/S_H ratio. Another approach of fractal analysis for indentifying earthquake precursor is also employed considering that the dynamics of the earthquakes manifest the state of the system driven to the point of self-organized criticality. In this state, the system is highly sensitive to any external perturbation whose time response exhibits characteristic of flicker noise or 1/f noise. Therefore, fractal properties by investigating the scaling characteristics of signals from sub-critical level to a self-organized criticality state could give us information on the earthquake processes.

Earthquakes that have occurred within 100 km radius from MPGO Ghuttu were analyzed for searching earthquake precursory behavior utilizing above methodologies and also using data sets from three places (Bhatwari, Adibadri and Ghuttu). Perturbations in night time differential plot of total magnetic field and anomalous third eigen value variations before the occurrence of earthquake indicate some precursory signature in total magnetic field observations. Similarly there are days before earthquake when increased polarization ratio and variation in fractal dimension, calculated from ULF band EM emission, indicates tectonomagnetic origin of EM signals. However at this stage no earthquake precursors is definite prognostic value, nevertheless attempts are being made to understand time variability of different geophysical parameters. Studies to identify various factors affecting measurements or observations in different analysis are being cross-examined for variety of precursors to make collective assessment to validate the earthquake precursors.

Radon time series analysis

Radon measurement data for the year 2011 obtained from 10 meter deep borehole show a clear seasonal pattern (Fig. 27), with high radon value (4556x100 count/15minutes) in summer/rainy season (May to August) and a low value (3807x100 count/15minutes) in winter (November-December). Similar trends in seasonal radon variation were also recorded in the previous years. The transition period between winter to summer (March and April) show rising pattern, with large fluctuations of radon concentration, whereas in October, transition period, between summer to winter show decreasing trend, with high variability in radon.

Besides the seasonal characteristics, the diurnal variation of borehole radon concentration was also studied for the year 2011. It was observed that the diurnal variation of atmospheric radon concentration was different in different seasons. In general, the hourly radon data have a diurnal variation with a maximum in afternoon and minimum in morning. It was observed that the during the winter season typical variation observed for a few days, borehole radon concentration rose steadily from around mid-night and attained maximum value at about 5 pm to 6 pm in the evening. The borehole radon concentration then dropped sharply in 2½ hours and reached minimum around 8 pm, remained at minimum levels from evening 8 pm to next day 12 pm (for about 15 hours). During the summer season which also include monsoon bore hole radon concentration shows different diurnal characteristics. In the months of March, April and May daily radon concentration start increasing around 11am and reached to the maximum at about 5 pm and then start decreasing again and reached to the minimum at 9 am in the morning. A similar trend in diurnal borehole air radon was observed in the month of October, November and December. The radon concentration in the rainy season (July, August and September) reaches to its maximum level. Although no diurnal variations have been observed during this period, which is due to the fact that the soil gets saturated with water and prevents radon from escaping into the atmosphere and vice versa so radon concentration remains nearly constant throughout the day. In the recorded measurements clear pattern of daily radon variations was not observed but occasional jerky radon variability due to long pauses in the rainfall was noticed. Beside radon, variability of other parameters like borehole temperature (gamma temperature), atmospheric temperature and rainfall for the year 2011, are shown in figure 27.

Global Positioning System

Monitoring of Ground Positioning System (GPS) is being used for crustal deformation and earthquake precursory study using GPS network mainly of the NW Himalayan region. With this objective, WIHG has improved the network capacity to nine stations in 2009-2011, as earlier only two stations were in operation. At present (2012) total ten permanent GPS stations (one each at Badrinath, Bhatwari, Munsiari, Dehardun, Ghuttu and Biharigarh in Garhwal Himalaya, one each at Naddi and Kothi in Himachal Pradesh, one station at Panamik in J&K and one station at Delhi in the Indian shield) are functioning in real time mode in the Himalayan arc. The raw data

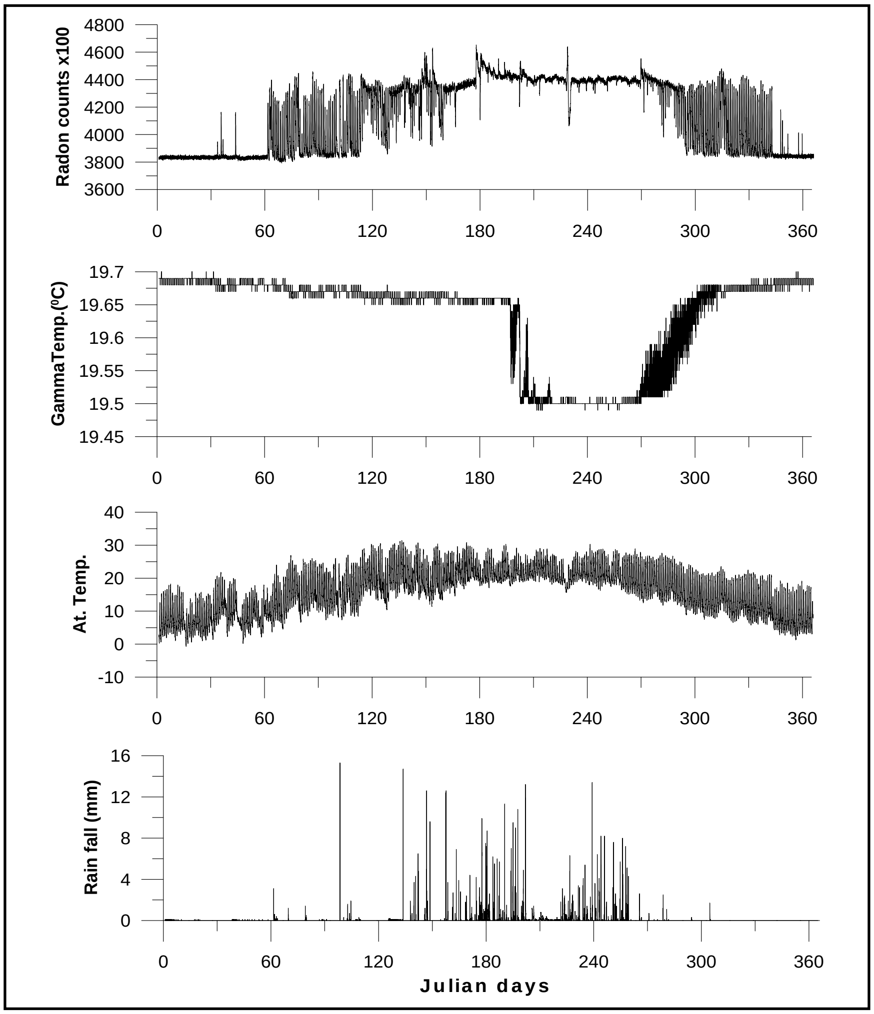


Fig. 27: Continuous data plot of radon, borehole temperature, atmospheric temperature and rainfall for the year 2011

from all receivers are being collected in binary format at the sampling interval of 30 sec. We have performed pre-processing using the TEQC utility software and post processing by advance version of Gamit/Globk software (Gamit10.40) and obtained the results in ITRF05 reference frame. The time series of GPS station at Ghuttu for the years 2007-2008 are depicted in figure 28. Beside that we have also processed the GPS data of around the Tehri Reservoir from 2006 to 2008. The velocity vector along with the reservoir water level fluctuation are presented in figure 29.

Seismic Precursor

The change in the velocity ratio Vp/Vs is one of the precursor phenomenon. This ratio decreases and then recovers shortly before an earthquake. On the basis of an observed drop of the Vp/Vs ratio from 1.73 on 30th July 1973 to about 1.5 over the next two days, Aggarwal *et al.* (1975) have reported a successful prediction of an earthquake in the Blue Mountain Lake area of USA. A prediction was made on 1st August that an earthquake of magnitude 2.5-3.0 would occur in a few days. An earthquake of magnitude 2.6 had occured on 3rd August.

Similar precursory studies are being carried out from the data acquired in the VSAT linked Broad Band Seismic Network in the NW Himalaya. Using the micro-earthquake data of the Garhwal Himalaya, the variation of Vp/Vs from July 2007 to February 2012 has been carried out. 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. The Vp/Vs ratio of the present data of the Garhwal region is shown in figure 30 .

Nonlinear Time Series Analysis of accelerograph data

An effort is made to use nonlinear time series analysis methods for the analysis of accelerograph data recorded at Multi-Parametric Geophysical

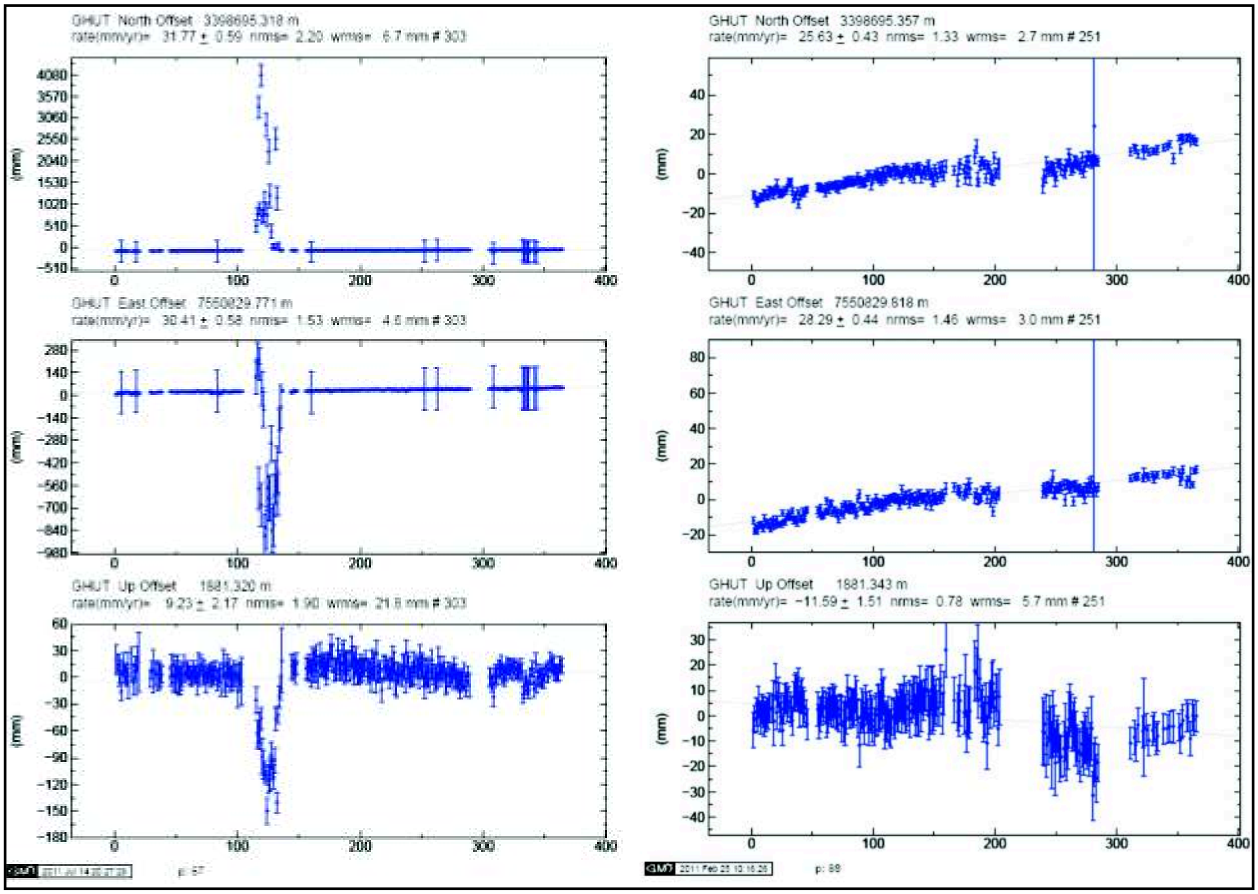


Fig. 28: Horizontal and vertical component variation for the year 2007 and 2008

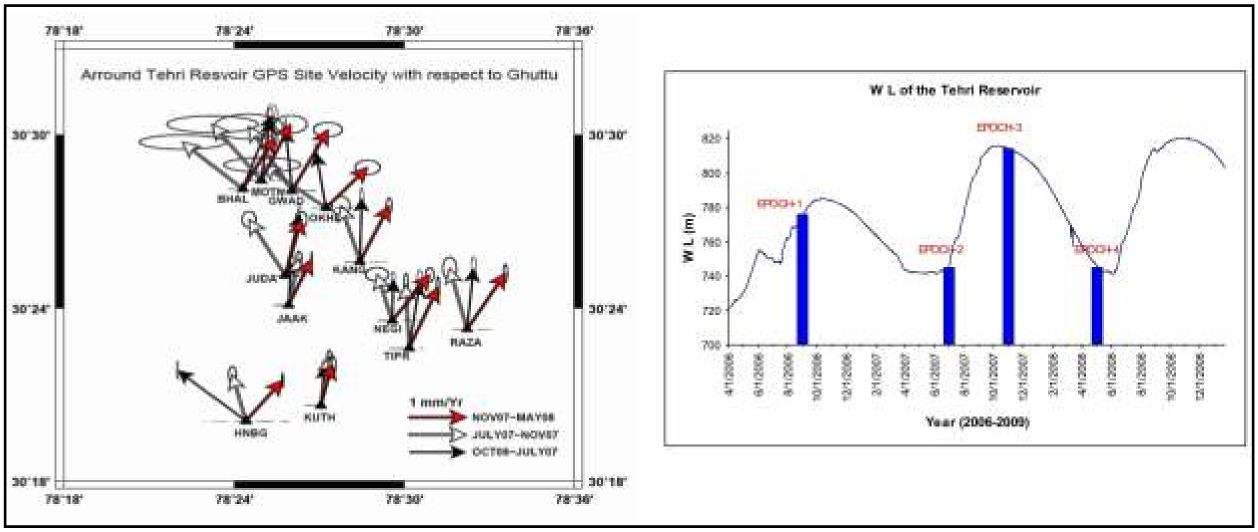


Fig. 29: (a) Velocity vectors for the period Oct., 2006-May, 2008 (b) Reservoir water level from April 2006 to Dec. 2008

Observatory (MPGO) at Ghuttu. Initially few earthquakes located within 100km around Ghuttu MPGO observatory has been tested by this method. An attempt is made to find out the behavior of oscillatory motion (whether linear / nonlinear, stochastic deterministic), degree of freedom involved, degree of complexity, spectral content etc. for better understanding of the dynamics of earthquake process. The phase space, which describes the evolution of the behavior of a system, is reconstructed using the delay-embedding theorem as suggested by Takens (Lect. Notes in Math., Vol. 898, pp. 366, 1981). The time

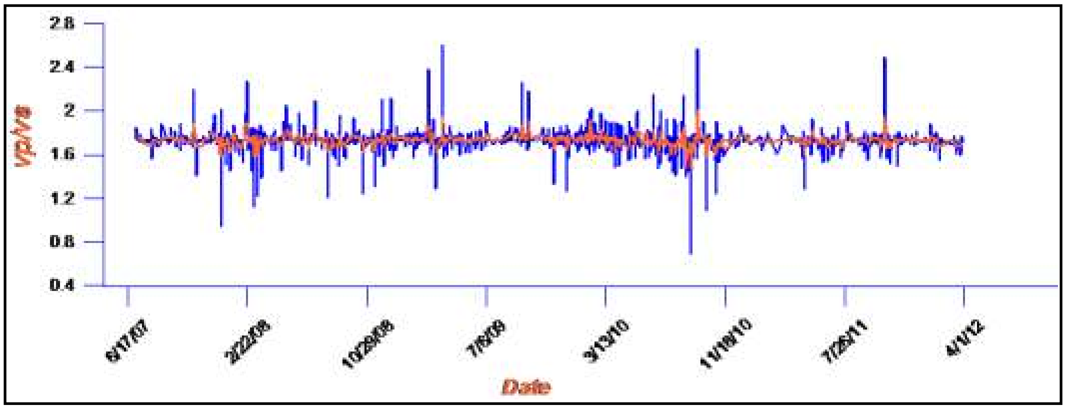


Fig. 30: The plot of Vp/Vs for the earthquakes recorded through VSAT seismic network during July 2007 - March 2012

delay used for the reconstruction is chosen after examining the first minimum of Average Mutual Information (AMI) of the data. The dimensionality is determined by the methods of correlation sum (Grassberger and Procaccia, 1983; Phy. Rev. Lett., Vol. 50, pp. 346-349), which is a fraction indicating the ground acceleration during earthquake process to be chaotic in nature. The singular value decomposition method (Broomhead and King, 1986; Physica D, Vol. 20, pp. 217-236) is also applied to the accelerograms to determine an orthogonal basis for embedding and dimensionality of the underlying system. The preliminary study shows that the earthquake mechanism can be treated as a low dimensional nonlinear dynamical system. Further studies using nonlinear time series analysis is under process.

Component 5.2c :

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

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

Shear wave velocity investigations of Donga Fan

The characterization of sediments in a tectonically active complex region is very important from the seismological point of view in order to study the possible earthquake effects (site effects). However the main issue is that whether one should consider Vs_{30} site amplification which is commonly used in estimating site amplification or the actual thickness of sediments. In tectonically active complex region, the frontal part of the Himalayan front comprises thick fan sediments and most of the populations are residing on these fan sediments. Most of countries use Vs_{30} parameters as a base for site amplification in their seismic codes. In India seismic codes are prepared based on seismic zonation map of India, which is primarily based on occurrences of previous earthquake and their site amplifications. Presently, in India most of the studies carried out for different cities use Vs_{30} parameters but it has been realised that during the earthquake loading the actual strong motion is represented as a bed rock motion. Yet, despite the widespread use of this parameter, there is no universal agreement that Vs_{30} is the valid proxy to site amplification at any site. There is no doubt that soil rigidity is defined by the sub soil shear wave velocity, however soil amplification appears to be so complex to be related to Vs profiles in the upper 30 m soil column alone. So in the backdrop of doubts raised after understanding the behaviour of upper 30 m soil column by various researchers, an experiment has been conducted in the frontal part of the Himalaya where thick sediments are deposited in the form of fan deposits and can have disastrous effects during strong earthquake. Although it has been observed during 1-D site effect analysis that if impedance contrast between the overlying sediments and the bedrock is more the site amplification will be very high. The shear wave velocity more than 1000 m/s has been considered as bed rock level in this area. Further, shear wave velocity has been derived for the Vs_{30} (30 m soil column) and VsZ (Vs of total thickness of sediments) response analysis. The response analysis shows variation in both natural period and amplification ratio whereas no relation could be established using Vs_{30} or actual thickness of sediments parameters. Also the results show decrease in peak ground acceleration at the surface level, in general, as compared to Vs_{30} parameters for a given earthquake. Similarly, the decrease in spectral acceleration value in terms of 'g' has also been noticed in spectral acceleration values for single double storey building (10 Hz and 5Hz level respectively) using actual thickness parameters, however, the spectral acceleration values for multi-storey building (10 Hz level) increased almost three times (Fig. 31). Thus the study illustrated that in active tectonic belts the use of actual thickness of sediments should be used for site amplification rather than Vs_{30}.

Detection of Water Bodies using seismic methods

The changing environment, increasing urbanization and increased use of water lead to drying up of springs and reduction in the discharge. Further, deforestation and erosional activities (natural and anthropogenic) have greatly affected the hydrological regime and environment of Doon valley. Inadequate recharge due to changing environments and increased temperature has increased the demand of ground water. The ground water plays an important role in solving the periodic water crisis as it serves as source of uncontaminated water. Geophysical methods have been proved to be boon for hydrological investigations and generally resistivity method was used for locating water bodies. First time a seismic method has been used in Doon valley for identification of water bodies under Donga fans sediments. Experiments has been conducted only at those sites which were identified as spring or wells as per Geological Survey of India toposheet but are found dried today. A seismic reflection survey was conducted at about ten sites using multichannel analysis of surface waves at more than ten sites e.g. Badowala, Bahadarpur, GIC Langa, Kotra Santaur, Rajawala, ICFAI Institute complex, Charba, Chandanpur Khurd etc. The 2-D profiles of these sites show very good indication of moist conditions below 15-20 m depth. The identification of these waters bearing sediments using seismic methods is probably a break through as till today only resistivity method was the only technique used for identification of water bearing bodies.

In all, data from 240 sites were sampled for the present study. The preliminary results show the resonance frequencies ranges from 0.3 to 8.0 Hz in the different part of valley. The obtained resonance frequencies will be used to determine the distribution of soft soils as well as their thickness. The thickness was calculated using empirical relationship by following equation:

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

Where, H: thickness, S_{av}: Average Shear wave velocity and $F_{H/V}$: Frequency by H/V.

The Nakamura (H/V) technique is widely used for determination of predominant frequencies of geological sites, and a fairly large area could be surveyed in a relatively short time with limited resources. In the absence of a high resolution subsurface model for Doon valley, this study will establish model for soil thickness and resonance

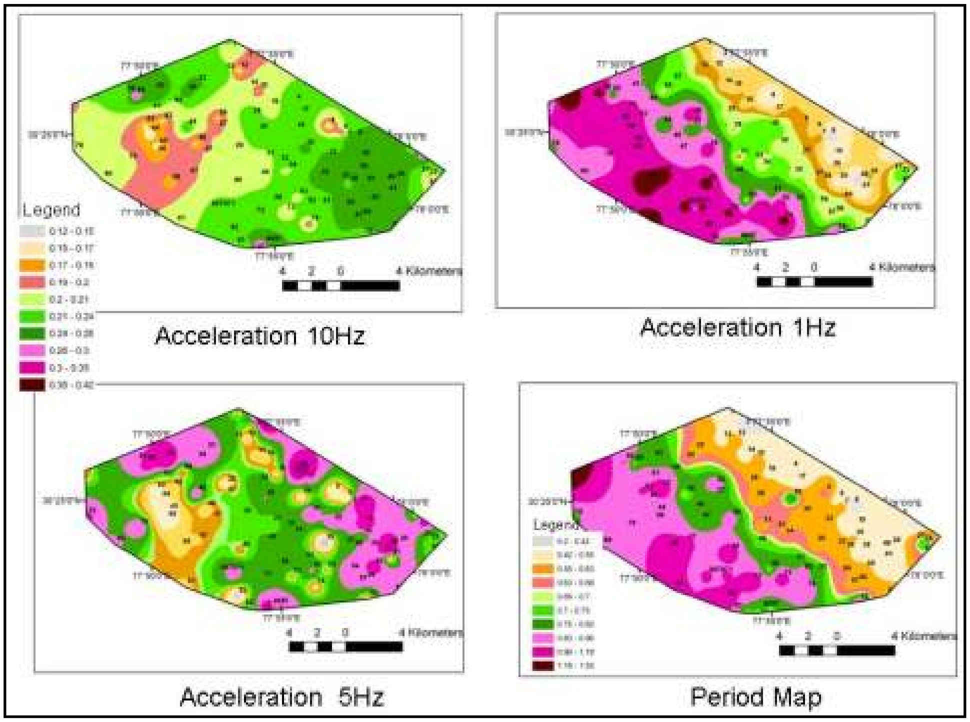


Fig. 31: A spectral acceleration map at different frequency level and site period map (extreme right) of Donga Fan deposits after response for the actual thickness of sediments

frequencies which may serve as basic inputs for earthquake mitigation actions.

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

(Rajesh S., S.C. Vaideswaran and P.K.R. Gautam)

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

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

On the dynamics of pore space fluid in the Doon Valley

The Doon, situated at the foot hills of Himalaya is home for more than 1.5 million people and juxtapose to the Plate Boundary Fault like the Main Boundary Thrust (MBT), and not much far from the seismically active Main Central Thrust (MCT). Apart from known dependency of pore space fluid flow due to prevailing hydrological gradient in the Doon valley, there exists major contributions from local deformations associated with solid earth tide and microseismics. Thus in an hypothetical scenario of moderate magnitude earthquake that may occur nearer to any of these boundary faults, then what would be the behaviour of Doon alluvium pore space fluid, would it cause fluid or mud ejections? Or cause other secondary effects like cavity formations.

Our aim was to check these hypotheses by analysing the temporal gravity data and tidal surface displacements acquired during the year till the end of 2007 in the Wadia Institute using a relative field gravity meter. Time series analysis of temporal gravity data in each session along with solid earth tidal displacements reveal that both these observations are predominantly influenced by semi-diurnal (12 hours), ter-diurnal (8 hours) and quarter diurnal (4 hours) components.

The dynamical behaviour of fluids inside the pore spaces when subjected to external exciting natural periodic forces such as luni-solar tides and a-periodic microseismics such as distant great earthquakes, respectively were studied by deriving the medium momentum diffusivity. The characteristic energy decay response of the Doon alluvial medium suggests that the luni-solar tide (12 hrs, 8 hrs, 4 hrs) causes the deformational and gravity change mainly at low decaying frequencies. However, the decay response of the pore space fluid is predominant at high frequency gravity and deformational changes owing to the local excitation effect of passing distant great or major earthquakes. The changes in the temporal gravity due to one such great earthquake of Mw= 8.1, occurred on 13.01.2007 at Kuril Islands and another major earthquake of Mw = 7.5, happened on 21.01.2007 at Moluccas sea have also been analysed. The order of the calculated momentum diffusivity at high decay frequencies that was excited by distant earthquakes closely matches with that of the standard kinematic viscosity of the water. These results explain that fluids present in the pore space in Doon valley when subjected to greater pore pressure changes undergo consequent changes in the flow due to the co-seismic deformation caused by passing distant great or major earthquakes, which in turn can cause secondary seismic effects such as fluid ejections as shown in figure 32.

On the failure of fault propagation above 14° N followed by the M_w =9.1 Sumatra Andaman earthquake of 26th Dec 2004: "Comparison with a continental analogy of Interaction of transverse Ridge structures like the Delhi-Haridwar ridge on to the Himalayan convergent zone"

It has been observed earlier that at a depth range of 163 to 260 km below in the Garhwal Himalaya region, the multiple wavelength geoid anomalies are relatively higher, which in fact correlated with the sub-surface extension of the Delhi - Haridwar Ridge (DHR) system. The absence of great earthquakes in the Garhwal region might have a relation with the transverse interaction of DHR system with the Himalayan convergent zone. The relatively high geoid anomaly of the subdued DHR system in the Garhwal Himalaya abuts to the Himalayan convergent zone; in fact, acts as a stress barrier and plausibly played a role in containing the fault rupture processes and hence may be diffusive in nature. An analogy of such transverse Ridge-convergent collision system exists erstwhile in the Indian plate along the same continuation of the India-Eurasia collision zone at its eastern convergent margin and close to the North Andaman region. Where, many investigators reported abrupt cessation of the fault rupture up to 14° N along the frontal arc of the Sumatra-Andaman oblique convergence zone followed by the 26 December 2004 Sumatra-Andaman earthquake (Mw = 9.1 to 9.3). Reasons behind such cessation or failure in the propagation of fault rupture were not known and had been investigated through a new methodology called Geoid to Topography ratio using satellite altimeter derived geoid and gravity over the region. It has been inferred that the mantle plume related under plated compensating body of the southern Ninetyeast Ridge cause a density driven gradient flow between the ridge and the subducted lithospheric slab. Thus the oceanic

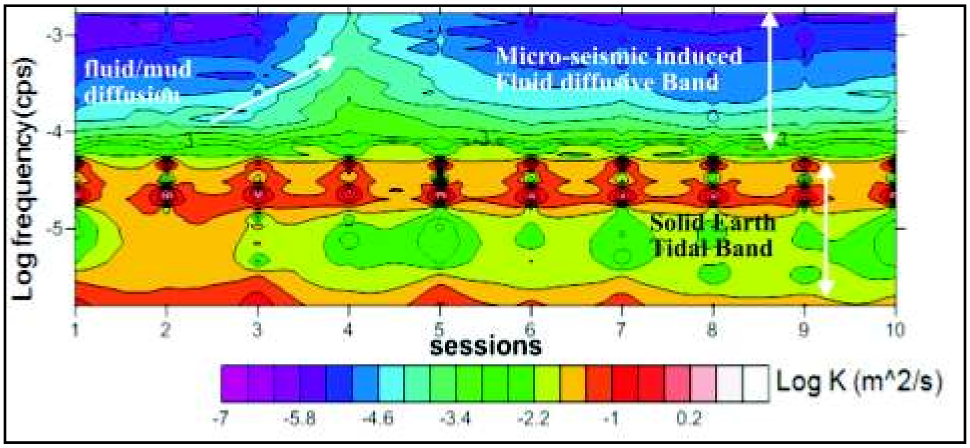


Fig. 32: Momentum diffusivity or Kinematic Viscosity of fluids present in the pore spaces of Doon alluvium show the diffusive action (shown in arrow) of shallow subsurface fluids as induced by the distant Great Kuril earthquake.

Fig. 33: Permanent GPS station locations in the Garhwal-Kumaun and Himachal Himalaya

analogy says that the dynamics of Ninetyeast Ridge collision with convergent margin is in quasi-synonymy with the DHR-Himalayan convergent systems, such that the density driven gradient flow between the abutting transverse structure and the subducting lithospheric slab acts as stress diffusers.

The WIHG-GPS network is currently operational with ten stations spanning from Garhwal-Kumaon to Himachal Himalaya (Fig. 33).

The acquired continuous positional data were processed using GAMIT/GLOBK and constrained with respect to the IGS stations. Figure 34 shows the time series positional anomalies of a few stations with their current horizontal velocity estimates. For stations such as Ghuttu, Badrinath, Dehra Dun and Munsyari have horizontal velocity estimates of 38.17±0.62 mm, 26.49±0.69 mm, 47.57±1.49 mm and 45.65±1.97 mm, respectively, as per the 2009 observations with respect to ITRF05 reference system.

Component 5.3b :

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

(S.C. Vaideswaran)

The Tehri Dam Project is a prestigious irrigation and hydropower project. The 260.5 m high dam is built downstream on the confluence of the Bhagirathi and Bhilangana rivers in Uttarakhand, India. This intra-plate convergent zone has been seismo-tectonically very active. The project was surrounded by several controversies and apprehensions, especially, following the 6.8 magnitude Uttarkashi earthquake of 20 October 1991, located north of the dam site. The concerns about

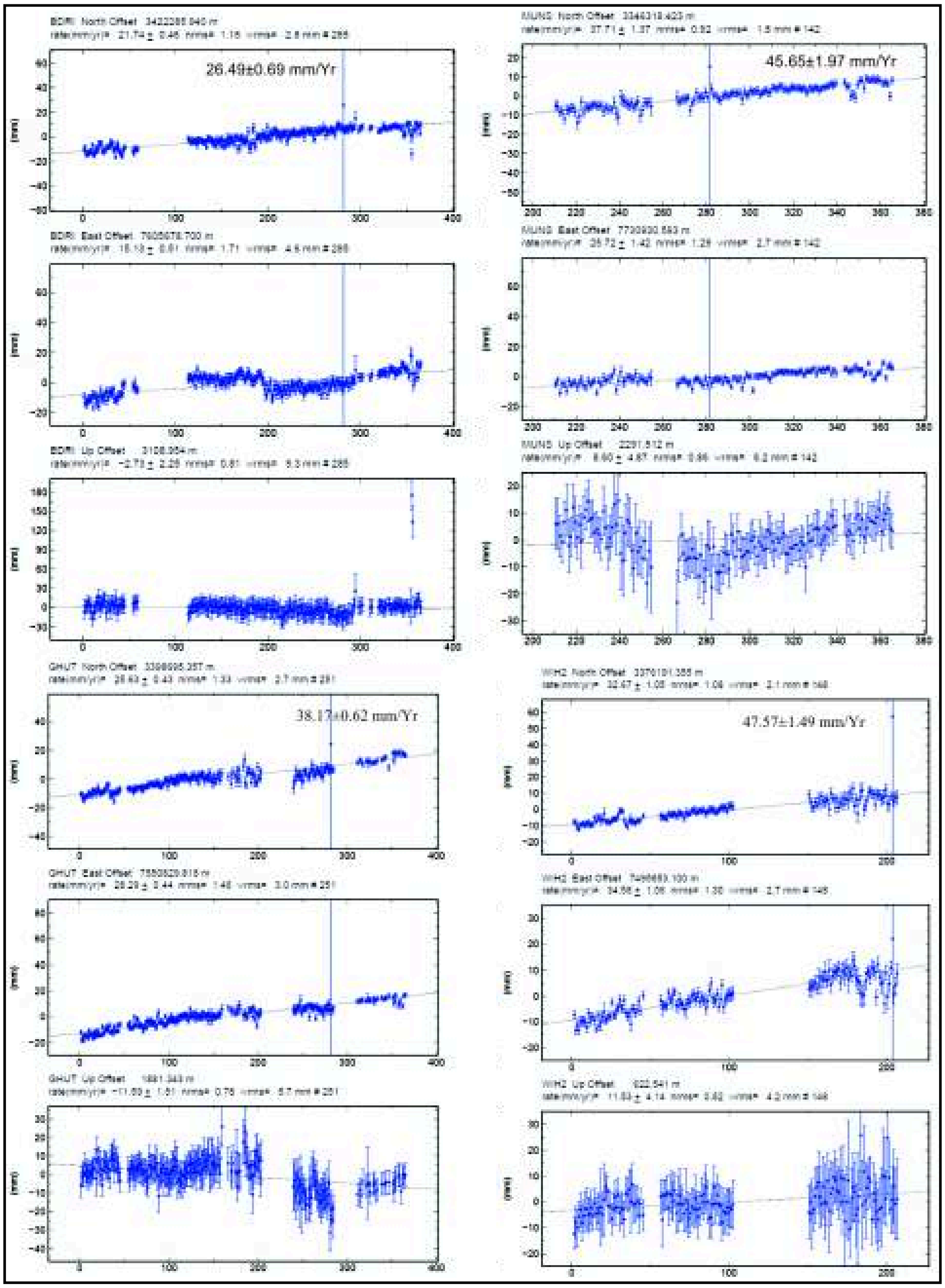


Fig. 34: Horizontal time series positional anomalies of Ghuttu, Badrinath, Dehra Dun and Munsyari stations

the disaster that might arise due to failure of the dam following an earthquake was raised. The dam is situated in Zone 1V of the seismic zonation map of India. Several thrust systems, faults and shear zones mark the dam site. Subsequent to the Uttarkashi earthquake, the Chamoli earthquake occurred with a magnitude of 6.6 on 29 March 1999 towards north-east of the dam site. Despite several measures taken up for the safety of the dam in the event of an earthquake, the concern for triggered seismicity due to the loading of the reservoir still looms large. Therefore the study of ground motion and seismicity in the near vicinity of the dam was much required.

The study of reservoir induced ground motion using the space geodetic technique, Interferometric Synthetic Aperture Radar (InSAR), was tried with ENVISAT-ASAR data operating in C-band (5.6 cm wavelength). Seven scenes during the years 2003 to 2005 (preloading) were combined to form four interferograms (Table 3). The scenes were provided by European Space Agency (ESA) through category 1 project at reproduction cost. These scenes were chosen keeping check on consistency in season, changes in vegetation cover and checking cloud cover by using MODIS data for the acquisition dates to avoid errors occurring due to atmospheric phase delays in order to retrieve maximum coherence. Trying to maintain minimum perpendicular baseline, the interferogram pairs were selected to cover 35 days (~ one month), 280 days (~ six months) and 455 days (~ one year) to check how coherence changed with time and also in attempt to capture any deformation signatures corresponding to the ongoing tectonic activities in this seismo-tectonically active region in the absence of the reservoir load. The data was processed using SARscape software and Goldstein filtering techniques. However, excepting the Dehra Dun valley region, very less coherence could be retained in the interferograms. Beyond the MBT in the north of Dehra Dun, the buckled and folded structure of the crust due to the convergence of the Indian and the Eurasian plates causes extreme layover conditions. The Tehri Lake has had a fluctuation of about 80 m from the MDDL (740 m) every filling season since initial filling started in October 2005.

If coherence could have been retained for interferograms for the Tehri region interesting results might have been possible. In such a case perhaps a persistent scatterer (PS) technique would have been better suitable. Unfortunately so far the largest constraint for InSAR application is continuity of data acquisition over our specific area. Differential interferometry is especially influenced by baseline geometry, thermal noise, changes due to scene rotation, wind, vegetation, atmospheric water vapour, ionosphere and troposphere disturbances. As a past earthquake analysis using InSAR, an attempt has been made to understand the linear fault field of moderate earthquakes that occured in the western Himalayan region. European Space Satellite (ERS) data was used to study the Chamoli earthquake of 29 March 1999. Interfergram was generated using ERS 1 and 2, ascending track 12 datasets of 21 September 1998 and 7 September 1999 (temporal resolution 351 days). The baseline difference has been calculated to be 48 m, which gave an advantage for interferometry. The interferogram generated showed that given good pairs of scenes with good temporal resolution and/or baseline difference have proved to be successful for even a rugged region. The software SARscape, version 4.3 has proved to be successful for interferometric processing. Similar results from other moderate earthquakes can provide better understanding to the significance of moderate earthquakes.

Table 3: ENVISAT-ASAR IMS_IP data used for interferometric study in the region. All scenes belonged to Track 291, Swath L2 of the descending pass

Interfero-metric Pair	Date of Acquisition	Orbit	Baseline Difference	Days Difference	Period
Pair 1	10 Nov. 2003	8862	64	35	~ 1 month
	15 Dec. 2003	9363			
Pair 2	01 Sept. 2003	7860	-169	280	~ 6 months
	07 June 2004	11868			
Pair 3	12 July 2004	12369	-195	385	~ 1 year
	01 Aug. 2005	17880			
Pair 4	07 June 2004	11868	214	455	> 1 year
	05 Sept. 2005	18381			

In 2007 11 VSAT linked seismic network was established by WIHG at Dehra Dun, Tapovan, Adibadri, Gaurikund, Ghuttu, Deoban, Kotdwar, Chakrata and Kharsali in the state of Uttarakhand, and Nahan and Kotkhai in Himachal Pradesh. The network covered the dam site precisely. The data from 2007-10 and also data from other networks (ISC catalogue) between 2000 and 2010 has provided a correlation of seismicity and water level fluctuations in the Tehri reservoir. In a comparison of seismicity during filling and drawdown periods, it has been seen that greater number of earthquake events occurred during lower water level periods of the reservoir and reduced seismicity was observed in the filling periods. During initial filling seismic events showed a lower magnitude as well as frequency of occurrence of earthquakes. Earthquakes with magnitude above 3 occurred coinciding with low reservoir levels. The understanding that the Himalaya being in a compressive environment and therefore the load from the reservoir should rather stabilize than induce seismicity for this region can be held true as observed from our study. Induced pore pressure conditions from fluid permeability to hypocentral depths can, however, present a delayed condition for occurrence of earthquakes. Further, lower b-values are seen to precede higher magnitude earthquakes. B-values showed a temporal variation between 1.04 and 1.80. These results have been been compiled for the publication.

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Sushil, R., Kumar, Sushil, Bhargava, R., Singh, R.K. & Desai, C. (Guest Editors): Journal of Information and Operations Management ISSN: 09767754 & E-ISSN: 09767762, Volume 3(1), 2012.

Tewari, Vinod C. & Seckbach, Joseph (Eds.): Stromatolites: Interaction of microbes with sediments. Springer, Germany, 1st Edition., 2011, XXIX, 751p. 40 illus., 20 in color, Hardcover ISBN: 978-94-007-0396-4.

Technical Reports

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Jayangondaperumal, R. 2011: A report of a year advanced training in Neotectonic received from the Centre for Neotectonic Studies, University of Neavad, Reno, USA under the Boyscast. Submitted to the SERC, DST (July-2010-July-2011).

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Philip, G., Bhakuni, S.S. & Sah, M.P. 2012. Geological interpretation of QuickBird satellite data in connection with the design of alignment and associated survey work along the stretch of realignment for Katra-Dharam section (km 65.000 to km 93.000) of USBRL project. Submitted to RITES Ltd.

Virdi, N.S. & Philip, G. 2012. Active faults and Neotectonic activity (with reference to Seismic hazards) in parts of Outer, Lesser and Higher Himalaya between Satluj and Yamuna-Tons rivers in Eastern Himachal Pradesh (AFNAH-II). Project Completion Report Submitted to Dept. of Science and Technology, New Delhi.

SEMINAR / SYMPOSIA / WORKSHOP ORGANISED

Workshop on the Himalayan Glaciers and the Community Responsibility, September 26 - 27, 2011

The workshop on the Himalayan Glaciers and the Community Responsibility was jointly organized by the Wadia Institute of Himalayan Geology (WIHG), Uttarakhand Space Application Centre (USAC) and the Himalayan Environmental Studies and Conservation Organization (HESCO), Dehradun at Wadia Institute of Himalayan Geology, Dehra Dun on September 26-27, 2011. The workshop focused on the Himalayan glaciers, climate change and mutual responsibilities of the local community, the scientists and the environmental activists.

The workshop was presided by the Chief-Guest Her Excellence Smt. Margaret Alva, the Governer of Uttarakhand. Prof. Anil K. Gupta, Director, WIHG, emphasized the importance to preserve the Himalayan glaciers, which among other life-supports, contribute water for the survival of 30-40% population of our country, besides being prime attraction to the tourists. He further expressed that the deliberations of the two-day workshop would certainly help the Government of the State to plan programmes and policies for the welfare of the local people as well as help promotion of scientific studies, related to the glaciers.

Her Excellency Smt. Margaret Alva, Governer of Uttarakhand during her visit to the Institute

There was a general recommendation that scientific research being done by the scientists in different organizations of the state and central governments should be made available to the common man / community living near the glaciers for educating them to know the ongoing impact of the climate change on glaciers. Local communities should be involved in the studies by the glaciologists and environmentalists.

Her Excellency Smt. Margaret Alva, Prof. Anil K. Gupta and Padmashri Dr. Anil P. Joshi sharing the dias during the inauguration function of the workshop

Indo- Iceland workshop, October, 21 - 22, 2011

A two days workshop on earthquake prediction was organized at Wadia Institute of Himalayan Geology, Dehra Dun on October 21 - 22, 2011. The workshop was the outcome of memorandum of understanding (MoU) signed by the Wadia Institute of Himalayan Geology and Iceland, in 2007 and further efforts of Prof. T. Ramasami, Secretary, Department of Science and Technology (DST), Govt. of India and Prof. Anil K. Gupta, Director, Wadia Institute of Himalayan Geology. The workshop was inaugurated by Padmashri Prof. Harsh K. Gupta, Panikkar Professor, who shared his thoughts and experiences with special reference to seismicity and earthquake recurrence at Koyna, India. The inaugural function was attended by number of distinguished guests from different institutions of Dehra Dun, scientists of WIHG and participants from Iceland. The workshop was designed to aim at sharing the experiences of scientists of both the countries in the field of earthquake prediction in order to frame collaborative project(s) involving scientists from both sides.

The workshop was designed in four technical sessions to cover different aspects of earthquake precursor studies and understand geodynamics of the

Padmashri Prof. Harsh K. Gupta, Panikkar Professor along with. Prof. Anil K. Gupta, Prof. G. Eiriksson and Prof. R. Stefansson sharing the dias during the inauguration of Indo-Iceland workshop

Himalaya with one special session on the Sikkim earthquake. In this workshop 23 deliberations were made by scientists from India (NGRI, WIHG, IMD, IIT, Roorkee, Kurukshetra University, NEIST Jorhat) and Iceland (University of Akureyri, Icelandic Meteorological Office, Swedish Seismic Network, Uppsala University). The last session was for technical discussion and preparation of recommendations. After thorough discussion by the scientists of both the nations, it was agreed that the geophysics group of Wadia Institute will prepare a comprehensive research draft proposal related to the two themes i.e. a) Development of algorithm for Automatic earthquake parameter determination, and b) Moment Tensor Solution of earthquakes. Two months time frame was tentatively decided for mutual exchange of first draft copy of the above project with due intimation to DST.

Hon'able Minister Shri Vilasrao Deshmukh, Minister for Science & Technology and Earth Sciences, Govt. of India lighting the auspicious lamp during the inauguration of workshop on IMHG-2011

International Conference on Indian Monsoon and Himalayan Geodynamics (IMHG 2011), November 2 - 5, 2011

Wadia Institute of Himalayan Geology, Dehra Dun organized an International Conference on Indian Monsoon and Himalayan Geodynamics (IMHG 2011) from November 02 - 05, 2011. The focal themes for the discussion and research presentation were designed recognizing the challenge of understanding the tectonic evolution and exhumation of the Himalaya and its linkage with the climate and monsoon in the Indian subcontinent. The themes of the conference included (i) continental and marine records of climate change, (ii) crustal evolution and geodynamics of the Himalaya, (iii) monsoon in the Indian Subcontinent, (iv) source-sink relationships and (v) climate-tectonic expressions in the hinterland and foreland. There was overwhelming response from various Indian organizations and the Foreign researchers to participate in the conference. Total 140 participants including 7 foreign scientists attended this event. In total forty eight oral presentations were made and fifty five posters were presented during the technical sessions. Following recommendations have emerged in this conference:

(a) Exhumation of various lithotectonic belts of the Himalaya vis-a vis Monsoon needs to be focused in greater details with emphasis on the inputs of state of art data on the subject,

(b) Climate records from the Himalaya and adjoining region should be generated and monitored,

(c) Collaborations across different disciplines of geosciences should be promoted to evolve and refine models of the geodynamic evolution of the Himalaya.

Hon'able Minister Shri Vilasrao Deshmukh, Minister for Science & Technology and Earth Sciences, Govt. of India along with Prof. Anil K. Gupta, Prof. A. Sahni and Dr Rajesh Sharma sharing the dias and releasing the abstract volume during the inauguration function on workshop on IMHG-2011

AWARDS AND HONOURS

- Prof. Anil K. Gupta, Director has been elected as Fellow of the Indian National Science Academy (INSA), New Delhi.
- Prof. Anil K. Gupta has been awarded J.C. Bose National Fellowship for his fundamental contribution to the study of Indian monsoon variability.
- Dr V.C. Tewari has been elected as the Vice-President of the Indian Geological Congress, Roorkee.
- Dr Rajesh Sharma and Dr D.R. Rao have been elected as members of the National Academy of Sciences, India (NASI).
- Dr Naresh Kumar was awarded extended Junior Associate membership of the International Centre of Theoretical Physics (AS-ICTP) Trieste, Italy.
- Dr Pradeep Srivastava has been awarded M.S. Krishnan Gold Medal from the Indian Geophysical Union.
- Dr Pradeep Srivastava was awarded Wadia Institute Best paper award for the year 2011.
- Dr Vikram Gupta, Dr Pradeep Srivastava, Dr Koushik Sen, Shri Yogesh Ray and Ms Ruchika Sharma were awarded prize for their posters presentations in the IMHG - 2011.
- Shri Yogesh Ray was awarded 'Young Researcher Award' by the Ministry of Mines for the year 2010.

VISITS ABROAD

- Dr Pradeep Srivastava visited Irvine, USA to participate in the fourth Indo-American Frontiers of Science symposium from April 17 - 20, 2011.
- Dr Naresh Kumar visited ICTP as Junior Associateship of ICTP Trieste, Italy from May 01, 2011 - August 28, 2011. During this period he also visited Vienna University in Austria.
- Dr A.K. Mahajan and Dr Ansuya Bhandari visited Canmore, Alberta, Canada to attend 26th Himalaya--Karakoram-Tibet Workshop from July 11 - 14, 2011.
- Dr Sushil Kumar visited Taipei, Taiwan to attend the International workshop "Asia Oceania Geosciences Society (AOGS)" from August 08 - 12, 2011.
- Dr S.K. Rai visited Prague (Czech Republic) to attend "Goldschmidt International Conference-2011" from August 14 - 19, 2011.
- Dr A.K. Singh visited United Kingdom (UK) under BOYCAST Fellowship for one year (29th August, 2011 till 29th August, 2012) to work in the Department of Earth and Environmental Sciences, The Open University, Milton Keynes, UK.
- Dr B.N. Tiwari visited, NEOMED University, Ohio and Duke University, North Carolina, USA from September 03 - 21, 2011 for paleontological research work on Miocene horizons.
- Dr S.C. Vaideswaran visited Earth Observatory of Singapore (EOS), Nanyang Technological University, Singapore for collaborative work with Prof. Paul Tapponnier from September 04 - 24, 2011.
- Shri V. Sriram visited Taipei, Taiwan to attend the International Training Program for Seismic Design of Structures from October 24 - 28, 2011.
- Dr Sushil Kumar and Dr Devajit Hazarika visited San Francisco, California to attend the AGU Fall Meeting from December 05-09, 2011.

Ph.D. THESES

Name of Student	Supervisor(s)	Title of the Thesis	University	Awarded/ Submitted
Kanchan Deoli Bahukhandi	Dr S.K. Bartarya (WIHG) Dr N.A. Siddique (UPES)	A study on Surface and Groundwater quality of Dehradun and Haridwar Districts of Uttarakhand: Impact Assessment of Urbanization and Industrialization	University of Petroleum and Energy Studies (UPES) Dehra Dun	Awarded
Rakesh Bhambri	Dr R.K Chaujar (WIHG) Dr S.C. Kulshreshtha (CCS)	An analysis of glacier changes in Garhwal Himalaya using remote sensing and GIS techniques	Chaudhary Charan Singh (CCS) University, Meerut	Awarded
Irfan Ahmad	Dr A. K. Dubey (WIHG) Prof. Silvio Seno (Univ. of Pavia)	Structural and kinematic analysis of outer thrusts for seismotectonic risk assessment in foreland arcs (Siwalik and Po-plane forelands)	University of Pavia, Italy	Awarded
Shipra Choudhary	Dr Pradeep Srivastava (WIHG) Dr Y.P. Sundriyal (HNBGU)	Late Quaternary Evolution of Alaknanda Valley in the vicinity of North Almora Thrust	H.N.B. Garhwal University, Srinagar (Uttarakhand)	Awarded
Yogesh Ray	Dr Pradeep Srivastava (WIHG) Dr Y.P. Sundriyal (HNBGU)	Late Quaternary aggradation and incision phases in upper reach of Ganga River system: implications to climate-tectonic Interaction	H.N.B. Garhwal University, Srinagar (Uttarakhand)	Submitted
Debaprasad Sahoo	Dr V.C. Thakur (WIHG) Dr Y.P. Sundriyal (HNBGU)	Neotectonics - active tectonics of frontal Siwalik range and Soan dun in Himachal Pradesh, NW Himalaya	H.N.B. Garhwal University, Srinagar (Uttarakhand)	Submitted
Ruchika Sharma	Dr Vikram Gupta (WIHG) Dr Y.P. Sundriyal (HNBGU)	An integrated study of physical, mechanical and acoustic properties of rocks of the Bhagirathi and Alaknanda valleys and their inter-relationship	H.N.B. Garhwal University, Srinagar (Uttarakhand)	Submitted

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

- Brainstorming session on "Science Plan of the Programme on Dynamics of Glaciers in the Himalayas" at WIHG Dehra Dun, April 20-21, 2011
  Participant: D. P. Dobhal
- Workshop on "Advanced school on scaling laws in Geophysics: mechanical and thermal processes in geodynamics" at ICTP, May 23 - June 03, 2011
  Participant: Naresh Kumar
- International symposium on "Tibetan Plateau and the 24th Himalaya- Karakoram-Tibet Workshop" at Canmore, Canada, July 11-13, 2011
  Participants: A.K. Mahajan and Ansuya Bhandari
- Seminar on "Subsurface structure and tectonic deformation investigation in the NW Himalaya using seismological data" at Institute for Meteorology and Geophysics, Vienna University, Vienna, July 14, 2011
  Participant: Naresh Kumar
- Brainstorming session on "Water quality and identification of future course of action" at Uttarakhand Space Application Centre, Dehra Dun, August 05, 2011
  Participant: S.K. Bartarya
- International workshop "Asia Oceania Geo-sciences Society (AOGS)" at Taipei, Taiwan, August 08-12, 2011
  Participant: Sushil Kumar
- Meeting of the "Glaciology Programme of DST" at New Delhi, August 25, 2011
  Participant: D.P. Dobhal
- Workshop on "Geohazard organized jointly by Ministry of Earth Sciences, New Delhi and University of Bergen Norway" at New Delhi, September 13, 2011
  Participants: A.K. Mahajan, Vikram Gupta and Naresh Kumar
- 8th International symposium on Gondwana to Asia "Supercontinent Dynamics: India and Gondwana" at National Geophysical Research Institute (NGRI), Hyderabad, August 26-28, 2011
  Participants: Naresh Kumar, D.K. Yadav and D. Hazarika
- Workshop on "Himalayan Glaciers and Community Responsibility" at Wadia Institute of Himalayan Geology, Dehra Dun, September 26-27, 2011
  Participants: D.K. Mishra, Rajesh Sharma, G. Philip, D.P. Dobhal, P.S. Negi and S.C. Vaideswaran
- Workshop on "Challenges in Climate change; Resilience and Adaptation India - ICIMOD Day" at ICIMOD Nepal, September 30, 2011
  Participant: D.P. Dobhal
- 7th International Conference on "Asian Marine Geology (ICAMG-7)" at National Institute of Oceanography (NIO), Goa, October 10-14, 2011
  Participant: V.C. Tewari
- National Symposium on "Recent Advances in Applied Geochemistry: Current Status and Future Trends" at the Atomic Mineral Division (AMD), Hyderabad, October 19-21, 2011
  Participants: D.R. Rao and M. Daga
- Indo-Iceland workshop on "Earthquake prediction" at Wadia Institute of Himalayan Geology, Dehra Dun, October 21-22, 2011
  Participants:V.C. Thakur, Sushil Kumar, A.K. Mahajan, Vikram Gupta, D. Hazarika and A.K.L. Asthana
- Workshop on "Disaster Remedial Measures and impact on Roads and Infrastructures" at Institutions of Engineers at Dehra Dun, October 23, 2011
  Particpiant: Vikram Gupta
- International conference on "Indian Monsoon and Himalayan Geodynamics (IMHG-2011)" at Wadia Institute of Himalayan Geology, Dehra Dun, November 02-04, 2011
  Participants: Anil K. Gupta, V.C. Tewari, V.C. Thakur, Rohtash Kumar, R.S. Rawat, P.P. Khanna, S.K. Ghosh, N.K. Saini, K.K. Purohit, Kishor Kumar, N.S. Siddaiah, Rajesh Sharma, G. Philip, R. Islam, S.K. Bartarya, P.K. Mukherjee, T.N. Jowhar, Sushil Kumar, D.P. Dobhal, N. Suresh, P. Srivastava, Ajay Paul, S.S. Bhakuni, P.S. Negi, A.K.L. Asthana, K. Lokho, R.K. Sehgal, B.K. Mukherjee, Naresh Kumar, S.K. Rai, D. Hazarika, N. Meena and D.K. Yadav
- National Workshop on "Landslide hazard and Risk Assessment" at Geological Survey of India Training Institute, Hyderabad, November 14-15, 2011
  Participant: Vikram Gupta
- Training workshop on ""Climate Change and Carbon Mitigation" at Indian Council of Forestry Research and Education (ICFRE), Dehra Dun,

November 14-18, 2011
Participant: Santosh K. Rai

- XXVII Convention of "Indian Association of Sedimentologists" at JNU, New Delhi, November 24-26, 2011
  Participants: Rohtash Kumar and S.K. Ghosh
- 17th Convention of the "Indian Geological Congress and International Conference on NPESMD" at Indian School of Mines (ISM), Dhanbad, November 20-21, 2011
  Participant: V.C. Tewari
- Frame work programme -7 (FP-7) on "Green Energy" at Indian Institute of Petroleum, Dehra Dun, November 25, 2011
  Participant: P.S. Negi
- Meeting on "Roundtable discussion on bi and multilateral Indo-European Co-operation on Climate Research and Innovation" at New Delhi, November 28, 2011
  Participant: D.P. Dobhal
- AGU Fall Meeting in San Francisco, California, December 05-09, 2011
  Participants: Sushil Kumar and D. Hazarika
- XXIII Indian Colloquium on "Micropalaeontology and Stratigraphy" and International Symposium on "Global Bioevents in the Earth Historyn" at Department of Geology Banglore University, Banglore, December 09-11, 2011
  Participants: B.N. Tiwari S.K. Parcha, Kapesa Lokho, Parkasham, Ansuya Bhandari and S. Rawat
- International Conference on "Green Infrastructure and Eco-engineering - 2011" at Forest Research Institute, Dehra Dun, December 11, 2011
  Participant: P.S. Negi
- Training workshop on "isotope Hydrology" at National Institute of Hydrology (NIH), Roorkee, December 19-24, 2011
  Participants: S.K. Bartarya and Santosh K. Rai
- International conference on "Soft Computing for Problem Solving (SocPros 2011)" at IIT Roorkee, December 20 - 22, 2011
  Participant: T.N. Jowhar and Sushil Kumar
- 99th Indian Science Congress at KIIT Bhubaneswar, January 03-07, 2012
  Participants: R.S. Rawat, T.N. Jowhar, S.K. Parcha and Ansuya Bhandari
- Vastan Field Workshop on "Paleocene-Eocene fossiliferous sections in Surat (Western India)" January 16-19, 2012
  Participant: Kishor Kumar
- 36th Annual Session of Indian National Committee for the International Geoscience Programme (IGCP) at Geological Survey of India, Kolkata, January 17, 2012
  Participant: V.C. Tewari
- Workshop on "Himalayan Geology" at the Department of Earth Sciences, University of Oxford, UK, January 19, 2012.
  Participant: A.K. Singh
- Advanced training course on "Geotechnical Earthquake Engineering" at Structural Engineering Research Center, CSIR, Chennai, February 01-03, 2012
  Participants: A.K. Mahajan and Vikram Gupta
- International Conference on "Algal Summit" at Indian Phycological Society and TERI University, New Delhi, February 21-22, 2012
  Participant: V.C. Tewari
- Workshop on "Impact of Global Changes on the Dynamics of Snow, Glaciers and Runoff over the Himalayan mountain with particular reference to Uttarakhand" at G.B. Pant Institute of Himalayan Environment & Development (GBPIHED), Koshi Katarmal, Almora, February 27-28, 2012
  Participant: D.P. Dobhal
- International symposium on "Recent Advances in IT & IT Management (RAITM'12)" at SGRRITS Dehradun, February 28 -29, 2012
  Participant: Sushil Kumar
- Seminar on "Applications of Imaging, Visualization and Optimization Technologies" at Institution of Engineers, Uttarakhand State Centre, Dehra Dun, March 02- 03, 2012
  Participant: T.N. Jowhar
- International Conference on "Science & Geopolitics of Arctic and Antarctic (*i*-SaGAA-2012)" at India International Centre, New Delhi, March 09 -11, 2012
  Participants: S.K. Parcha and D.P. Dobhal
- National Seminar on "Geology and Geo-resources of Himalaya and Cratonic Regions of India" at Department of Geology, Kumaun University, Nainital, March 10 - 12, 2012
  Participants: R. Sharma and Ajay Paul
- Workshop on "Forest Fire Management in the state of Uttrakhand" at Uttrakhand Forest Directorate, Dehra Dun, March 21, 2012
  Participant: P.S. Negi

LECTURES BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
P. Srivastava	Irvine, USA	19.04.2011	Rivers in Himalaya: responses to the past climatic changes
P. Srivastava	University of Georgia, Athens, USA	22.04.2011	Himalayan Rivers: archives of climate change and Himalayan orogeny
R.J. Perumal	Oregon State University, Corvallis, USA	26.04.2011	New Results of Paleoseismic Investigations along the Active Himalayan Frontal Thrust, India
N.K. Saini	Archeological Survey of India, Dehra Dun	09.05.2011	X-ray analytical techniques for characterisation of Archaeological materials
N. Suresh	Archaeological Survey of India, Dehra Dun	10. 05.2011	Thermoluminescence dating
P.P. Khanna	Archeological Survey of India, Dehra Dun	10.05.2011	Inductively Coupled Plasma Mass Spectrometry: Instrumentation and Applications
R.J. Perumal	University of Cincinnati, Ohio	13.05.2011	New results of paleoseismic investigations along the active Himalayan Frontal Thrust, India
Rajesh Sharma	DIT, Dehra Dun	14.05.2011	Minerals and rocks
A.K. Dubey	WIHG, Dehra Dun	02.06.2011	Interference patterns of folds
Naresh Kumar	Conrad Observatory, Austria	13.07.2011	Multi-Parametric Geophysical observatory for earthquake Precursory research at Ghuttu, Garhwal Himalaya
A.K. Mahajan	WIHG, Dehra Dun	29.07.2012	Site characterization of the sedimentary cover at the Himalayan Foothills using active and passive seismic sources for estimation of earthquake hazard
P.K.R. Gautam	WIHG, Dehra Dun	05.08.2011	Geodynamics and kinematics scenario of the Indian plate
S.K. Bartarya	Uttarakhand Space Application Centre, Dehra Dun	05.08. 2011	Hydrochemistry and quality assessment of water around Tehri reservoir, Garhwal Himalaya
P.K. Mukherjee	Archeological Survey of India, Dehra Dun	08.08.2011	Building stones and their uses in historical monuments Weathering of Building Stones: Causes and Processes
N. Meena	WIHG, Dehra Dun	19. 08.2011	Solar - climate/ monsoon relation: some missing links
A.K. Dubey	HNB Garhwal University, Srinagar	21.09.2011	Structural evolution of the Himalaya
A.K. Dubey	HNB Garhwal University, Srinagar	21.09.2011	Development of flexural-slip folds

R. Islam	HNB Garhwal University, Srinagar	22.09.2011	Continental drift and plate tectonics
A.K. Jain	Lucknow University, Lucknow	27.09.2011	Geology and tectonics of the Trans -Himalayan and Karakoram Mountains
S.C. Vaideswaran	WIHG, Dehra Dun	27.09.2011	Implications of reservoir loading and water level fluctuations on seismicity around Tehri Dam, India
Rohtash Kumar	GSI Field Camp at Kala Amb, HP	23.10.2011	Stratigraphy and Sedimentology of the Himalayan Foreland Basin: Implication of tectonic and climate
G. Philip	GSI Field Camp at Kala Amb, HP	23.10.2011	Neotectonic activity in the Frontal belt of northwestern Himalaya
P. Srivastava	HNB Garhwal University, Srinagar	15.11.2011	Landscape evolution
Sushil Kumar	WIHG, Dehra Dun	15.11.2011	Geo feature and seismic zoning
D.P. Dobhal	ICFRE, Dehra Dun	17. 11.2011	Climate change impact on glaciers in Himalaya
D. Hazarika	WIHG, Dehra Dun	18.11.2011	Crustal structure and deformation in the India-Asia collision zone: constraints from receiver function analysis
G.Philip	GSI Field Camp at Kala Amb, HP	22.11.2011	Neotectonic activity in the Frontal belt of northwestern Himalaya
Rohtash Kumar	GSI Officer trainee, at Kala Amb, HP	22.11.2011	Stratigraphy and sedimentology of the Himalayan Foreland Basin: Implication of tectonic and climate
S.K. Bartarya	People's Science Institute, Dehra Dun	28.11.2011	Hydrogeology of mountainous terrain with special reference to Himalaya Evolution of Himalaya
P. Srivastava	Geological Society of India, Bangalore	30.11.2011	Himalayan rivers: implications to climate and tectonics of Himalaya
R. Islam	UGC Academic Staff College at AMU, Aligarh on	12.12.2011	Research advancement in Earth Sciences and its methodology
Sushil Kumar	WIHG, Dehra Dun	23.12.2011	The b-value as an earthquake precursor: Spatiotemporal variations for the NW Himalayan region, India, and detecting Tsunami genesis from recent earthquakes triggered under Sea
B.N. Tiwari	K.V. ONGC, Srikona, Silchar, Assam	29.12.2011	Geology, a good option for +2 students for their career
D.P. Dobhal	ICFRE, Dehra Dun	08.02.2012	Climate change evidences from rapid glaciers recession; an overview in Himalayan context
N. Kumar	WIHG, Dehra Dun	17.02.2012.	Quantification of tectonic elements in NW Himalaya using seismic wave attenuation

G. Philip	GSI Field Camp at Kala Amb for GSI Officer Trainees	20.02.2012	Neotectonic activity in the Frontal belt of northwestern Himalaya
A.K. Majahan	IIRS, Dehra Dun	21.02.2012	Seismic microzonation and probabilistic hazard assessment
G. Philip	IIRS, Dehra Dun	24.02.2012	Surface rupture mapping and paleoseismicity analysis
N.K. Saini	Gurukula Kangri Vishwavidyalaya, Haridwar	25.02.2012	Chemical characterisation of materials using instrumental analytical techniques
R.K. Sehgal	WIHG, Dehra Dun	23.03.2012	Vertebrate faunal studies of the Neogene Siwalik Group (NW Himalaya) with reference to migration history and Himalayan uplift
Rajesh Sharma	Kumaun University, Nainital	26-27.03.12	Lectures on 'Ore Geology'
Vikram Gupta	Aligarh Muslim University, Aligarh	30.03.2012	Natural Disasters in the Himalaya

TECHNICAL SERVICES

Analytical Services

The state of art instruments installed in the central facility laboratories of the Institute were employed to generate analytical data of very high standard. The users of these facilities were scientists and scholars from the Institute, as well as researchers from different universities, IITs, Govt. and Private Oraganizations from various parts of our country. A total of four thousand six hundred and seventy one samples were analyzed using XRF, ICP-MS, SEM, XRD and EPMA. The breakup for this is presented in the table below. The down time for all the instruments was zero during this period.

Lab. / Technique	Samples analyzed		
	WIHG Users	Outside Users	Total
XRF	518	1037	1555
ICP-MS	915	481	1396
SEM-EDX	111	132	243
XRD	545	830	1375
EPMA (slides)	53	49	102
Total samples analyzed	**2142**	**2529**	**4671**

Standardization of Laser Ablation system

Successfully interfaced ICP-MS with a 213 nm Laser Ablation system and optimized for trace element analysis. This technique can potentially be integrated with XRF to complement each other in providing complete analysis of silicate rock samples with single sample preparation.

Photography Section

During the year 2011-12, around 5500 images were captured using digital cameras to cover the various functions, including Foundation Day, Founder's day, National Science Day, National Technology Day, New Year's Day, various Seminars/ Symposia, and superannuation parties for institute staff etc. organized in the Institute from time to time. Apart from this, 900 photos of rock and fossil specimens were taken. The colour printing of 400 digital images was prepared from the photo lab in the market. During the reporting year, 11 new high resolution and high zoom digital cameras were procured for exclusive use by the scientists and research scholars of the Institute. With this a great majority of the scientists now have cameras issued permanently to them for their respective use in the field and laboratory. Other scientists and research scholars are provided high end digital cameras from a central pool as and when they require it for their field work.

Drawing Section

The Drawing Section catered to the cartographic needs of the scientists of the Institute including various sponsored projects. During the reporting year, the section has provided 10 geological / structural/ geomorphological maps, the tracing of aerial photograph index sheets (34) line diagrams / lithologs (13) for the scientists and research scholars of the Institute. The section has also prepared name labels, thematic captions and annotations during different activities and functions of the Institute.

Sample Processing Lab.

The sample processing laboratory provided thin/microprobe/polished sections as per the requirements of the Institute scientists. During the reporting year the laboratory provided 1767 thin and polished sections to various users for carrying out microscopic, fluid inclusion and EPMA studies. The lab has also powdered 1022 rock samples for carrying out major, trace and REE analysis by ICPMS, XRF and XRD and for TL/OSL Laboratory.

S.P. NAUTIYAL MUSEUM

The museum of the Institute is the major axis of education and continues to remain as a centre of attraction to the students and general public not only for the people of the country but also for the visitors from overseas. Students in large groups from different schools, universities, colleges and from other Institutions visited the museum and guided tours were provided to them. A large number of students continued to visit the museum for their respective school projects. This year more than 5,000 people visited the Museum from different parts of the country, besides visitors from abroad.

The Museum observed open days during National Technology Day (11 May 2011), Foundation Day (29 June 2011), Founder's Day (23 Oct. 2011) and National Science Day (28 Feb. 2012). Like preceeding years, a large number of students and general public visited the museum on these occasions. Science quiz and Hindi essay competitions were organized on the eve of Science week celebrations (20-28 Feb. 2012). In the Science quiz forty eight students participated from various schools from Doon Valley and the surrounding areas, whereas fifty two schools participated in the Hindi essay competition. Prizes were distributed to the students who stood first, second and third in these competitions.

LIBRARY

The Library of the Institute is one of the finest libraries in the field of earth sciences in terms of its collection and services in our country. It is a dedicated library consisting of books, monographs, journals and seminar/conference proceedings on Earth Sciences with special reference to Himalayan Geology. A large number of National and International scientific journals in the field of earth sciences are subscribed in the Library which are not available in other libraries in the northern part of the country. Apart from services to the Institute staff, it also caters the need of the academicians and researchers of sister organizations situated at Dehra Dun and various universities.

An Institutional Repository for organizing and disseminating the research out put of the Institute in Digital format is created using Open Source Software D-Space. It consists of full text research publications of the Institute scientists. The research publications are organized in year wise collections. The publications of Prof. D.N. Wadia and other staff of the Institute which were available only in print form were scanned and added to the Institutional Repository for online access to the users as soft version. A total number of 954 publication records were added to the repository during the period of this report. Presently the repository is in continuous growth and available at intranet (LAN) of the Institute.

The Library is member of the National Knowledge Resource Consortium (formerly known as CSIR-DST e-journals consortium). Now the Library has access to various Science and Technology packages of 18 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 is expected to grow further in terms of number of publishers.

The Library has subscription 84 Foreign and 44 Indian Journals in print form. The main thrust was given to provide full text online access of journals to the users on Intranet. Presently, the Library has full text online access to more than 1500 titles pertaining to various disciplines of thrust areas of the Institute. Since Elsevier has joined the consortia from January 2012, the Elsevier's '*Earth & Planetary Collection*' on science direct platform which was earlier subscribed by the Institute Library is presently accessible through the consortium. The Library has also added AGU Web collection to its subscription list for the year 2012.

The Library has purchased the back files of nine titles of journals published by the Wiley. The access for each title is starting from Vol. 1 to respective volume in the year 1996. The Library is already subscribing to these titles from 1997 to the current issue of each journal.

During the reporting period Library has also acquired 370 e-books and purchased 163 reference books (printed) while 28 books are received as gratis. The Library has a good collection of Hindi books to promote Hindi among the staff of the Institute. During the reporting period the purchase of Hindi books was doubled and a total number of 201 books are added to the Hindi collection. Library has also acquired a total number of 150 reprints of publications of various scientists.

PUBLICATION & DOCUMENTATION

The Publication and Documentation Section is involved in bringing out the regular bi-annual SCI journal 'Himalayan Geology' and publishing the Annual Report, Hindi magazine 'Ashmika', newsletter 'Bhugarbh Vani', lecture series, publicity brochures etc. During the year, the Section published 'Himalayan Geology' volumes 32(2) 2011 and 33(1) 2012, 'Annual Report' of the Institute for the year 2010-11 in Hindi and English, Hindi magazine 'Ashmika' volume 17, newsletter 'Bhugarbh Vani' volumes 1(1) 2011, 1(2) 2011, 1(3) 2011 and 1(4), 2012. It had also brought out the 'Abstract volume' of the International Conference on "Indian Monsoon and Himalayan Geodynamics (IMHG-2011)". Apart from this, work pertaining to printing of Lecture Series, publicity brochures, folders, invitation cards, certificates etc. was also carried out.

The section also provides the technical support service on AO/A3 size scanner & printer to scientists, research scholars and other staff of the Institute. More than 200 AO size maps / posters were printed and 500 maps / sheets were scanned during the year.

Himalayan Geology (journal) website http://www.himgeology.com is functioning with online enquiry, online prepaid subscription order and online Manuscript Submission facility under this Section. All information regarding the journal including contents and abstracts is up-to-date at the website. 'Himalayan Geology' is indexing in SCOPUS (Elsevier, Netherlands) and Thomson Reuters (USA).

CELEBRATIONS

National Technology Day

The 13th "National Technology Day was observed on May 11, 2011. An Open Day was observed on this day and Museum and other laboratories were kept open for public and for the school and college children. A large number of students and people visited the Institute Museum and other laboratories. On this occasion, Prof. Durg Singh Chauhan, Vice-Chancellor, Uttarakhand Technical University, Dehra Dun, delivered the Technology Day Lecture on the "*Technical enlightenment in the essence of the present decade*". The lecture was attended by students, public and by the Institute staff.

Chief Guest Prof. Durg Singh Chauhan delivering the National Technology Day Lecture

Foundation Day

The 43rd Foundation Day of the Institute was celebrated on June 29, 2011. Padma Shri Prof. K.L. Chopra, FNA, FASc, FNASc, FNAE, DSc. (hc), (Former Director, Indian Institute of Technology, Kharagpur) & President, Society for Scientific Values was the Chief Guest. He delivered the Foundation Day Lecture on "*Ethical Issues in Science and Technology*". On this occasion distribution of awards for the best research papers published by the Institute scientist was given by the Chief Guest. The award was given jointly to Dr Pradeep Srivastava and Sh Yogesh Ray for their paper entitled "Widespread aggradation in the mountainous catchment of the Alaknanda - Ganga River System: timescales and implications to Hinterland-foreland relationships" published in Quaternary Science Review.

Chief Guest Padmashri Prof. K.L. Chopra delivering the Foundation Day Lecture

The Best worker awards were also given to the Sh. Rakesh Kumar, (Jr. Tech. Officer) Sh. Tajender Ahuja, (Sr. Technical Assistant), Sh. O.P. Anand (Assistant), Sh. S.S. Bisht (Assistant), Smt. R.K. Nagpal (Stenographer), Sh M.M. Barthwal (UDC), Sh. Satya Parkash (Section Cutter), Sh. Ramkhilawan (Field cum Laboratory Attendant), Smt. Kamla Manral (Bearer), Sh Surender Singh (Bearer) and Sh. Vivekanand Khanduri for the good work carried out by them during the year 2011-12.

Founder's Day

The Institute celebrated its Founder's Day on 23 October 2011 in the honor of Prof. D. N. Wadia. On this occasion Founders Day Lecture was delivered by Padmashri Panikkar Prof. Harsh K. Gupta, National Geophysical Research Institute, Hyderabad. He delivered the Founders Day Lecture on the "*Reservoir triggered seismicity and earthquake recurrence at Koyna, India*" The lecture was attended by students and the Institute staff.

National Science Day

The National Science Day-2012 was organized in the Institute for a week-long activity, beginning with a Science Quiz Competition. The various educational institutions of Dehra Dun were invited for participation in the Science Quiz and Hindi Essay Competitions. Inspite of annual board examinations in the schools, a total of thirty four educational institutions participated in the quiz competition and thirty seven in the Hindi Essay competition. Besides this, Hindi & English Slogans competition was organised in which scientists, staff and research scholars of the Institute participated.

On this occasion (February 28, 2012), an open day was observed and all the laboratories were kept open to students and public. The students from Doon valley and far off places like Rishikesh, Selaqui, Vikas Nagar etc. visited the Institute. In total fifty two educational institutions with more than 4,000 school children and a large number of college students and public visited the Institute museum and laboratories. Scientists as well as the technical staff and research scholars explained the functioning of the various scientific instruments and their uses to the students and general public.

On this day various exhibits on the Himalayan glaciers, Earthquakes, Landslides, Origin of Life, Volcanoes, Rocks, Minerals, etc. were displayed. The National Science Day Lecture was delivered by distinguished Scientist, Dr Piyush Kuchhal, Head, Department of Physics, University of Petroleum and Energy Studies, Dehra Dun on "*Clean Energy Source: Nuclear Option*".

S.P. Nautiyal Memorial Lecture

Under the lecture series organized by the Institute, this year the S.P. Nautiyal Memorial Lecture was delivered by Prof. S.K. Shah, Former Head, PG Department of Geology, Jammu University, Jammu on February 23, 2012. He delivered the lecture on "*Bioevents and Climate Change*". It was attended by the staff of the Institute and various other dignitaries.

Science Outreach Programme

Under the Science Outreach Programme, Wadia Institute participated in the following exhibitions and programmes in order to create awareness among the people about natural disasters like Earthquakes, Landslides, Flash floods etc.

- ***"Garhwal Sarjan (Gairsain)- 2011 - A National Expo"*** at Garisen district Chamoli, Uttarakhand from October 14-16, 2011.
- ***"Pride of India" ISC Expo-2012*** organized by the Department of Science & Technology, New Delhi from January 3-7, 2012.
- ***Basant Mela - 2012*** organized by Indo Tibetan Border Police at Dehra Dun from February 11 - 14, 2012.
- ***RMSA (Rashtriya Madhyamic Shiksha Abhiyan) Vigyan Mela*** an exhibition held at Rajikiyi Balika Inter College, Dehra Dun on February 17, 2012.
- ***Vasant Utsav-2012*** held at Rajbhawan, Dehra Dun from March 3-4, 2012.
- ***International Conference on Science & Geopolitics of Arctic & Antarctic (I-SAGAA-2012)*** at India International Centre, Max Mueller Marg, New Delhi from March 9-11, 2012.

DISTINGUISHED VISITORS TO THE INSTITUTE

- Her Excellency, Smt. Margart Alwa, Governor of Uttarakhand
- Honorable Minister Shri Vilas Rao Deshmukh, Minister for Science and Technology and Earth Sciences, Govt. of India, New Delhi
- Padmashri Prof. K.L. Chopra, FNA, FASc, FNASc, FNAE, DSc (hc), Former Director, Indian Institute of Technology, Kharagpur
- Padmashri Dr Harsh K. Gupta, Panikkar Professor, National Geophysical Research Institute, Hyderabad
- Dr Arbin Mitra, Advisor DST, New Delhi
- Mrs Vandana Srivastava, FA, DST, DSIR
- Dr R. Srinivasan, Retd. Scientist, NGRI
- Prof. R.D. Kaushik, Dean, Faculty of Ayurveda and Medical Sciences and Faculty of Engineering and Technology, Gurukul Kangri University, Haridwar
- Dr Piyush Kuchhal, University of Petroleum and Energies Studies, Dehra Dun
- Mrs. Bandana Srivastava, FA, DST, DBT, DSIR
- Dr S.C. Kulshreshtra, SRGC, Muzaffarnagar
- Dr Samyank Jain, Neuro - Phychritrist, Meerut

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, 2011, during which essay competition and debate for school children and Institute employees was organized. Topic of Hindi essay for school children was “Prakritik Aapda Wa Bharat Mein Atankwad” and “Jalwayu Parivartan”. The topic of the debate for school chidren was “Pariyavaran evam Vikas”. On this occasion, a nara competition and Swarachit Kavita Path was also organized for the employees of the Institute.. During Hindi Pakhwara a workshop was organized, wherein Dr M.R. Saklani from Income Tax Office Dehra Dun delivered an invited talk. One day workshop in Hindi was organized during this period in which Dr Rajesh Tewari, a renowned opthamologist of Dehra Dun delivered a talk on “ Yogik Gyan Paddhati”. A hindi Kavya goshthi was also organized during the Hindi Pakhwara in which renowned kavies, Shri Leeladhar Jaguri, Shri Vipin Bihari Suman, Shri Rattam Singh Jaunsari and Smt Kusum Bhatt etc were invited for Kavita Path.

Chief Guest Padmashri Prof. K.L. Chopra along with Prof. Anil K. Gupta and Dr V.C. Tewari releasing the Hindi magazine 'Ashmika' during the Foundation Day Celebration

On the occasion of the 43rd Foundation Day of the Institute on June 29, 2011, the Hindi Magazine *'Ashmika'* volume 17 was released. The Annual Report of the Institute for the year 2010-11 was published in bilingual form.

MISCELLANEOUS ITEMS

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

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

2. **Monitoring of personnel matters**

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

3. **Mechanism for redressal of employees grievances**

There is a Grievance Committee consisting of four 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 2011-12.

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 2011-12.

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 2010-11. The details of information on various RTI cases during the year 2011-12 is presented in the table below:

The details of information on the RTI cases during the year 2011-12 are as under:

Details	Opening balance as on 1.4.2011	Received during the year 2011-2012	Number of cases transferred to other public authorities	Decisions where requests/ appeals were rejected	Decisions where requests/ appeals accepted
Requests for information	Nil	14	Nil	Nil	14
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 2012-13.

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

Group/ Category	Scientific	Technical	Administ-rative	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 2011-2012**

Plan	:	Rs. 2,225.03 lakhs
Non-Plan	:	Rs. 71.00 lakhs
Total	:	Rs. 2,296.03 lakhs

STAFF OF THE INSTITUTE AS ON 01.04.2012

Scientific Staff

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

Technical Staff

1.	Shri Saeed Ahmad	Sr. Librarian Gr.III (5)
2.	Shri M.M.S. Rawat	Sr. Tech.Officer Gr.III (5)
3.	Shri B.B. Sharma	Sr. Tech.Officer Gr.III (5)
4.	Shri A.K. Pandit	Sr. Artist cum Modellor Gr.III(5)
5.	Shri S.K. Dabral	Sr. Tech.Officer Gr.III (5)
6.	Shri Chandra Shekhar	Sr. Tech.Officer Gr.III (5)
7	Shri Samay Singh	Sr. Tech. Officer Gr.III (5)
8.	Shri Rakesh Kumar	Tech. Officer, Gr. III(4)
9.	Shri Ravindra Singh	Tech. Officer, Gr. III(4)
10.	Shri H.C. Pandey	Tech. Officer, Gr. III(4)
11.	Shri S.C. Kothiyal	Tech. Officer, Gr.III (4)
12.	Shri N.K. Juyal	Jr. Tech. Officer Gr.III (3)
13.	Shri T.K. Ahuja	Jr. Tech. Officer Gr. III (3)
14.	Shri C.B. Sharma	Assistant Engineer Gr. III (3)
15.	Shri S.S. Bhandari	Sr. Tech. Assistant Gr. III (2)
16.	Shri Rambir Kaushik	Sr. Tech. Assistant Gr. III (2)
17.	Dr Jitendra Bhatt	Sr. Tech. Asstt. (EDP) Gr. III (2)
18.	Shri Bharat Singh Rana	Sr. Tech. Assitt. Gr. III (2)
19.	Shri Pankaj Chauhan	Tech. Asstt. Gr. III (1)
20.	Shri Amit Kumar	Junior Engineer (Contractual)
21.	Shri V.K. Kala	Draftsman Gr.II (5)
22.	Shri Navneet Kumar	Draftsman Gr.II (5)
23.	Shri B.B. Saran	Draftsman Gr.II (5)
24.	Shri Shekhranandan	Section Cutter Gr.II(5)
25.	Shri Pushkar Singh	Section Cutter Gr.II (5)
26.	Shri Satya Prakash	Section Cutter Gr.II (5)
27.	Shri Santu Das	Section Cutter Gr.II (3)
28.	Shri Puneet Kumar	Section Cutter Gr. II (1)
29.	Shri Nand Ram	Elect.cum-Pump.Optr.Gr. II(5)
30.	Shri Lokeshwar Vashistha	S.L.T. Gr.II (3)
31.	Dr S.K. Chabak	S.L.T. Gr.II (3)
32.	Shri R.M. Sharma	S.L.T. Gr.II (3)
33.	Shri C.P. Dabral	S.L.T. Gr.II (3)
34.	Shri Satish Pd.Bahuguna	Sr.Lab. Assistant Gr. II (5)
35.	Shri S.K. Thapliyal	Sr.Lab. Assistant Gr.II (5)
36.	Shri Shiv Pd. Bahuguna	Sr.Lab. Assistant Gr.II (5)
37.	Shri Sashidhar Pd.Balodi	Sr.Lab. Assistant Gr.II (5)
38.	Shri Rajendra Prakash	Sr.Lab. Assistant Gr.II (5)
39.	Shri A.K. Gupta	Sr.Lab. Assistant Gr.II (5)
40.	Shri Tirath Raj	Sr.Lab. Asstt. (Photography) Gr.II(5)
41.	Shri Balram Singh	Sr.Elect.cum Pump Opt.Gr.II (5)
42.	Shri Pratap Singh	F.C.L.A.Gr. I (4)
43.	Shri Ram Kishor	F.C.L.A.Gr. I (4)
44.	Shri Ansuya Prasad	F.C.L.A.Gr. I (4)
45.	Shri Puran Singh	F.C.L.A.Gr. I (4)

46. Shri Ram Khilawan	F.C.L.A.Gr. I (4)
47. Shri Madhu Sudan	F.C.L.A.Gr. I (4)
48. Shri Hari Singh Chauhan	F.C.L.A.Gr. I (4)
49. Shri Ravi Lal	F.C.L.A.Gr. I (3)
50. Shri Preetam Singh	F.C.L.A.Gr. I (3)
51. Shri Vivekanand Khanduri	F.C.L.A.Gr.I (1)
52. Shri Sanjeev Kumar	F.C.L.A. Gr. I (1)
53. Shri Nain Das	Lab.Assistant
54. Mrs.Rama Pant	Field Attendant Gr. I (3)
55. Shri R.S.Negi	Field Attendant Gr. I (3)
56. Shri Ramesh Chandra	Field Attendant Gr. I (3)
57. Shri Khusi Ram	Field Attendant Gr. I (3)
58. Shri Tikam Singh	Field Attendant Gr. I (3)
59. Shri Bharosa Nand	Field Attendant Gr. I (3)
60. Shri B.B.Panthri	Field Attendant Gr. I (3)
61. Shri M.S.Rawat	Field Attendant Gr. I (3)

Administrative Staff

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

Ancilary Staff

1. Shri Dewan Singh	Driver
2. Shri Sohan Singh	Driver
3. Shri Ganga Ram	Driver
4. Shri Naresh Kumar	Driver
5. Shri Shyam Singh	Driver
6. Shri R.S. Yadav	Driver
7. Shri Surjan Singh	Driver
8. Shri Reza Uddin Chaudhary	Driver (Contractual)
9. Shri Anil Rana	Driver (Contractual)
10. Shri Girish Chander Singh	Guest House Attdt. cum Cook
11. Sh. Dinesh Parsad Saklani	Guest House Attdt. cum Cook
12. Mrs. Kamla Devi	Bearer
13. Mrs. Deveshawari Rawat	Bearer
14. Shri S.K. Gupta	Bearer
15. Shri Chait Ram	Bearer
16. Mrs. Omwati	Bearer
17. Shri Jeevan Lal	Bearer
18. Shri Surendra Singh	Bearer
19. Shri Ramesh C. Rana	Bearer (Contractual)
20. Shri Preetam Singh	Bearer
21. Shri Rudra Chettri	Bearer (Contractual)
22. Shri Harish Verma	Bearer (Contractual)
23. Shri Uttam Singh	Bearer (Contractual)
24. Shri Har Prasad	Chowkidar
25. Shri Mahendra Singh	Chowkidar
26. Shri Rohlu Ram	Chowkidar
27. Shri H.S. Manral	Chowkidar
28. Shri G.D. Sharma	Chowkidar
29. Shri Laxman S. Bhandari	Chowkidar (Contractual)
30. Shri Pradeep Kumar	Chowkidar (Contractual)
31. Shri Kalidas	Chowkidar (Contractual)
32. Shri Ummed Singh	Chowkidar (Contractual)
33. Shri Sang Bam Kach	Chowkidar (Contractual)
34. Shri Ashok Kumar	Mali
35. Shri Satya Narayan	Mali
36. Shri Ramesh	Safaiwala
37. Shri Hari Kishan	Safaiwala
38. Smt. Sang Bam Namo	Safaiwala (Contractual)

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

Governing Body
(w.e.f. 1.4.2011)

Sl.	Name	Address	Status
1.	Dr T. Ramasami	Secretary Dept. of Science & Technology Technology Bhavan, New Mehrauli Road New Delhi - 110016	Chairman
2.	Ms. Sheila Sangwan	Additional Secretary & Financial Adviser Dept. of Science & Technology Technology Bhavan, New Mehrauli Road New Delhi - 110016	Member
3.	Prof. (Mrs.) Archana Bhattacharyya	Emeritus Scientist Indian Institute of Geomagnetism Kalamboli Highway New Panvel (W) Navi Mumbai - 410218	Member
4.	Dr V.P. Dimri	CSIR Distinguished Scientist National Geophysical Research Institute Uppal Road, Hyderabad - 500007	Member
5.	Prof. U.C. Mohanty	Centre for Atmospheric Sciences Indian Institute of Technology, Delhi Hauzkhas, New Delhi - 110016	Member
6.	Prof. M.P. Singh	124, Chand Ganj Extn. (Opposite CM-7) Sector 'B', Aliganj Lucknow (UP)	Member
7.	Prof. Shyam Lal	Physical Research Laboratory Navrangpura Ahmedabad - 380009	Member
8.	Prof. R.P. Tiwari	Department of Geology Mizoram University Aizawl - 796009	Member
9.	Prof. Anil K. Gupta	Director Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member Secretary
10.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Non-Member Asstt. Secretary

Research Advisory Committee
(w.e.f. 1.4.2011)

Sl.	Name	Address	Status
1.	Prof. Ashok K. Singhvi	Outstanding Scientist Physical Research Laboratory Navrangpura Ahmedabad - 380009	Chairman
2.	Prof. R.P. Tiwari	Department of Geology Mizoram University Aizawal - 796009	Member
3.	Shri Ashwagosha Ganju	Director Snow & Avalanche Study Establishment (SASE) Him Parisar Sector 37-A Chandigarh - 160036	Member
4.	Prof. D.M. Banerjee	Department of Geology Delhi University Delhi - 110007	Member
5.	Prof. Vishwas Kale	Professor of Geography Department of Geography University of Pune Pune - 411007	Member
6.	Dr Rajeev Nigam	Scientist National Institute of Oceanography (NIO) Dona Paula Goa - 403004	Member
7.	Prof. Rajesh K. Srivastava	Department of Geology Banaras Hindu University (BHU) Varansi - 221005	Member
8.	Prof. Saibal Gupta	Department of Geology & Geophysics Indian Institute of Technology Kharagpur - 721302	Member
9.	Dr G.S. Srivastava	(Ex-Deputy Director General, GSI) 193, Vivek Khand -3, Gomti Nagar Lucknow - 226024	Member
10.	Dr V.M. Tiwari	Scientist National Geophysical Research Institute Uppal Road Hyderabad - 500007	Member

Sl.	Name	Address	Status
11.	DST Nominee	Department of Science & Technology Technology Bhavan, New Mehrauli Road New Delhi - 110016	Member
12.	Prof. Anil K. Gupta	Director Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member
13.	Shri R.S. Dattatreyam	Director Seismology Division India Meteorological Department Mausam Bhavan, Lodhi Road New Delhi	Member
14.	Dr Sridevi Jade	Centre for Mathematical Modeling & Computer Simulation (C-MMACS) NWTC, Belur Bangalore - 560037	Member
15.	Dr D.R. Rao	Scientist 'F' Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member Secretary

Finance Committee
(w.e.f. 1.4.2011)

Sl.	Name	Address	Status
1.	Prof. M.P. Singh	124, Chand Ganj Extn. (Opposite CM-7) Sector 'B', Aliganj Lucknow (UP)	Chairman
2.	Ms. Sheila Sangwan	Additional Secretary & Financial Adviser Dept. of Science & Technology Technology Bhavan, New Mehrauli Road New Delhi - 110016	Member
3.	Prof. Anil K. Gupta	Director Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member
4.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member
5.	Shri Harish Chandra	Finance & Accounts Officer Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member Secretary

Building Committee
(w.e.f. 1.4.2011)

Sl.	Name	Address	Status
1.	Prof. Anil K. Gupta	Director Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Chairman
2.	Ms. Sheila Sangwan	Additional Secretary & Financial Adviser Dept. of Science & Technology Technology Bhavan, New Mehrauli Road New Delhi - 110016	Member
3.	Shri Harsh Mani Vyas	G.M. (Infrastructure Development) Shed No. 32, Tel Bhawan Oil & Natural Gas Corporation Dehra Dun - 248001	Member
4.	Representative of Survey of India	Shri D.N. Pathak Superintending Surveyor Surveyor General's Office Survey of India, Hathibarkala, Dehra Dun - 248001	Member
5.	Dr Rajesh Sharma	Scientist 'F' Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member
6.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member
7.	Shri C.B. Sharma	Assistant Engineer Wadia Institute of Himalayan Geology 33, General Mahadeo Singh Road Dehra Dun - 248001	Member Secretary

STATEMENT OF ACCOUNTS

Goyal Bhanot & Co.

Chartered Accountants

H.O. : 1, Turner Road, Clement Town
Dehradun - 248002, Uttarakhand

B.O. : 23, E.C. Road, Opp. CJM School
Back Gate, Dehradun, Uttarakhand
Ph. 0135-6543358, 2711730

306, Sachdeva Coporate Tower Plot 17
Karkardooma Community Centre
New Delhi-110092, Ph. 011-45873419

Email : info@goyalbhanotco.com

AUDITOR'S REPORT

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

We have examined the attached Balance Sheet of **Wadia Institute of Himalayan Geology, 33, GMS Road, Dehradun,** as on 31st March, 2012 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 furnished 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, 2012.
- 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 12th, 2012
Place: Dehra Dun

AUDITOR'S REPORT

Goyal Bhanot & Co.

Chartered Accountants

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Dehradun - 248002, Uttarakhand

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Email : info@goyalbhanotco.com

Annexure 1 to the Main Audit Report

The following observations were noted during the course of audit for the financial year 2011-12.The same have been discussed with management and comments and explanations of the management thereon have also been obtained.

1. The institute is maintaining accounts on cash basis except interest accrued on investments, which is not in conformity with the generally accepted accounting policies adopted in India and as per the Accounting Standard 1 "Disclosure of Accounting Policies" issued by the Institute of Chartered Accountants of India. The "Uniform Accounting Format" of financial statements for the Central autonomous bodies as has been made compulsory by the Ministry of Finance w.e.f. 01.04.2001, and adopted by the Institute also, recommends accrual method of accounting.
2. The total funds which remained un-utilized as on 31.03.2012 could not be bifurcated into Plan and Non-Plan funds as separate bank account and books of accounts are not maintained. Hence it is not possible to verify how much of the funds have been utilized from Plan or Non-Plan Funds separately. However, as informed, the Institute is preparing a separate statement to bifurcate the amount utilized to respective funds in the form of utilization certificate.
3. The Recurring fund of the Corpus fund of the Institute is negative by Rs 1,49,58,835.00 as per Schedule 1 which shows that the institute has utilized non-recurring fund to the tune of the said amount for recurring purposes.
4. The Institute has not booked the current liability for the retirement benefit of the employees as per Accounting Standard 15 "Employees Benefits" as issued by the Institute of Chartered Accountants of India.
5. The financial statements of the institute and the projects sponsored by the other agencies and the CPF, GPF and the new pension scheme are prepared separately. As per Accounting Standard 21 "Consolidation of financial Statement" required to be maintained as per guidelines 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 only stock register of the Institute is maintained.
   b) The additions to fixed assets are not numbered properly.
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, 2012. As per the management the same policy had been adopted in the previous financial years also.
   b) The fixed assets are being accounted for on payment basis. In case the payment is made in parts then the depreciation is wrongly charged on only the amount that has been paid as against the full value of the invoice.
8. The Institute has not bifurcated the advances indicating the period of outstanding given to staff and Parties. The Party Debtors amounting to Rs. 126,921/- and Staff Debtors amounting to Rs 18,659/- are outstanding since more

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Chartered Accountants

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than 4 years. The advance which could not be realized in due course should be written off with the approval of the competent authority.

9. The Institute has transferred fixed assets of 7 projects sponsored by other agencies to WIHG and fixed assets of 2 projects to other projects 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 19 other sponsored projects in the F.Y. under Audit. The research activities under the said projects have also been completed; however, fixed assets have not been transferred to WIHG.

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

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

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-
CA RAJNISH BHANOT
[FCA, Partner]

Date: 12th July, 2012
Place: Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

BALANCE SHEET
(AS AT 31st MARCH 2012)

(Amt in Rs…)

Particulars	Schedule	Current Year	Previous Year
LIABILITIES			
Corpus/ Capital Fund	1	41,73,34,945	41,83,37,566
Reserves and Surplus	2	-	-
Earmaked/ Endowment Fund	3	12,75,154	14,46,535
Secured Loans & Borrowings	4	-	-
Unsecured Loans & Borrowings	5	-	-
Deferred Credit Liabilities	6		-
Current Liabilities & Provisions	7	28,28,881	26,22,518
TOTAL		**42,14,38,980**	**42,24,06,619**
ASSETS			
Fixed Assets	8	31,32,30,985	31,45,31,599
Investments from Earmaked/ Endowment Funds	9	31,422	29,024
Investment- Others	10	-	-
Current Assets, Loans & Advances	11	10,81,76,573	10,78,45,996
TOTAL		**42,14,38,980**	**42,24,06,619**
Significant Accounting Policies	37		
Contingent Liabilities and Notes on Accounts	38		

"As per our separate report of even date"

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-
CA RAJNISH BHANOT
(FCA, Partner)

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

Date : 12th July, 2012
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

INCOME & EXPENDITURE ACCOUNT
(AS AT 31st MARCH 2012)

(Amt in Rs…)

	Particulars	Schedule	Current Year	Previous Year
A	**INCOME**			
	Income from sales/ services	12	-	-
	Grants/ Subsidies	13	22,96,03,000	23,93,58,200
	Fees/Subscription	14	38,000	73,000
	Income from Investments (Income on Invest from Earmarked/ Endowment - Fund)	15	8,63,654	8,69,934
	Income from Royalty, Publication etc.	16	48,883	55,711
	Interest earned	17	38,86,929	28,15,147
	Other Income	18	13,63,497	20,33,868
	TOTAL (A)		**23,58,03,963**	**24,52,05,860**
B	**EXPENDITURE**			
	Establishment Expenses	20	15,56,41,078	12,54,26,769
	Other Research & Administrative Expenses	21	3,96,06,722	2,57,13,666
	Expenditure on Grant/ Subsidies etc.	22	-	-
	Interest/ Bank Charges	23	2,010	5,004
	Depreciation Account	8	5,20,56,111	4,84,71,150
	Increase/ Decrease in stock of Finished goods, WIP& Stock of Publication	A-2	1,18,841	1,26,122
	Loss on sale of vehicle	A-19	-	97,700
	TOTAL (B)		**24,74,24,762**	**19,98,40,411**
	Surplus/ (Deficit) being excess of Income over Expenditure (A - B)		1,16,20,799	4,53,65,449
	BALANCE BEING SURPLUS /(DEFICIT) CARRIED TO CORPUS FUND		**1,16,20,799**	**4,53,65,449**
	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/-
CA RAJNISH BHANOT
(FCA, Partner)

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

Date : 12th July, 2012
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

RECEIPTS & PAYMENTS ACCOUNT
(For the year ended 31st March 2012)

(Amt in Rs…)

Particulars	Schedule	Current Year	Previous Year
RECEIPTS			
Opening Balance	24	6,98,07,158	2,83,45,663
Grants - in - Aids	26	22,96,03,000	23,93,58,200
Grants - in - Aids/Other Receipts (Ear Marked)	27	19,65,279	5,07,215
Loan & Advances	28	7,05,65,619	6,14,54,954
Loan & Advances (Ear Marked)	31	-	-
Fees/Subscription	14	38,000	73,000
Income from Investments	15	8,63,654	8,69,934
Income from Royalty, Publication etc.	16	48,883	55,711
Interest earned on Loan to Staff	17	38,86,929	28,15,147
Other Income	18	13,63,780	22,00,668
Investment (L/C Margin Money)	34	3,03,00,000	5,31,00,000
TOTAL		**40,84,42,302**	**38,87,80,492**
PAYMENTS			
Establishment Expenses	20	15,56,41,078	12,54,72,259
Other Administrative Expenses	21	3,96,06,722	2,57,13,666
Expenditure on Grant/Subsidies Etc.	22	-	-
Interest/ Bank Charges	23	2,010	5,004
Loans & Advances	29	6,79,24,139	6,29,44,144
Loans & Advances (Ear Marked)	32	15,79,000	-
Investment (L/C Margin Money)	35	2,43,35,000	3,03,00,000
Fixed Assets	36	4,01,37,319	7,40,12,040
Ear Marked Fund Expenses	33	3,86,279	5,26,221
Grant - in - Aid (Ear Marked) Refunded	30	1,73,779	-
Closing Balance	25	7,86,56,976	6,98,07,158
TOTAL		**40,84,42,302**	**38,87,80,492**

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/-
CA RAJNISH BHANOT
(FCA, Partner)

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

Date : 12th July, 2012
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

SCHEDULE FORMING PART OF ACCOUNTS FOR THE YEAR ENDED 31st MARCH 2012
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 deposit.

2. INVESTMENTS

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

3. 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 transferred from projects sponsored by other agencies are capitalized at net book value on closure of project activities.

4. 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.

5. MISCELLANEOUS EXPENDITURE

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

6. ACCOUNTING FOR SALES & SERVICES

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

7. 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.

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

Date : 12th July, 2012
Place : Dehra Dun

AUDITOR'S REPORT

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

HEDULE FORMING PART OF ACCOUNTS FOR THE YEAR ENDED 31st MARCH 2012
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	2,43,35,000
	iii)	Bills discounted with banks	- Nil -
c)	Disputed demands in respect of		
	i)	Income -tax	58,36,245
	ii)	Sales tax	- Nil -
	iii)	Municipal Taxes	- Nil -
d)	In respect of claims from parties for non-execution of orders, but contested by the Entity		- Nil -

2. CAPITAL COMMITMENTS

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

3. LEASE OBLIGATIONS

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

4. CURRENTS ASSETS, LOANS AND ADVANCES

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

5. TAXATION

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

6. FOREIGN CURRENCY TRANSACTIONS

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

c)	Earnings		
	i)	Value of Exports on FOB basis	- Nil -
	ii)	Grants	- Nil -

7. The payments to auditors during the F.Y. 2011-12 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 4,01,37,734.00 as per Schedule '8' has been transferred to Non Recurring fund on account of purchase/transfer of capital assets from total grants received from the Department of Science & Technology, Government of India.

9. The 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	AFNAH-II (NSV)	28,900	11,100	40,000
2	ILTP-NEMFIS (BR)	26,071	16,382	42,453
3	MGIE (BR)	22,70,755	28,46,954	51,17,709
4	GEES	27,15,294	17,48,279	44,63,573
5	GANGA BASIN (BR)	37,224	14,297	51,521
6	ECGHR (GP)	1,16,792	1,92,878	3,09,670
7	ECD (BR)	54,23,142	49,02,991	1,03,26,133
	TOTAL	**1,06,18,178**	**97,32,881**	**2,03,51,059**

10. 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

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

Schedules 01 to 38 and Annexures 1 to 18 annexed to are an integral part of the Balance Sheet as on 31st March, 2012, Income and Expenditure Account and Receipts & Payments Account for the year ended on 31st March, 2012.

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

Date : 12th July, 2012
Place : Dehra Dun