Annual Report

2005-2006

Annual Report

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WADIA INSTITUTE OF HIMALAYAN GEOLOGY
DEHRA DUN

Credits : R.K. Mazari, K.K. Purohit, D.R. Rao, V.P. Singh and Rambir Kaushik

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WADIA INSTITUTE OF HIMALAYAN GEOLOGY

33, General Mahadeo Singh Road, Dehra Dun - 248 001
EPABX : 0135-26227387, 2624806, 2623109
Fax : (91) 0135-2625212 E-mail : wihg@sancharnet.in
website : http://www.himgeology.com

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YEAR AT A GLANCE

Wadia Institute of Himalayan Geology is an autonomous Institute of the Department of Science & Technology, Government of India, devoted to basic and applied research on geology, natural resources, environment and natural hazards in the Himalaya. Moving towards the last year of the 10th Five Year Plan, the focus of research activities was on stock taking and reorienting our activities to achieve the targeted objectives. An overview of the on-going activities showed that major research activities in the thrust areas have progressed well towards the projected goals. An important step initiated during the year was to prepare a Vision Document for the Institute to identify research areas to be focused in the next 5 to 10 years. This exercise has provided a base for drafting the 11th Five Year Plan document. The necessary steps in this direction are already in the pipeline.

With an objective to provide the necessary infrastructural facilities to produce internationally competitive data base research at the Institute, a phased-manner programme for the up-gradation of analytical facilities was taken up during the year. A state of art Cameca-SX 100 Electron Probe Micro-Analyzer has been established and it is now functional to obtain the chemical composition of minerals on micro-scale (grain level) and to study petrogenesis and P-T path. Prof. V.S. Ramamurthy, former Secretary, Department of Science & Technology, Government of India inaugurated the unit. In addition, a new TL/OSL unit for dating the Quaternary sediments, advance rock magnetic system for characterizing the magnetic properties under high magnetic fields, and a new generation Scanning Electron Microscope (SEM) with Energy Dispersive X-ray Analyzer for internal morphological features along with chemical compositions of micro-fossils/minerals were added to the in-house laboratories. All these facilities are accessible to researchers from national institutions and universities. During the year, the use of these analytical facilities has recorded 50 per cent growth and still efforts are on to enhance the utilization of these facilities both by external and internal users. In order to supplement the survey-based investigations, 12 numbers of broadband seismometers were procured for launching passive seismological studies to map the deep structures of the Himalayan collision zone.

The establishment of a Multi-Parametric Geophysical Observatory for earthquake precursor research under the Mission Mode Project on Seismicity is in the final stages. The HIMSELP Programme to create a fruitful link between the Institute and Colleges/Secondary School Teachers/Students has resulted in the propagation of the awareness on seismic hazards. Further, to attract young minds for research career in emerging areas in the earth sciences, the Institute has taken a major initiative of organizing Summer Training-cum-Research Programme for students pursuing their final year M.Sc./M.Tech degree course. As part of this, 12 students from different universities were selected to work with the Institute scientists for two months in the coming year in areas of active fault mapping, geomorphology, earthquake precursors and seismicity in selected corridors of the Himalaya.

The Institute continued to strive to promote inter-disciplinary collaborative research with sister institutions. As part of this, sensitivity analysis investigations involving multi-channel analysis of shear wave, electrical resistivity tomography and transient electromagnetic imaging were undertaken jointly with NGRI, Hyderabad and ITC, Netherlands. The combined approach has shown the merit of mapping the shallow surface structures that have direct relevance to basin evolution, palaeoseismology and climate-tectonics interaction. The continuous growth in the analytical laboratory facilities, field equipments and inter-linkages with other academic institutions has ensured significant progress in all the on-going projects. Significant achievements in each of the thrust areas are highlighted below.

Geodynamics and Crustal Evolution

Geochronology (^{40}Ar-^{39}Ar) and fluid inclusion studies indicate that the Karakoram Fault in the Karakoram Fault Zone started moving upward from the depth of 21 km at 15 Ma reaching a maximum depth of 7 km by 8 Ma. The rapid exhumation of the Karakoram Fault is attributed to sudden drop in pressure after 8 Ma. The discovery of metamorphic microdiamonds from the Tso Morari Crystalline Complex in Ladakh indicates that the host rocks underwent ultrahigh-pressure, high temperature metamorphism during India-Asia collision. This also suggests that the volume of the Indian crustal slice subducted to the diamond stability field and tectonically bounced back on the surface by the buoyancy driven force. Geochemical studies in the Tso Morari region show that there was an initial phase of plume activity (Cambrian or earlier) resulting in basaltic magma in the eclogite layers at the sub-lithospheric level. In the Kumaon area the composition of the Askot Crystallines suggests that these rocks were derived from the mafic/intermediate magmatic products formed above the subduction slabs of the oceanic lithosphere.

As regards the structural style in part of the Higher Himalaya, the model based studies show that the younger hanging wall rocks (i.e. Vaikrita Group) lie above the older footwall rocks (i.e. Munsiari Formation) along the Vaikrita Thrust, which is due to inversion tectonics where normal faulting and metamorphism were followed by thrusting characterized by displacement amount less than the displacement during the early normal faulting.

Basin Evolution

Biostratigraphical studies in the Zanskar region show the occurrence of two ichnofaunal assemblage zones (Early Cambrian), which holds stratigraphic importance as no body fossils of this age have been reported from this region so far. Presence of abundant diversified microfauna in the Shali Group in Himachal Lesser Himalaya has revealed that the Inner Carbonate Belt encompasses Precambrian-Cambrian (PC-C) boundary (542 Ma) like that shown by the Mussoorie Group in the Outer Carbonate Belt. This study confirms that in the Shali Belt too there was a major hiatus of > 1 billion years duration in the successions. The significance of this hiatus is that it is represented throughout the Lesser Himalaya, the Ganga basin and the Vidhyan basin of the Indian peninsula. In the Bhagirathi valley, Neoproterozoic carbonate sequence was deposited in shallow marine environment, and in the Mussoorie-Dhanualti section Early Cambrian trace fossils indicate their potential use in the correlation of the Tethyan and Lesser Himalayan horizons.

Magnetostratigraphic and rock magnetic studies on the Subathu Formation in Himachal Pradesh have shown as many as 11 magnetic polarity events, out of which five reversals are assigned the ages of 41.257 Ma, 40.13 Ma, 39.631 Ma, 39.552 Ma and 38.426 Ma. In regard to 2.7 km thick Siwalik Group in the Ravi re-entrant three megacycles dating 12.77-8.39 Ma, 8.39-5.71 Ma and 5.71-4.48 Ma have been identified. In the case of Dharamsala Formation in Kangra valley Early Miocene upper premolar fossil of a large-bodied mammal *Prodeinotherium* has been recovered and serves as a clue for understanding the pre-Siwalik large mammals of the Himalayan region. The discovery of fish fauna from the same stratigraphical horizon in association with earlier known microfaunal assemblages indicates that the Dharamsala Basin characterized by freshwater elements was connected with marine realm through water channels. Biostratigarphic work on Siwalik Group in Ramnagar area of Jammu shows the occurrence of two carnivore taxa which are the descendants of native Indian subcontinent carnivore lineage.

Natural Hazards

Geomorphological studies in the Kullu valley reveal that the area is most vulnerable to cloudbursts. As many as 36 cloudbursts have occurred in Himachal Pradesh during 1990-2001, out of which Kullu valley has witnessed 15. Analysis of the data indicates that significant environmental changes have taken place during the last 50 years or so as shown by drastic variation in rainfall from 353 cm in 1950 to 60 cm in 2001, and temperature change from -10° C to -4° C during the same period.

Study on active faults using high-resolution satellite data in the proximity of the Main Boundary Thrust (MBT) has revealed the presence of five active fault traces in the Pinjaur Dun, whereas a new active fault trace oblique to HFT, designated as the Singhauli Active Fault (SAF) proves that the hitherto believed HFT is not a blind thrust. In Himachal and Uttaranchal Himalaya 2560 local and regional earthquakes, with depth of local earthquakes ranging from 4 to 24 km were recorded during the year. Microzonation studies were carried out in Chandigarh and Shimla areas to identify and quantify soil response to seismic waves. Multichannel Analysis of Surface Waves technique was used in Dehra Dun city to obtain an idea about the profound effect of ground motion amplification on soils. For Dehra Dun city three zones of amplification have been mapped. Studies on seismicity, seismotectonics and seismic hazard assessment show that in general the crust is at low temperature that will promote brittle behaviour and conditions for episodic failure as compared to creep under the piling strain from plate collision at the Himalayan plate boundary. Data on earthquakes in Hindu Kush-Himalayan region show that the upper mantle velocity structure changes with depth i.e for a depth of 100 km the velocity is 8.1 km/s, whereas below 100 km depth it is 8.3 km/s.

GPS data collected from Malaysia, Indonesia, Sumatra, Burma and all permanent Indian GPS stations was processed for studying the co-seismic and post-seismic deformation related to December 26, 2004 Sumatra-Andaman earthquake and March 27, 2005 Nias earthquake, which indicate that sites in southern India moved eastward by 25 mm, decaying to 2-4 mm in the northwestern Himalaya. Both Nias and Sumatra-Andaman earthquakes ruptured approximately 1800 km of the Andaman and Sunda subduction zones. Substantial postseismic effects over a region several 100s wide surrounding the eastern Indian Ocean are predicted for simple layered viscoslastic models.

Glaciology and Natural Resources

Geohydrological study in part of Uttaranchal Himalaya show that base flow estimation by hydrograph separation method indicate that springs related to rock structure bear 20-40% of the total discharge, colluvium related have 47-60% and fluvial related possess 45-65% discharge; karst related springs show 22-37% discharge. Three groundwater flow paths, namely, shallow, moderate and relatively deep have been observed.

Ground Penetration Radar studies on Dokriani glacier show that the maximum thickness of this glacier is 80-85 m. As regards the glacial runoff of the Garhwal glaciers, separating the influence of monsoon component with respect to the bulk glacier runoff, it was observed that the monsoonal component in glacial discharge during 1999 and 2000 ablation period increased to 26% from 10% in 1994 and 1998. Annual monitoring of the Chorabari glacier indicates that the glacier retreated by 12 m in the central part and 8 m and 10 m in the marginal part of both sides of the glacier.

Geochemical studies on stream samples in the Proterozoic metasedimentary terrain of the Garhwal Group and MCT zone were carried out to identify the anomalous zones for potential uranium and tungsten mineralization in this region. For better characterization of the granitic standard, 2500 units of data from 44 international laboratories for about 50 constituent elements was used, and as far homogenization of the bulk samples inter-laboratory agreements of data were found to be excellent.

Palaeoclimate and Environment

Century-scale palaeoclimatic records show that the Pinder valley was predominantly cool between ~3500 and 1600 cal yr Bp with two distinct phases of dry climate during 3300-2300 and 2100-1600 cal yr BP. From 1600 cal yr onwards there has been progressive wetness until the present with higher temperatures during 1600-740 cal yr BP, 640-460 cal yr BP, and 270-57 cal yr BP; intermittent periods were relatively cold. In regard to climate-tectonic relationship in part of the Alakananda valley the studies show that the base of T_1 terrace at Deoprayag started developing around 21,000 years ago and the process of aggradation continued even after 10, 000 years before present. This indicates that the major part of aggradation occurred during increased phase of aridity of the Last Glacial Maximum (LGM) and incision followed in increasingly wet after the LGM. Geochemically, the sediments that lay in the younger flood sequences were originated in the upper catchment of the Alaknanda. Studies on the alluvial fans and river terraces of the Pinjaur Dun indicate that the first order alluvial fan aggradaded before 96.5$\pm$25.3 ka and stopped after 83.7$\pm$16.3 ka, whereas deposition of the second order alluvial fan initiated in 72.4$\pm$ ka and continued till 24.5$\pm$4.9 ka. The terraces were deposited at 16.3$\pm$2.1 ka, 4.5 ka and 2 ka.

Northeast Himalaya

In eastern Arunachal Pradesh three phases of deformation have been observed. The first phase produced small-scale tight isoclinal folds; second phase produced isoclinal to slightly open type folds, whereas the third phase created broad open type of folds (eastern syntaxis) at the regional scale. Also during this phase the eastern part of the eastern syntaxis started moving towards northwest due to push of the SE block of Myanmar. Structural studies in the Eastern Snytaxial Bend (ESB) in Arunachal Pradesh show that the Main Boundary Thrust (MBT) and the Himalayan Frontal Thrust (HFT) represent the folded structures. The major part of the ESB forms the NNW plunging Siang antiform in the Siang valley, whereas the MBT and HFT are characterized by active brittle thrusts, normal and strike-slip faults. The steeply dipping brittle normal faults are the youngest gravity collapse structures, which developed after the thrust movement was locked.

In the western Arunachal Pradesh five tectonostratigraphic groups have been mapped in Kameng and Subansiri valleys with most of them having the thrust contacts. In the Kameng and Subansiri valleys, active fault running for 10 kilometers each have been identified leading to displacement of the terraces. In the Rangit window in western Sikkim studies have revealed the presence of, whereas in the Eastern Himalayan Syntaxial Bend the core of the Siang window consists of thick volcano-sedimentary sequences. Geochemical and petrogenetic studies suggest that these rocks might have been generated from enriched source by multi-stage metasomatic processes with varying degree of partial melting. Based on the first appearance and the last occurrence of marker species and their ranges, three foraminiferal biozones have been established in south-central Nagaland.

Academic Pursuits

The research pursued under different on-going projects during the year has led to the publication of 55 research papers both in national and international journals; about 105 research papers are in press/communicated. In addition to this 65 papers were presented in national and international seminar/symposia/workshop by the Institute scientists; many of these include invited/keynote review talks. Further, two research scholars earned their Ph.D. degree, while four theses have been submitted for the award of the Ph.D. degree.

Awards and Honours

Significant research contributions made in the fields of Experimental Structural Geology and Paleomagnetism and Rock Magnetism has led to the award of National Mineral Award of the Ministry of Mines, Government of India and C. Radhakrishnamurthy Award of the Geological Society of India, to two scientists of the Institute for the years 2004 and 2005 respectively.

Publications

The Institute brings out regular Himalayan Geology publications. During the year volumes 26(2) and 27(1) were brought out along with volume 11 of the in-house Hindi magazine Ashmika and Annual Report of the Institute for the year 2004-05 both in Hindi and English. Books entitled "Earthquakes Laboratory Practice", and "National Programme on Seismicity: Highlights and Achievements" were also brought out by the Institute.

Knowledge Dissemination

To disseminate and promote geoscience research in the Himalaya, the Institute organizes seminars, symposia and workshops on various special themes. The Institute organized the XXII Convention of Indian Association of Sedimentologists (IAS-2005) on December 21-23, 2005, Workshop on Himalayan School Earthquake Laboratory Programme (HIMSELP) to provide training to school teachers in earthquake processes and instruments, on September 29-October 4, 2005; Workshop on Inventory of Glaciers and Glacial Lakes and the Identification of Potential Glacial Lake Outburst Floods (GLOFs) Affected by Global Warming in the Mountains of Uttaranchal Himalaya, on 14 July 2005; and a National Field Workshop on the Sub-Himalayan Palaeogene Sediments, with a view to motivate an integrative approach to highlight the uniqueness and wealth of information that these sediments hold in the context of India-Asia collision on March 24-26, 2006.

Official Language Implementation

In order to promote Hindi for the implementation of the official language policy of the Union of India, general orders and circular notices were issued both in Hindi and English. Hindi magazine Ashmika was published by the Institute. The Hindi version of the Annual Report of the Institute was published and circulated. Hindi fortnight was celebrated during September 14-28, 2005 and various programmes in Hindi were organized.

BALDEV RAJ ARORA
Director

PROGRESS IN RESEARCH PROJECTS

1. GEODYNAMICS AND CRUSTAL EVOLUTION

1.1 SUB PROJECT

Crustal evolution in the Trans-Himalayan regions of Tso-Morari, Indus and Shyok Suture Zones.

(S.K. Paul, H.K. Sachan, and D.R. Rao)

The Indus Suture Zone is considered as welded plate junction between the Indian and Tibetan-Karakorum blocks. It is commonly believed that the different ophiolite suites in the Indus Suture Zone were the result of a single eastward progressing collision event initiated in early Eocene time. The study highlights the internal deformation of the Indus Suture Zone and the Karakorum strike-slip fault in eastern Ladakh.

The intra-oceanic southward thrusting has obducted the remnant of the oceanic lithosphere (ophiolite) over the plateform sediments of the Tethyan sequence. This thrusting event can be observed from Upshi to Henle trending NW-SE. The continued convergence has steepened the early thrust fault and reactivated into dextral strike slip fault. To the north of ISZ, an active Karakorum dextral strike slip fault exhibits about 120 km offset. This fault can be traced from Muji basin in Pamir in the northwest, passing through the Permian, Early Mesozoic sediments and Karakorum batholith in its central part and finally merges with ISZ in southern Tibet in the east. Due to large scale movement along these two major dextral shear zones (ie. ISZ and Karakorum Fault), a mega riedal shear zone developed. Named Dungti-Henle Fault and exhibiting dextral strike slip movement can be traced from Dungti to the north and Henle to the south. It merges with the Karakorum Fault near Dungti and southern margin of ISZ near Rongdo to the south and then moves further southward through Henle and beyond southwestern Tibet along the ISZ. The forearc basin and Ladakh Plutonic Complex of ISZ in eastern Ladakh are dextrally displaced to the order of about 10 km by this fault and formed in brittle to brittle ductile regime. The NNW-SSE trending straight strike continuation of Zildat Ophiolitic Melange between Rongdo and Henle is the evidence of late obduction (Post Oligocene) of Zildat Ophiolitic Melange along this shear plane of Dungti-Henle Fault.

The fluid inclusion and ^{40}Ar-^{39}Ar chronology carried out on mylonites of Karakorum fault zone from Tangtse area indicate a change in fluid composition with time event. The ^{40}Ar-^{39}Ar chronology study of the selected samples has been done at Isotope Lab of Department of Earth, Atmospheric and Planetary Sciences, MIT, USA. From the studies it is found that the fluids involved in the initiation of movement of fault are of carbonic, carbonic-aqueous and aqueous in nature, while at the later part of movement carbonic-aqueous and aqueous fluid become predominant. The density and salinity of the inclusions changed as fault moved upward and finally the salinity of fluid decreased drastically (2 wt.% NaCl) near the surface at about 3 km.

The fluid inclusions and ^{40}Ar-^{39}Ar chronological data suggest that the Karakorum Fault started moving upwards from the depth of 21 km at 15 Ma along isochoric path till 8 Ma up to a depth of 7 km with a strike-slip fault motion. The implosion type of texture as shown by secondary inclusions present in the mylonitic quartz grain which were formed due to isothermal decompression at the late stage of exhumation. This fast exhumation of Karakorum Fault was due to sudden drop in pressure after 8 Ma. After this the motion of fault changed into transpressive motion and continued up to 6 Ma till it reached a depth of 3 km below surface.

The discovery of metamorphic microdiamond and graphite mineral from the Himalaya indicates that the surface rocks suffered ultrahigh-pressure, high-temperature metamorphism in response to India-Eurasia collision. The microdiamond and graphite crystals are preserved within eclogites and gneissic rocks of the Tso-Morari Crystalline Complex, NW Himalaya. The SEM images of microdiamonds display polycrystalline aggregates $<5\ \mu m$ size, whereas graphites reflect amorphous to flaky structure. The estimated $P > 4.0$ GPa and $T\ 900 \pm 50°C$ with accompanying carbonate and silicate phases favor crustal source for the microdiamond formation. Here we interpret that the volume of Indian crustal slice have been subducted to diamond stability field and tectonically bounce back on the surface by buoyancy driven force.

The geochemistry of eclogites and garnet-amphibolites from the Tso-Morari region, Ladakh has also been investigated to characterize their protoliths on the basis of immobile elements, especially trace elements including REE. The eclogites and garnet-amphibolites have shown coherent compositions, except for the UHP metamorphic minerals being preserved in eclogites. Compositionally, the metabasites range from 'depleted' to 'enriched', and span from within-plate basalts (WPB) to MORB fields, and match with various enriched or 'transitional' MORB types (e.g., on

Ti-Zr-Y and Nb-Zr-Y ternary plots). Isotopically they have Sr_i ratio ~ 0.706 which is similar to some of the Ocean Island Basalt (OIB). The rocks under study suggest that the enriched components are probably derived by melting of a mantle source with an enriched OIB-type component rather than due to the crustal contamination. We propose a rift environment for their protoliths and relate to advanced intra-continental rift situation. Furthermore, our geochemical studies envisage an initial phase of plume activity (Cambrian or earlier) resulting in basaltic magma in the eclogitic layers at sub-lithospheric levels, wherein they were subjected to crystallization under ultra-high pressure conditions. At a later stage the reactivation of faults (probably during Permo-Triassic times) acted as channels for the emplacement of high pressure rocks in the continental crust. Subsequently, the ultra-high pressure rocks got re-equilibrated as amphibolites, with some remaining as relict eclogites, which later got exposed to the surface during various phases of the Himalayan uplift.

1.2 SUB PROJECT

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, T.N. Jowhar, Rajesh Sharma and D. R. Rao)

X-ray Diffraction studies have been carried on more than 270 samples from the Himalayan Granitoids for structural state determination, identification and melt temperature determinations. The study indicates that the structural state transformation in the alkali feldspars are due to post-crystallization deformation i.e. the Tertiary Himalayan event is responsible for the inversion of monoclinic symmetry (Orthoclase) to triclinic symmetry (Microcline) in the alkali feldspars of the Granitoids in space and time, quite later than their crystallization from a melt. This regional event has also affected the earlier events and structural elements in the macro and micro scales.

The studies on the complex fluids in the granitic systems in space and time in the Himalayan terrain indicates that the tungsten (W) is more compatible with the fluorine (F) bearing systems, while the tin (Sn) is more compatible with the chlorine (Cl) bearing systems, and this model is applied in search of new mineralized zones in the Garhwal & Kumaun Lesser Himalaya. The field study in Bungidhar-Dudhatoli-Jaurashi-Baijnath-Kapkot-Berinag in the Garhwal and Kumaun Himalaya indicates a definite relationship of mineralization with fluids. Some new locations for graphite, polymetallic sulphides, besides Sn and W are reported. The field study further confirmed that the Berinag Formation in its type area is not a thrust but a normal sequence above the Carbonates. The geochemical studies of crystallines from Dudhatoli (Garhwal Himalaya) were also carried out partly for some rare metals (work in progress).

The petrographic and mineralogical studies carried out on Gangotri Granite and Higher Himalayan Crystallines show that they contain quartz, plagioclase, K-feldspar, muscovite and tourmaline. K-feldspar is microcline microperthite and show cross-hatched twinning. Tourmaline contains inclusions of plagioclase, apatite and monazite. EPMA data on tourmaline, K-feldspar, plagioclase, biotite, muscovite and garnet was obtained on few samples from the Gangotri Granite and Higher Himalayan Crystallines by utilizing Cameca SX50 Elecrtron Probe Micro Analyser at Geological Survey of India, Faridabad. EPMA analysis of tourmaline from four samples of Gangotri Granite was done. Classification of tourmaline was done using program by Yavuz (2002). All the analysed tourmaline belong to Alkali Group and are Schorl. Aluminum in T sites varies from 0.013 to 0.202, In Y sites, Al varies from 0.186 to 0.491, Mg from 0.037 to 0.684, Fe^{2+} from 1.639 to 2.218, Mn from 0.000 to 0.041 and Ti from 0.049 to 0.171. In X sites Na varies from 0.619 to 0.777 and (Na + Ca + K) from 0.645 to 0.831. These tourmalines are zoned and from core to rim Mg decreases, whereas Fe^{2+}, Ti, Mn and Ca increase. There is a negative correlation between Mg and Fe^{2+}. Plagioclases are rich in albite component, X_{AB} varies from 0.934 to 0.984 and X_{AN} varies from 0.014 to 0.058. In K-feldspar (microcline-microperthite), X_{OR} varies from 0.928 to 0.975 and X_{AB} varies from 0.025 to 0.072. Temperature estimates were also done for the Gangorti Granite using two feldspar thermometry and plagioclase-muscovite geothermometer.

The geochemical and fluid inclusion studies of the granitoid rocks from the central part of Askot Crystallines, Kumaun were carried out in order to understand their origin. The studies show that the rocks in general have granodiorite to adamellite composition, and show geochemical evidence of magmatic origin. Their fluid inclusion studies have suggested four types of inclusions. The early inclusions include vapour-rich biphase aqueous inclusions, and liquid-rich biphase saline aqueous inclusions, which show primary features, and are interpreted to be trapped during the initial crystallization of the granitic magmas. The late inclusions include the monophase carbonic inclusions and carbonic-aqueous inclusions and are considered to be of primary to secondary origin. The rocks also commonly show geochemical attributes of orogenic magmatism, and plot in the field of post-collision volcanic arc field, showing characteristic negative anomalies for Nb and Ti. From the studies carried out, it is suggested that, the rocks are derived from the mafic/intermediate magmatic products formed above subduction slabs of oceanic lithosphere or those underplated or subcreted at the base of the crust during subduction along the continental margin.

The study of barite mineralization in the Outer Lesser Himalaya between the Giri and Ganga valleys indicates that the Barite in the Proterozoic siliciclastic Nagthat Formation is basically stratiform which during Tertiary Himalayan Orogeny got remobilized to yield secondary type in the adjacent rocks. The source for barium is the tuffaceous rock in the underlying Chandpur Formation in the area. Even there are pebbles and clasts of barite in the rocks overlying the Nagthat Formation i.e. Blaini Formation, which are also deformed in nature.

The fluid inclusion data for the successive stages of limestone, dolomite, magnesite and sulphide-bearing quartz veins in Proterozoic carbonate rocks of the Lesser Himalaya show that the subsurface fluids were H_2O–NaCl–KCl ± $MgCl_2$ ± $CaCl_2$, and showed successive increase in salinity and temperature. The salinity of the pore fluid during limestone diagenesis was in the range of ~7.5–15 eq wt.% NaCl and the magnesite-forming fluids had a salinity of about 9 to 19 eq wt.% NaCl. This progressive rise in salinity is attributed to a more saline fluid in the deeper zones. The inverse relation between homogenization temperatures and final melting temperatures suggests mixing of the fluids during diagenesis, and highly depleted $\delta^{18}O$ values rule out participation of magmatic fluid in the mixing. A late stage carbonic fluid is linked with talc formation. The low temperature of sulphide-forming epigenetic solutions, as obtained from fluid inclusions, is also substantiated by the chemical data from these sulphides. $\delta^{34}S$ values in galena infer that magmatic sulphur was probably not involved, and the sulphur of the galena is derived from an isotopically heavy source.

The study of talc deposits in the Deoban Formation of Inner Kumaun Lesser Himalaya shows that they occur as fine grained fibrous aggregates, restricted to small irregular patches or pockets within the magnesite. The assemblage magnesite+silica+talc indicate equilibrium conditions. Fluid inclusion studies suggest talc formation at very low X_{CO2}. A peak temperature of 240 to 260°C and pressure of 2.2 Kbar have been inferred from fluid inclusion studies of talc-magnesite assemblage.

Work on understanding the propagation of uncertainties in geothermobarometry was also initiated. Assignment of uncertainties to P-T estimates is very important, because these uncertainties have significant effect on the confidence of a tectonic interpretation. It is, therefore, necessary to perform and report error propagation calculations while providing P-T estimates, as without the uncertainty estimates, the results of the P-T calculations are not complete. Sources of uncertainties and propagation of these uncertainties in geothermobarometry were reviewed. Four basic sources of uncertainty, are disequilibrium effects, calibration uncertainties, analytical uncertainties and solution modelling. The concept of error propagation is described in general and methods of error propagation, specifically, Monte Carlo Method and High-Precision Relative Thermobarometry (ΔPT) approach are discussed and reviewed. It is concluded that the Numerical error propagation by Roddick, 1987 (Geochim. Cosmochim. Acta, 51, 2129-2135) is better than the other techniques discussed as it can be applied to complex problems of geothermobarometry and is faster and more informative and can also test the fulfillment of assumptions and validity of error estimates.

1.3 SUB PROJECT

Study of frontal and oblique ramps in the Western Himalaya.

(A.K. Dubey, Keser Singh, and R.J. Perumal)

In sharp contrast to the commonly observed fact of thrust tectonics, younger hanging wall rocks (i.e. Vaikrita Group; age: Late Mesoproterozoic to Early Neoproterozoic) lie above the older footwall rocks (i.e. Munsiari Formation; age: Paleoproterozoic) along the Vaikrita Thrust in the Higher Himalaya. The phenomenon is explained by an inversion tectonics based model where normal faulting and metamorphism was followed by thrusting characterized by displacement amount less than the displacement during the early normal faulting. The present day hanging wall tilt towards north may have been caused by a later thrust initiated as piggy back sequence accompanied by folding and Himalayan metamorphism.

A model to explain the occurrence of the younger high-grade rocks on the thrust hanging wall is presented in Figure 1. The first stage (Fig. 1a) represents the initial disposition of rocks and initiation of normal listric faults during the pre-Himalayan tensional regime in the region (i.e. Precambrian until just before the Tertiary compressional phase; Bhat, 1987). The top gray bed is a reference horizon to understand the subsequent displacement patterns along the thrusts. Faults 1 and 2 represent the present day Vaikrita and Munsiari thrusts respectively. The normal faulting, which took place during the tensional regime led to anticlockwise rotation of the hanging wall rocks along the horizontal axes and tilting of the rocks towards the foreland (Fig. 1b). The dip of the fault is likely to be steeper towards the Indus Suture, which forms the main axial zone of the tensional stress (Bhat, 1987). Consequently, the northern fault shows a greater dip and a greater normal fault displacement. The hanging wall rocks reach a deeper crustal level and suffer a higher grade of metamorphism. Deposition of fresh sediments in the rift basin and subsequent metamorphism took place during the subsidence caused by normal faulting. At the onset of Tertiary compressional phase of the Himalayan orogeny, the early normal faults reactivated as thrust faults (Fig. 1c) (Dubey and Bhat, 1986; Dubey, 2004). The steeper dip of Fault 1 led to an early thrust locking, prior to reaching the null point (Williams et al., 1989) thereby allowing the higher grade younger rocks (i.e. Vaikrita) to rest on the thrust hanging wall. The structure indicates that the normal fault displacement along the Vaikrita Thrust was of a greater magnitude as compared to the subsequent thrust displacement. However, it is to be noted that the amount of thrusting during the inversion tectonics may vary along the strike of Fault 1 and it is possible that the younger hanging wall rocks may not occur all along the length of the Vaikrita Thrust. A larger thrust displacement is envisaged along the Munsiari Thrust (Fault 2). This is also evidenced by the fact that the Munsiari rocks at several places are in contact with the Berinag Formation (Valdiya, 1980), which is regarded as of similar age (1800 ± 13Ma, $^{207}Pb/^{208}Pb$, single zircon ages for Rampur metabasaltic rocks; Miller et al., 2000), along the Munsiari Thrust. The initiation of a new thrust in the southern direction (Fault 3, Ramgarh Thrust; Fig. 1c) and subsequent development (Fig. 1d) led to clockwise rotation and tilting of the hanging wall rocks in the dip direction of the thrusts.

The orientation of the layering shown in Figure 1 is unlikely to be preserved during the Tertiary metamorphism. Since folding is concomitant with the Himalayan metamorphism, the resulting fold styles do not conform to the expected fold patterns that are characteristic of this particular geometry (e.g. Dubey and Bhakuni, 1998). The final geometry will also be modified by the development of subsequent thrusts, back thrusts, pop-up structures and fold patterns.

The understanding of the tectonic and metamorphic evolution of the southern border of HHC of Zanskar Himalaya is very important on account of, 1) Tethyan rocks are also exposed along its southern border, 2) tectonic and metamorphic transition between HHC and Chamba/Kashmir succession still remains poorly constrained, and 3) Lesser Himalayan rocks exposed in the Chenab valley and their relation with the HHC is yet to be explored. The HHC

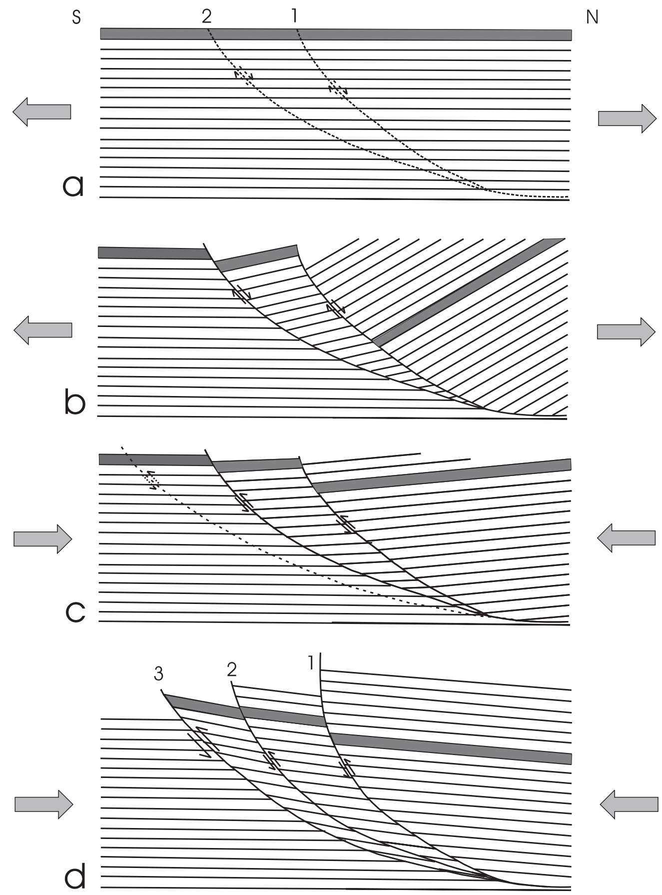

Fig.1 A simplifed mode for structural evolution of a part of the High Himalaya illustrating occurrence of younger rocks on the thrust hanging wall and older rocks in the footwall.

exposed south of Kishtwar window along the Chenab valley are studied and a tectonic contact with the underlying Lesser Himalayan rocks is interpreted as the MCT. The new tectonic interpretation is not in line with the existing views, which demarcates the MCT around the Kishtwar Window. Structurally up the HHC has another contact with the Tethyan sequence, this contact is again in the south of the HHC. The biotite schist of the HHC is in tectonic contact with the Bhaderwah or Chamba Formation of the Tethyan succession and is observed along the Doda-Bhaderwah section. Similar observations are made along the Kishtwar- Marbel Pass section, where again biotite schist of the HHC is tectonically overlain by the Tanol Formation (=Chamba Formation) of Kashmir nappe. The tectonic contacts at the base of Tethyan succession with the underlying HHC indicate that both Chamba and Kashmir nappes have translated southward along The Chamba and Chattru Thrusts respectively. The extension of the MCT both towards NE and SW of this valley is interpreted as concealed below the Tethyan rocks of Chamba and Kashmir nappes, since these nappes were developed later than the MCT. The recognition of a major tectonic break, commonly described as Trans Himadri Fault/

Tethyan Thrust/Zanskar Shear Zone, along the northern side of the Tethys Himalaya with the HHC is an established fact. It supports the present contention of a tectonic break between the Chamba and Kashmir nappes. The crystallines exposed in the Kulu valley is traced further northward and a tectonic contact is marked with the Tethyan rocks of the Chamba nappe. More data of adjoining areas is required to workout the geometry of this tectonic contact.

The study of Oblique and Frontal Ramps of Dehra Dun Re-entrant, NW Lesser Himalaya had identified cross strike discontinuity (CSD) in the centre of Dun valley, to demonstrate this structural feature. Some TL/OSL samples have been collected for dating. In addition, conjugate fractures were studied and recorded their orientation along the CSD. All the above data are being interpreted and various plots and diagrams are prepared. Based on the orientation distributions of AMS fabrics, the CSD can be divided as 4 segments as north, central, south and farthest south. The northern and central segment show simple shear dominated transtentional fabric, whilst south and farthest south segments show pure shear dominated transpression. Thus, the structural style of the CSD along its strike i.e. from north to south varies considerably. Further, the stress analysis of conjugate fractures along and across the CSD suggest bimodal stress distribution compatible with the AMS fabric.

Mapping had been carried out for the co-seismic secondary ground deformation related to the October 8, 2005 Kashmir earthquake event in the Indian side viz., (i) Titwal-Tangdhar, (ii) Baramulla-Uri-Chamkot, (iii) Punch-Rajouri and (iv) Jammu-Sialkot sections. The field study demonstrates that the October event mainly generated the liquefaction features related lateral spreads and sand blows with numerous rock falls. No surface ruptures related to the causative fault was observed except the rock falls along it. The lateral spread related ground fractures were carefully studied and the displacement measured for a clue to the latest local tectonic signature pertaining to this earthquake. The ground fractures appeared to have a direct link with hidden causative subsurface active faulting related to this earthquake. Also evidence was obtained to associate the process of surface cracking with the major tectonics. Stress analysis was performed to reconstruct the principle compressive stress direction through the orientation of ground fractures for the studied sections (Fig. 2). The stress analysis yielded WNW-ESE contrasting compressive stress direction near the epicentral areas, which is against the regional convergence direction of the Indian plate. While away from the epicentral areas, such as Uri and Jammu, sections yielded NNE-SSW parallels to the regional convergence direction of the Indian plate. The shortening directions WNW-ESE near the epicentral area (i.e. Muzaffarabad) fits well with N-S

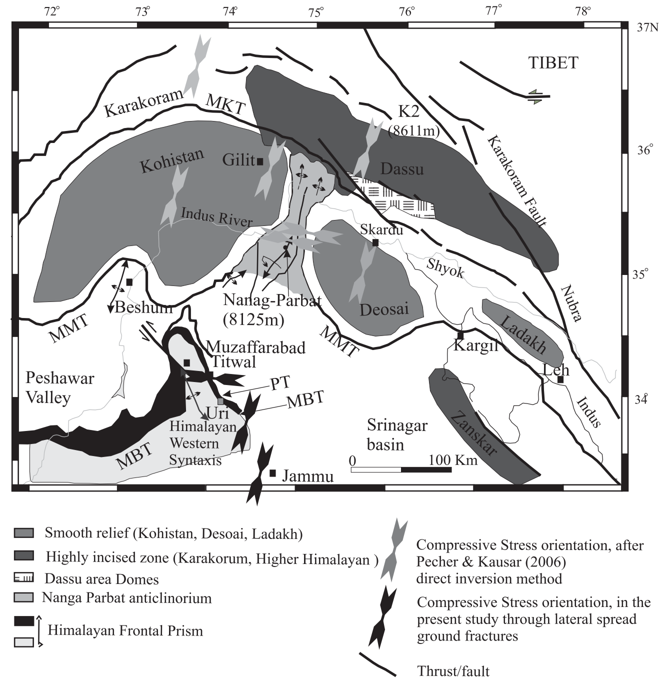

Fig. 2. A simplified tectonic map of western termination of the Himalaya ranges in North West India and Northern Pakistan. Principle compressive directions are shown in double arrows and draped on the map.

trending Muzaffarabad anticline. The documented shortening direction through ground fracture is similar to the Nanga Parbat anticline region reported earlier (Bossart *et al.* 1988) as well as recently by Pecher and Kausar (2006). The reconstruction of local tectonic stress using lateral spread ground fractures obtained in the present study is probably first of its kind.

2. BASIN EVOLUTION

2.1 SUB PROJECT

Evaluation of bio-event stratigraphy in the Cambro-Ordovician succession of Zanskar-Spiti Himalaya and buildup of reproducible palaeontolological database for the Lower Palaeozoic succession of Tethyan Himalayan regions.

(S.K. Parcha)

Stratigraphic significance of Ichnofossils

The ichnofossils were studied from the Early Cambrian successions of the Zanskar region and are of a significant stratigraphic importance as no body fossils of this age have been reported from this region so far. The body fossils recorded from the overlying beds is mainly of the middle

Middle Cambrian age. In the present study two ichnofaunal assemblage zones were identified. These zones occur much below the trilobites bearing horizons, though few ichnofossils of these assemblage zones extends up to the horizons rich in trilobite fauna. The recorded ichnofauna represents resting as well as grazing traces along with trails mostly preserved in sediment-water interface boundary of intercalated shale, siltstone and sandstone beds. It is observed that the preservation of ichnofossils is mostly controlled by the characteristics of the sedimentary matrix. The presence of ichnofossils of arthropod origin and in particular of trilobites lie within the lower part of the Karsha Formation is important for determining the age of these horizons.

Ichnofacies

Two ichnofacies were identified in the Purne-Phuktal and Kurgiakh-Surichun La sections. In the lower part, the ichnofaunal community is dominated by the *Skolithos* ichnofacies. In stratigraphic up-section, the *Skolithos* ichnofacies is progressively followed by the ichnofaunal elements of the *Cruziana-Skolithos* ichnofacies. The transitional zone of the *Cruziana-Skolithos* ichnofacies do contain a reasonably wide range of ichnogenera dominated by the complex burrow patterns along with the resting and grazing traces of deposit feeders. It has been noticed that a significant number of arthopod crawling traces along with the trilobite scratch marks and of unknown affinities are equally abundant (Fig. 3).

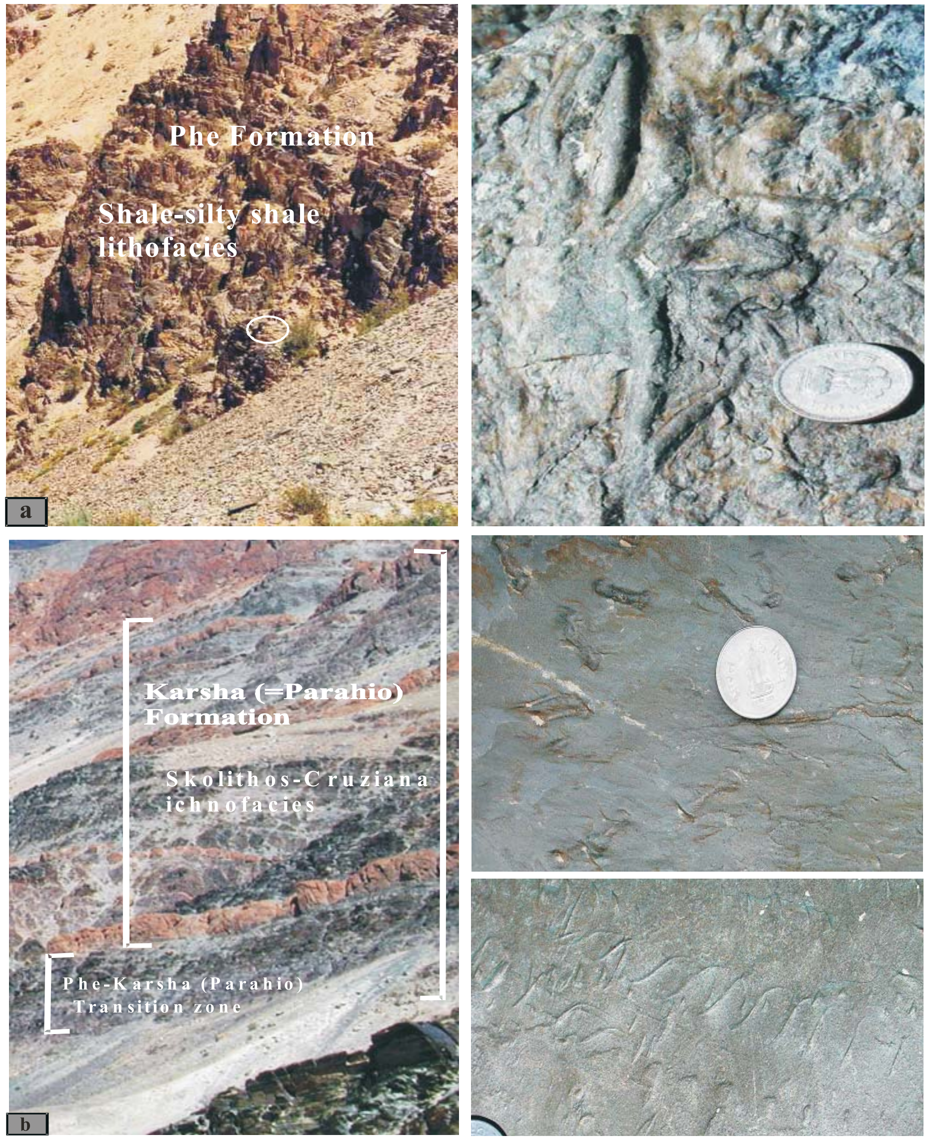

Fig. 3. Ichnofossils from the Phe and Karsha formations of the Zanskar Region of Ladakh Himalaya

The increase in the ichnofaunal diversity along the Phe-Karsha transitional zone reveals abundance of oxygen and organic matter. This transition from low to high diversity is confined to only few tens of meters at the top part of the Phe Formation and within the basal part of the Karsha Formation. The preserved depth of bioturbation in recorded and studied sections revealed that the ichnofossil tiers are very shallow and restricted at the sediment-surface boundary only. No ichnofaunal elements of deeper tier are observed.

New Trilobite fauna from the Middle Cambrian succession of the Zanskar Himalaya

In the present investigation the Cambrian trilobite fauna was collected from the southeastern part of the Zanskar region of Ladakh Himalaya which includes both agnostid and polymerid trilobites. Besides this some new genera are identified from one of the sections, which indicate Middle Cambrian age.

Morphometric analysis of Trilobites

On the basis of morphometric analysis of trilobite genera it is found that the misclassification rates in CART (Coefficient and Regression Tree) and cluster analysis are comparable, while it is reduced substantially by the use of (RF) Random Forests.

2.2 SUB PROJECT

Biostratigraphic evaluation of selected PC/C (Precambrian/Cambrian) and P/T (Permian/ Triassic) boundary sections of NW Himalaya.

(R.J. Azmi)

The study on the biostratigraphic evaluation of the Inner Carbonate Belt of the Kumaun-Garhwal Lesser Himalaya (Deoban-Gangolihat Belt) was extended this year to the Shali Belt of Himachal Lesser Himalaya. Reconnaissance sampling of each formation (total eight) of the Shali Group was done. The preliminary biostratigraphic results so far obtained (jointly with Dr. Deepak Joshi, SRF/WIHG) reveal the presence of abundant calcareous algae (*Girvanella*, *Renalcis*), agglutinated foraminifera (*Platysolenites*, *Glomospira*), numerous skeletal tubes and sclerites, and diversified organic walled microfossils (Fig. 4). Occurrence of these skeletal microfossils would suggest that the Shali Group encompasses the Precambrian–Cambrian (PC-C) boundary (542 Ma), like that of the well established Mussoorie Group (Blaini-Krol-Tal) of the Outer Carbonate Belt. Recently, based on the discovery of a typical earliest Cambrian Protoconodont assemblage from the Gangolihat Dolomite

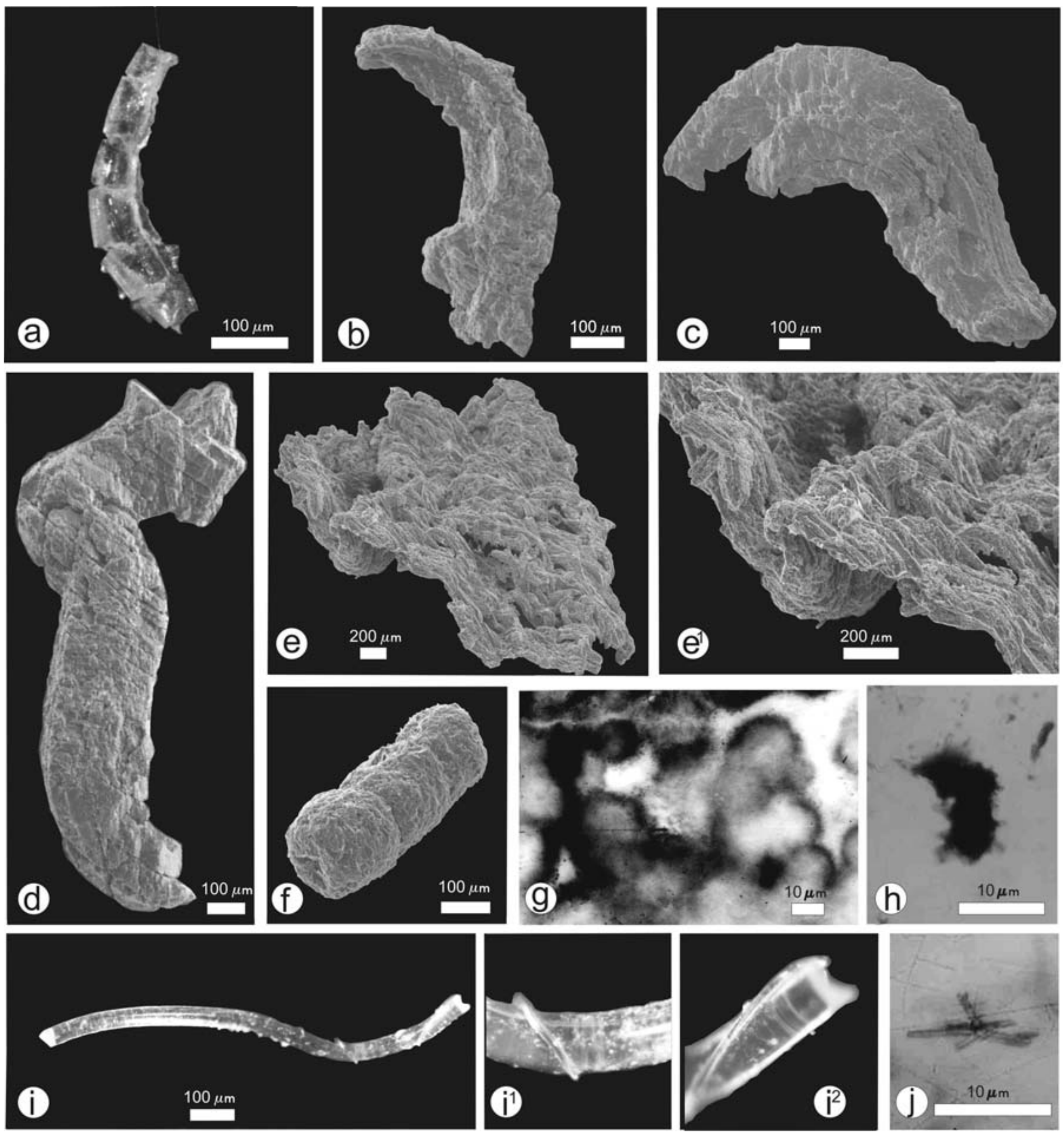

Fig. 4. Precambrian-Cambrian boundary interval microfossils from the Shali Group, Himachal Lesser Himalaya. **a-d** and **f**, small shelly fossils; **e**, **g** and **i**, calcareous algae; **h**, small acanthomorphic acritarch; **j**, sponge spicule.

PROGRESS IN RESEARCH PROJECTS

(Deoban Formation), this formation of Kumaun was chronostratigraphically equated with the Krol-Tal succession (Azmi & Paul 2004). Prior to this new result, the Deoban–Shali Inner Carbonates were generally considered being of Riphean (Mesoproterozoic, ~1400 Ma) age based on several decades of work on stromatolites, that had the major bearing on the structural interpretations of the Lesser Himalayan stratigraphy. Another significant outcome of the present study is that it confirms a major hiatus of >1 Billion Years duration in the Shali Belt too, as was earlier suggested for the Kumaun-Garhwal Lesser Himalayan successions (Azmi & Paul 2004). Further, significance of this major hiatus is that it is present throughout the Lesser Himalaya, the Ganga Basin and the Vindhyan Basin of the Indian Peninsula. Everywhere, this hiatus separates the low grade metamorphics (Damtha/ Jaunsar/Bahraich/Bijawar Group of Paleoproterozoic age) from the overlying carbonate dominating platformal sediments (Shali/Deoban/ Gangolihat/ Mussoorie/ Semri Group, all beginning from the Early Vendian ~635 Ma). The present study thus suggests that more than half of the Proterozoic Eon (1958 Ma duration) is missing from the sedimentary basins of the Lesser Himalaya and the central Indian Peninsula. This revelation would be helpful in constraining the early evolutionary history of the sedimentary basins of India, including the Himalaya.

2.3 SUB PROJECT

The Mesoproterozoic and Neoproterozoic microbial carbonate sedimentation and carbon isotope stratigraphy of the Bhagirathi valley, Uttaranchal Lesser Himalaya.

(V.C. Tewari)

Field work was carried out in the Bhagirathi valley, Garhwal Lesser Himalaya in September 2005. Following areas and sections were systematically lithologged and samples were collected for laboratory studies.

Dharasu – Lambgaon- Pratap Nagar section

This section is characterized by cherty – intraclastic brecciated bluish grey dolomite (equivalent of Deoban Limestone). About one thousand meter thick stromatolitic limestone is well exposed near Pratap Nagar. The stromatolite assemblage recorded include columnar forms (*Conophyton, Colonella columnaris*), branching forms (*Baicalia, Jurusania)* and long columns (*Gymnosolen* and *Minjaria*). Thinly laminated pink limestone bands and pink and green shales are found interbedded with grey limestone as facies variation. Oolitic limestone, fenestral fabric and oncolitic structures have been reported as well. The Berinag (Nagnithank) Quartzite is found tectonically overlying the limestone. The sedimentary structures like wave dominated ripple marks, large scale cross laminations, herring bone cross bedding, climbing ripple laminations, etc. are very well developed in the sandy units and indicate shallow marine depositional environment (tide dominated facies).

Shyalna – Bramakhal section

Vuggy, cherty, brecciated, fenestral limestone is well developed around the village Shyalna in Uttarkashi district. The limestone is also oolitic, intraclastic and stromatolitic (mostly stratified forms). It continues towards Dunda on Dharasu – Uttarkashi road section. Berinag and Rautgara quartzites are well developed on road section and show a variety of shallow marine sedimentary structures.

Tehri – Chamba road section

A well exposed Neoproterozoic Cryogenian diamictite and Ediacaran dolomite was lithologged. Large quartz clasts are found in the glacial diamictite units. Finely laminated purple – green shales are found associated with grey quartzite units overlying the diamictite units. Juvenile *Beltanelliformis* (possible Ediacaran forms) are also found in shales. This sequence is repeated many times and the sequence boundaries have been recognized. A global correlation of the Cryogenian and Ediacaran stratigraphy is shown in Figure 5.

Pokhri – Nagnath road section

Cherty grey dolomite, brecciated dolomite, and stromatolitic dolomite is found along Pokhri – Nagnath road section. This dolomite is equivalent of the Lameri (Deoban) Limestone. The chert samples have been collected for the recovery of the microbiota. The microbial buildups sketched in the field include: *Colonella columnaris, Kussiella kussiensis, Jurusania sp., Gymnosolen sp.,* suggesting Mesoproterozoic to Neoproterozoic age.

Petrographic thin sections and thick sections for microbiota were prepared and studied in detail for microfacies, diagenesis, miro fabric and microstructures of the stromatolite laminae. The cherty oolitic lomestone shows a variety of oolitic structures such as concentric, concentric cum radial, radial and deformed moon shaped oolites. Important microfacies identified are micrite, dolosparite, oomicrite, oodolosparite, various diagenetic stages of replacement have been observed. X-ray diffraction of limestone and dolomite has shown the presence of calcite, dolomite, quartz, and siderite. Chemical analysis of some selected samples was done for elemental analysis. Microstructures of stromatolite *Conophyton cylindricus* shows well developed axial zone. Petrographic thick sections of cherts have yielded filamentous and circular cyanobacterial remains and are being identified. Lithologs showing facies variations, sequence boundaries, sedimentary structures, and microbial buildups etc.were finalized. Depositional environment is shallow marine for the carbonates and the sandy units within carbonate units.

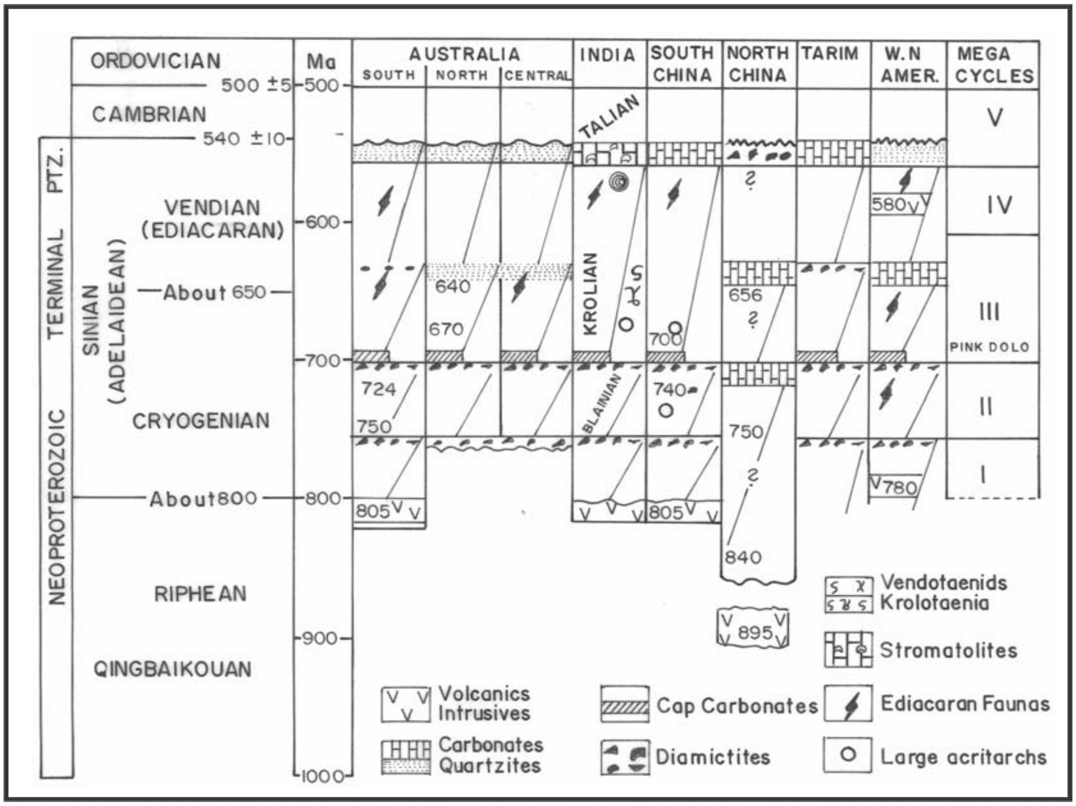

Fig. 5. Global correlation of the cryogenian and Ediacaran stratigraphy.

2.4 SUB PROJECT

Late Proterozoic-Early Cambrian Palaeobiology of Lesser Himalayan sequence of Himachal-Uttaranchal Himalaya with reference to evolution of life and its global relevance.

(Meera Tiwari)

It is well known that trace fossils present in the Neoproterozoic-Cambrian boundary sections in the worldwide localities are generally well-preserved and well- diversified, and the boundary is defined by the first appearance of the trace fossil, *Treptichnus pedum*. Recent studies in the Mussoorie hills of Uttaranchal have revealed several trace fossil-bearing sections, especially in the Arenaceous sandstone-shale beds of the Upper Tal quartzite member. The best preserved section is along the Mussoorie–Dhanaulti section. The Tal Formation is a thick stratigraphic unit but most fossils are facies dependent. The present assemblage of trace fossils is found in the form of burrows, tracks and trails along with the scratch marks. The trails occur as grooves and ridges with positive epirelief on jointed and fractured micaceous sandstone, which makes it difficult to collect the complete specimen. Sometimes these traces are found in a clustered, pit- like forms. It is difficult to assign whether these impressions represent negative epirelief or hyporelief. The traces are identified mainly as *Monomorphichnus* isp, *Dimorphichnus* isp., *Dimorphichnus* isp A, *Diplichnites* isp A, *Planolites* isp., *Skolithos* isp, *Merostomichnites* isp, and ?*Neonerites* isp (Fig. 6).

Mostly trace fossils produced by arthropods occur at the horizon at or shortly below these containing trilobites. It has been noticed that the Neoproterozoic trace fossils are small, simple, unbranched and were made close to the sediment-water interface, whereas early Cambrian trace fossils are well-diversified traces of bilaterian animals, showing morphological diversity and complexity. Trace fossils like *Monomorphichnus, Planolites, Skolithos, Diplichnites* and Dimorphichnus are known from the other early Cambrian successions of the Tethyan Himalayan sediments of Kashmir and Spiti. In the Zanskar region, their occurrence is below the trilobite-bearing horizons. *Monomorphichnus* occurs close to the Neoproterozoic-Cambrian boundary in many sections. In the Neoproterozoic-Cambrian boundary GSSP in Newfoundland, *Monomorphichnus* first appears 2.5 m above the base of the *Treptichnus pedum* zone and is used along with *Treptichnus pedum* in defining the base of the basal Cambrian Stage. In the Lesser Himalayan sequence, earlier

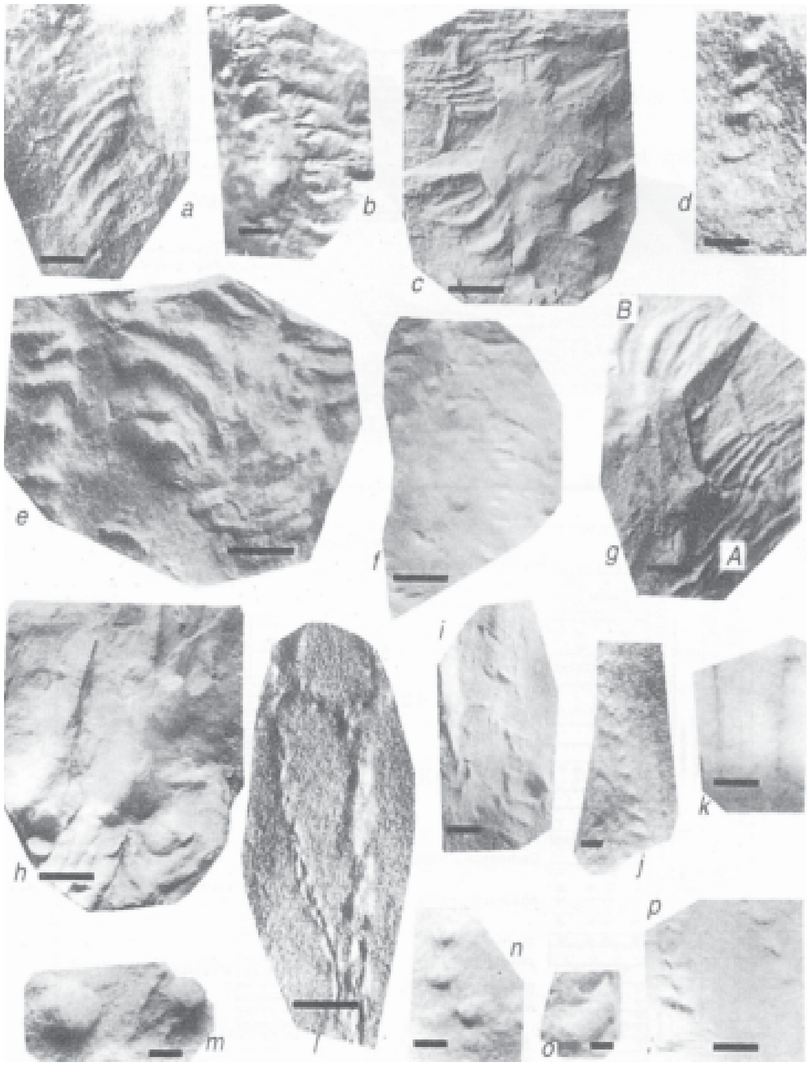

Fig. 6. a,c.g (A), Monomorphichnus isp.; **b**, Merostomichnites isp.; **d**, Ichnogenus A; **e**, Dimorphichnus isp.; **f,g (B)**, **i**, Scratch marks; **h**, Planolites isp., **j,p**, Diplichnites isp. A; **k**, Ichnogenus B; **l**, ?Neonereites isp.; **m,n**, Skolithos isp.; **o**, Planolites B; bar= 1 cm.

worker assigned a Lower Cambrian age to the Arenaceous member of the Lower Tal Formation, on the basis of trace fossil occurrence. Trace fossils like *Skolithos*, making pipe rock facies are abundant in the Arenaceous member of Tal Formation and is common in Lower Cambrian of Scotland and Sweden. A diverse assemblage of brachiopods, microgastropods, hyolithids and poriferids of Lower Cambrian affinity was reported from the Calcareous member. Further report of a rich assemblage of brachiopod from shale member of Upper Tal Formation suggested Atdabanian (+Qiongzhusian/ Chiungchussu) stages of the Early Cambrian to the Upper Tal Formation. The beds that overlie and underlie the brachiopod horizon exhibit fairly well preserved trace fossils, including small vertical burrows and trilobite fragments. The Lower quartzite member of the Upper Tal exposed in Sirmur district, Himachal Pradesh also shows presence of *Palaeophycus* isp., *Skolithos* isp., and arthropod traces of Lower Cambrian affinity. It was observed that the trace fossils present in the Tal Formation show marked behavioral complexity and diversity and occur at various horizons, but distinct zones are not evident. The present finds of trace fossil assemblages can be correlated with other trace fossil assemblage of the Tethyan and Lesser Himalayan horizons, and hence are of stratigraphic significance. Due to scarcity of body fossils at this level, the present assemblage can be useful in identifying the complete early Cambrian succession in the Tal formation.

2.5 SUB PROJECT

Geochemical and sedimentological studies of Proterozoic clastic succession of Lesser Himalaya.

(S.K. Ghosh and R. Islam)

Studies were carried out in both Outer (OLHB)- and Inner (ILHB)- Lesser Himalayan sedimentary belts in regard to measuring of lithosection, lithofacies distribution, types of siliciclastic rocks, nature of pebbly conglomeratic bands, changes along sedimentary and basic volcanic contacts and geochemical character of the associated basics. Three litho sections were measured along *Sumari road* (Nagthat Fm., OLHB), *Bhugani –Khirsu road* (Nagthat Fm OLHB), *Kaliasaur-Rudrapryag* (Berinag Fm., ILHB). Seven lithofacies are indentified in these sections, namely – Granular/Gritty siliciclastic (GS), Coarse-grained siliciclastic (CGS), Medium-grained siliciclastic (MGS) and Interbedded medium- and fine- grained siliciclastic (IMFS), Fine-grained siliciclastic (FGS), and Shale facies (SH). From the present field studies it has been observed that the distribution of GS and CGS facies is especially concentrated in the east-west trending belt which lies north of the Tons Thrust.

From the petrographic point of view the siliciclastics of this belt can be divided into two types (i) siliciclastic- which has retained the sedimentary texture and suffered the diagenesis, and (ii) siliciclastic, which has lost the sedimentary texture and suffered the metamorphism, and named as *Meta-*

siliciclastic. The later one is very much widespread in the Inner Lesser Himalaya-Berinag Formations.

In the ILHB, a conspicuous occurrence of ~2 m thick conglomeratic band has been noticed that lies below the Berinag Formation. The conglomerate is constituted of 5-10 cm size meta-siliciclastic clast embedded in recrystallized quartz mosaic. Yet another interesting feature noticed in Kaliasaur area is a 2 m thick greyish green cherty band along the contact of siliciclastic and basic volcanics. Detailed study is in progress.

The volcanic rocks associated with sedimentary package appears to be syn-sedimentary in nature, (as stated by previous workers also), however cross cutting relationship is also observed in Bhimtal- Bhowali section of Outer Lesser Himalayan Belt (OLHB). These volcanic rocks of Outer and Inner Lesser Himalayan belts are essentially associated with arenaceous rocks, which are of purple pink colour (IMFS facies) siliciclastic rocks and occur in a regional scale (from Kali in Kumaun to Sundernagar in Beas valley). This may indicate shallow marine beach/shore face environment prevailing during the emplacement of basic volcanic rocks. Interestingly the sandstones are having distinctly well rounded quartz detritals which are bimodal (fine and coarse) and well sorted in their size fraction. Further the basic volcanic rocks which have discordant relationship with siliciclastic rocks are essentially greyish white in colour and recrystallized (meta-siliciclastic) in nature. This may infer there may be two phases of volcanic activity during the Proterozoic time.

In general, it is not always possible to clarify the relationship between dykes and associated volcanic flows. Many continental mafic volcanic suites have no feeder dykes. In other words dykes and lava flows are not always contemporaneous. In case of Nagthat volcanic rocks the spatial correspondence is very clear, but we can't precisely define the age relationship between the two. In terms of REE and multi element patterns the dykes and lava flows have very close chemical similarities, with most of the distinct anomalies being reflected by the dykes and flows. This may indicate that both must have followed a similar petrogenetic evolution and may be derived from a similar mantle source.

In the Inner Lesser Himalayan Belt (ILHB) a doleritic dyke is associated with Sor slates at Masangarh. They show discordant relationship with country rocks. The rocks are sub-alkalic in nature. Relationship between TiO_2 and Zr indicate fractionation. In general, dykes are distinctly enriched in incompatible elements and LREE relative to primitive mantle, but continental signature is marked by negative Nb, Sr, P and Ti anomalies in mantle normalized spider diagram.

2.6 SUB PROJECT

Evolution of the Himalayan Foreland Basin.

(Rohtash Kumar, S.K. Ghosh, Kishor Kumar, B.N. Tiwari, N. Siva Siddaiah, R. Islam and S.J. Sangode)

The studies are focused on the upper part of the Subathu Formation in four localities, namely: Kaushalya Nala section in Kalka area; Kumarhatti area; Saharan area and Bagthan area. Kaushalya Nala section has *Nummulites* bearing dark grey shale and lensoid bodies of fine dark grey- fine sandstone and limestone in the lower part with increasing percentage till limestone gains percentage increasing in the upper part. This succession passes upward into red mudstone referred to as "passage bed". The overlying succession has narrow deep incised channel fill bound by red pedogenic siltstone with trace fossils and concretions in mature soil profile. Various litho-facies identified in the 270 m thick Subathu-Dagshai passage in the Kaushalya Nala are grouped broadly into four distinct facies assemblage having different depositional setting (Fig. 7).

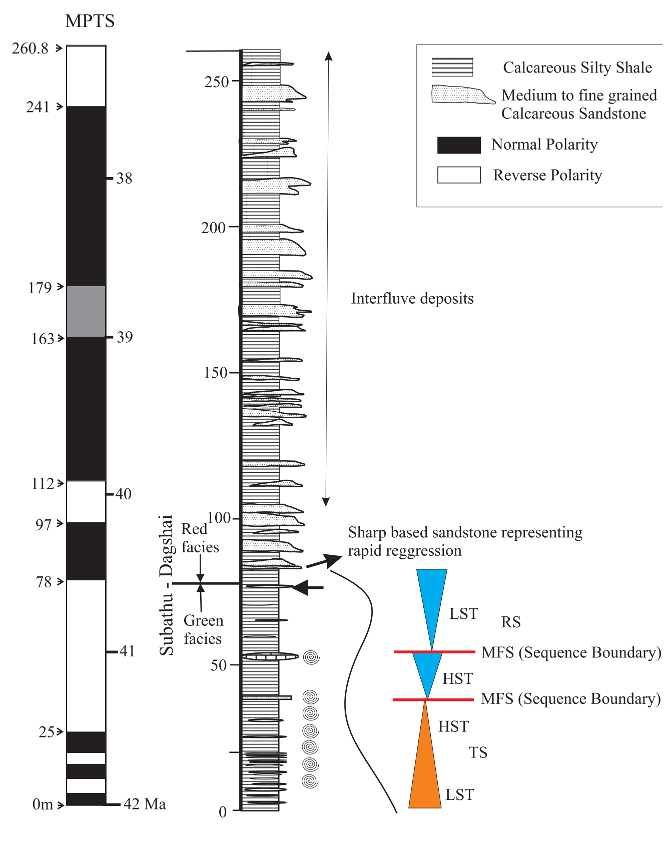

Fig. 7. Magnetic Polarity Time Scale (MPTS) with ages in Ma and the thickness in meters, lthology and the inferred sea level changes for the Kaushalya Nala section. LST: Low stand, HST: High stand, MFS: Main flooding surface, TS: Transgressive surface, RS: Regressive Surface.

PROGRESS IN RESEARCH PROJECTS

The *Facies Assemblage 'A'* is 77m thick and comprises dark grey to grey shale with sandstone and limestone lenses. This assemblage has large foraminifers. This facies assemblage is further divided into three sub-facies assemblages based on sandstone and limestone content, and fossil recovery. The temporal facies arrangement shows two maximum flooding surfaces representing both high and low stand system track. The *Facies Assemblage 'B'* is characterised by grey to red shale transition and laterally have variable thickness from 7 m to more than 20 m. Red shale shows oxidation and in place vertebrate fossils are also reported. This facies assemblage represents a major regression phase. The *Facies Assemblage 'C'* is thickly bedded whitish grey, compact sandstone with intervening pedogenic mudstone. Thickness of this assemblage is also variable from 20 m to 30 m. The base of this sandstone is sharp and has gutter cast. This facies assemblage represents rapid regression phase. The *Facies Assemblage 'D'* consists of ribbon sandstone bounded by thick paleosol horizons. A total of 33 fining upward cycles are observed in the 156 m thick succession. This succession represents inter-fluve deposits. In this succession, no marine influx is observed after facies assemblage B. This represents continuous uplift after ~40 Ma.

Based on magnetostratigraphic and rock magnetic studies of the Subathu-Dagshai marine to continental transition succession exposed along the Koshaliya Nala section, significant changes are documented for magnetic polarity, magnetic fabric, mineralogy and sedimentation rate. A total of 11 magnetic polarity events are encountered. Out of this five reversals are assigned the ages of 41.257 Ma, 40.13 Ma, 39.631 Ma, 39.552 Ma and 38.426 Ma with a scope for refinement with further detailed study. These ages have estimated the sediment accumulation rates of ~5 cm/ka for Subathu, ~ 6 cm/ka around the passage beds and ~ 9 cm/ka for Dagshai sequence with a peak of 19 cm/ka at *ca* 39.6 Ma. A sharp change in the magnetic mineralogy from ferrimagnetic (anoxic) minerals to antiferromagnetic (oxic) minerals is noted at ~30 m (~40.75 Ma) below the 'red shale' zone (*i.e.*, the uppermost part of Subathu Formation/'Passage Beds' at 40-40.5 Ma)'. Magnetic fabrics infer fluctuations till ~ 41.25 Ma and streamlined paleoflow directions are observed only after ~39.5 Ma. Two high energy events are noted: a) at ~39.8 Ma with paleoflow reversal followed by high rate of sedimentation, and b) at ~39.15 Ma without much change in the paleoflow and rate of sedimentation. The former suggests a response to syn-orogenic folding/thrusting within the basin and the later depicts a response to major climatic shift and demands more detailed studies around these events. Our study indicates that the shallow marine, largely anoxic Subathu basin started receiving the continental input at least 500ka prior to the deposition of red (passage) beds. This indicates contrasting geomorphic conditions within the basin with growing continental morphology during this time.

The petrographic studies of Kaushalya nala section samples shows that the sandstones of the Facies Assemblage 'A' are in general greyish green, moderately indurated, medium-to fine grained, texturally sub-mature sublithic arenite. The detritals are mostly subangular to sub-rounded with few very well rounded clasts and are moderately sorted. Quartz constitutes the dominant component (~60%) and shows corrosive boundary with calcareous cement. Feldspars are rare; if at all present, they are altered into sericitic matrix. Rock fragments include mainly silty chert, calcareous shale, argillite and siltstone. Matrix is mainly clayey-chloritic and the cement includes micritic to macro-sparitic calcite and ferruginous at places. Glauconite, zircon and garnet are some of the common accessory minerals present. Facies Assemblage 'C' is essentially composed of white to off-white hard and compact silici-clastic rocks. Texturally and compositionally it is more mature. Compositionally it is quartz rich and grain sizewise it is coarser and well sorted. The grain contact is either sutured or concavo-convex type, which is not so common in the underlying Subathu sandstone. Feldspar is also rare in this sandstone. Rock fragments include mainly silty chert, chalcedonic chert, multi crystalline quartz aggregates, argillites and rare low grade metamorphics. The important feature of the sandstone is the siliceous cement, and overgrowth around quartz detritals, which is an uncommon feature in the Cenozoic sandstones of the Himalayan foreland basin. The other important point to be noted is that by seeing the roundness and sorting of the detrital population, it is rather difficult to envisaged it to be beach sandstone as it should have at least abundant well rounded to rounded detritals and well sorted framework. The Facies Assemblage D has brownish sandstone which is very much similar to Facies Assemblage A, but with change in percentage of quartz (>70%), presence of feldspar, calcareous and abundant ferruginous cements. Considering the preliminary petrographic study, it can be interpreted that sandstone detritals till Facies Assemblage C were derived from closely located sedimentary- metasedimentary source area. This is in close agreement with that of the findings of Srivastava and Casshyap (1983). But there remains a question about the siliciclastic nature of Facies Assemblage C as to why it is so different in terms of induration, thickness, colour, composition, particularly the siliceous cement and quartzose nature.

Geochemical studies of mud rocks of Lower Tertiary were carried out for their major, trace and rare earth elements. The majority of the samples are closer to the PAAS in major oxide content. A-CN-K triangular plot displays a normal weathering history. Kaushalya river section samples plot at the same region as PAAS, but much closer to the Al_2O_3 apex, with some samples ploting near CN point, which may be due to the higher concentration of Na. This higher content Na may have been derived from highly saline pore water within the mud rocks. The trace elements like Sc, V, Co, Ni and Ga show moderate to high depletion compared to the PAAS, suggesting poor supply from the mafic source. Chondrite normalized REE pattern exhibits enriched LREE relative to HREE along with a small variable Eu anomalies. Higher La/Yb ratio (avg. 12.0) suggesting slight depletion of HREE relative to PAAS, can be observed in Zr behaviour in PAAS normalized plot also. Overall chemical data suggest that these mud rocks are derived from highly acidic rocks and little contribution from the mafic source.

Siwalik Group: A Cyclostratigraphic attempt

The 2.7 km thick Siwalik succession along Ravi re-entrant consists of three Megacycles categorized on the basis of lithology.

Megacycle A constitutes sandstone-mudstone, Megacycle B constitutes conglomerate-sandstone-mudstone and Megacycle C consists of thickly bedded conglomerate. The section is constrained using magnetostratigraphy between 12.7 and 4.4 Ma. Megacycle A (12.77-8.39Ma) consists of alternation of thick grey multistory-multilateral sheet sandstone with easterly paleoflow and the intervening mudstone package between the grey sheet sandstone bodies consists of mudstone-paleosol bound buff single storey ribbon sandstone bodies with prominent southerly paleoflow. Lacustrine, crevasse and levee deposits accompany the buff sandstones. The grey sheet sandstone is interpreted as axial river deposits (ARD) and the mudstone-paleosol-buff sandstone is interpreted as alluvial slope deposits (ASD). The grey sheet sandstone bodies have an erosional basal contact with the underlying units and a gradational upper contact with the overlying mudstone package. The intervening mudstone-paleosol-buff sandstone package have a variable duration in the order of 80-560ka.

Megacycle B (8.39-5.71Ma) constitutes ARD and ASD alteration along with incorporation of gravelly channels and is overlying conformably on Megacycle A. Except for a drastic increase in grain size these mudstone-paleosol-gravelly channels show similar characters as the mudstone-paleosol-buff sandstone and hence form a part of the ASD.

Megacycle C (5.7 - 4.4Ma) consists of thickly bedded conglomerate with alteration of course-fine grain sizes. These are generally sheet bodies without discernable channel margins and lower and upper contacts.

The ARD in Mega Cycle A and B constituting thick grey multistorey facies are observed in the dated section from 12.7 Ma and 5.7 Ma till the first appearance of thickly bedded conglomerate. These thick grey multistoried bodies are associated with low mudstone content. The complex mosaic of the erosional surfaces in the multistorey-multilateral framework of the sandstones reflects poor preservation of individual storey signifying lack of accommodation space. The other interpretation is a relatively high discharge that could have promoted successive scouring at the expense of accumulation. Low accommodation is suggested by the close spacing and/or mosaic of erosional surfaces. An upward increase in preservation of channel storeys and decrease in storey thickness in the individual sandstones suggest overall controls by accommodation whereas the scouring of the storeys due to high discharge indicates climatic control. During channel establishment onto new areas the rivers incises the floodplains and started aggrading, whereas during high discharge periods, enlarged channels incised the underlying sand body itself and reworked the adjacent muds along the banks which were probably relatively thin and occured as mudclasts on the erosional surfaces. Under waning stage, major channels silted up and show ripples and parallel on top and a floodplain mud sheet may have developed laterally across its banks. Within the multistorey sandstone the topmost storeys have complete preservation of fining up cycle from large scale cross-stratification to ripple marks which signifies channel abandonment. Flume models, theoretical considerations and outcrop studies suggest that fluvial sheet sandstones are common in low-gradient settings during base level fall and early rise periods and indicate alternate expansion-contraction surface with respect to ASD.

The alternation of course-fine grain sizes of the conglomerate in Megacycle C corresponds to the progradation-retrogradation of the gravel front. The gravel front progradation corresponds with phases of tectonic quiescence, whereas retrogradation reflects (renewed) tectonic activity. As the creation of accommodation space due to subsidence stops the fans are forced to prograde into the basin in order to disperse their sediment while maintaining an equilibrium slope. Intervals of tectonic activity are recognized in stratigraphic section by vertical stacking of layers with coarse-fine grain-size fractions.

Two types of cycles are recognized: the tectonic cycles ($\approx 3^{rd}$ order 1 to 10 Ma depositional cycles; i.e., continental scale tectonism) and the climatic (Milankovitch) cycles as 4-5^{th} order with a periodicity of 0.1 to 0.5 Ma (may be local-episodic tectonics). The depositional cycles are long term tectonic processes giving rise to Megacycles, whereas the minor cycles are controlled primarily by short-period autocyclic sedimentary and/or tectono-climatic processes including channel switching and differential subsidence.

The attempt to interpret these fluvial deposits in terms of sequence stratigraphy is based on the patterns of associated changes widely recognized within the cyclic-stratigraphy and can be confidently applied in such successions but more understanding is warranted. Although it is beyond doubt that the cyclicity discerned was related to repeated base level changes which gave rise to the prominent cyclicity. The formation of sixteen cycles within the 12.77–5.71 Ma period suggests a short term tectono-climatic cyclicity superimposed on the long term Megacycles.

Deinothere material from Upper Dharmsala Formation

We have recorded *Prodeinotherium* (Proboscidea: Mammalia) from mid-Tertiary Dharmsala Group of Kangra valley and laid emphasis on its biochronological and palaeobiogeographical implications. It is a rare fossil of a large-bodied mammal from the Dharmsala Group of the Kangra valley of Himachal Pradesh and to go further is an isolated upper premolar of *Prodeinotherium,* a genus of an extinct proboscidean clade. The find represents the highest trophic level taxon known so far from the Dharmsala and coeval horizons, and is important in understanding the pre-Siwalik large mammals of the Himalayan region of India. The Dharmsala Group has previously yielded a rodent and a typical fish remains (Tiwari and Bhandari, 2004 and 2005). Earlier Tiwari et al. (1991) and Feist and Tiwari (1999) studied fairly diversified associated assemblage comprising aquatic elements like chara gyragonites, ostracods, fishes, crocodiles etc. The new record corroborates early Miocene age assigned earlier to the yielding horizons and extends the palaeogeographical expanse of *Prodeinotherium,* so far from early Miocene horizons of Pakistan, towards the east up to Kangra valley in Himachal Pradesh of India by ~400 km.

The following is the summary of description and comparison of the tooth and the related biochronological and palaeobiogeographical analyses:

(i) As per records today, Kangra valley was the easternmost abode of relatively less cursorial immigrant deinothere *Prodeinotherium*; all previous records of the genus are from across the Hazara-Kashmir Syntaxis. However record of younger, more evolved and cursorial form *Deinotherium* are known from far off places up to Nepal towards the east and Piram Island towards south in western India.

(ii) Conjecturally *Prodeinotherium* remained restricted to the basins proximal to coastal areas having closed forest, whereas better cursorial traits in *Deinotherium indicum* enabled them to inhabit far from coastal areas as well (e.g. *Deinotherium indicum* in Dang valley, Nepal). Presence of *Dasyatis* in the Dharmsala assemblage too apparently supports the 'proximal to coastal areas' contention.

(iii) Occurrence of *Prodeinotherium* of early Miocene age from basal horizons of the Upper Dharmsala Formation substantiates earlier age constraining on the basis of chara (Feist and Tiwari, 1999) and lends support to hypothesis arguing for revival of terrestrial vertebrate habitat with basic trophic levels (basic biomass + primary consumers) because of initiation of foreland basin (*sensu stricto;* due to regional thrusting) in early Miocene. Earlier coastal habitats of the Subathu Basin supporting terrestrial vertebrate community of multiple trophic levels in the region vanished because of eustatically driven forced regression in the middle Eocene (Tiwari 2005).

Palaeogeographic implications of a typical fish remains

Discovery of *Dasyatis* and *Enchodus* in the Upper Dharmsala Formation is atypical to the hitherto known early Miocene freshwater microfaunal assemblage. Earlier known microfaunal assemblage comprised cyprinids, chara gyragonites, thin-shelled ostracods, gastropods with latest addition of a molar and an incisor of an unnamed rodent and a premolar of *Deinotherium*. Reworked clusters of foraminiferal tests too have been recovered in modest numbers indicating that northerly extensions of underlying marine horizons were brought towards south along a regional thrust with initiation of thrusting on southern flank of the Himalaya in early Miocene and thus were part of provenance; we have made specific observations to say that the atypical fish remains have come from then cohabiting aquatic fauna and are not part of the reworked component from older marine horizons providing the clusters.

In the context of regional geological evolution these finds indicate that Dharmsala Basin, characterized by freshwater elements, was connected with marine realm through water channels; this connection was route for these anomalous marine elements to the basin. While this explains their occurrence with the associated typical freshwater Upper Dharmsala assemblage, it leads to infer that since the deposition of these yielding horizons in early Miocene substantial geographical reorganization have taken place. Noticeable changes have since then led to the absence of any nearby water channel directly connected with sea and enhanced magnitude of distance from nearest sea, that is, Arabian Sea. It is conjectured that a lost channel might have served as the connection between the basin and nearby southwesterly sea.

Imprint of sea level variations and tectonics

The quality of the Tertiary continental fossil record hailing from topmost Subathu beds, Murree and coevals, and Siwalik successions in NW Outer Himalaya is in focus in the perspective of regional tectonics and sea level variations.Earlier this theme was taken up on global scale by Mike Benton (2003) who enumerated his views on quality of fossil record in the context of 'molecular age doubling' and 'oldest fossils' with fascinating conclusion.

Once again the Himalayan Foreland fossil record is under close scrutiny with associated vision that fossil record contains a biotic and an abiotic signal. Since quality of the Tertiary fossil record from the horizons on the southern flank of the NW Himalaya is inconsistent without any observable explanations, it certainly indicates to change in physical parameters which do not find manifestation in exposed sedimentary record available for collecting fossil assemblage and field data. In our perception lowering of sea level following accumulation of ice in Polar regions and/or reduction in volume of outpoured hot magma in late Eocene destroyed established coastal vertebrate habitat and thereby brought down quality of vertebrate fossil record by inflicting break in continuum. At a marked variance to our view Fara (2002) argues that while sea level change is a fundamental parameter for consistent marine fossil record quality, it is not so in the case of continental fossil record.

The break in continuum came to an end with the initiation of the foreland basin setting that stabilized and thus restored basic biomass on sedimentary cover in early Miocene and by middle Miocene quality of continental fossil record reached up to the mark. And thus quality of Tertiary continental fossil record in pre-Siwalik and Siwalik basins in NW Outer Himalaya has gone back and forth due to forced regression of Subathu Sea causing loss of fluvial accommodation and beginning of foreland basin setting in the NW Indian Outer Himalaya.

Carnivore remains and coprolites (fossil excrements) from Siwalik horizons

Siwalik Carnivora comprises index elements indicating maturity of successive trophic levels of food pyramid of the evolving Cenozoic terrestrial ecosystem on the southern flank of the Himalaya. Carnivore fossil remains and coprolites (Fig. 8 & 9) from Bharil area in conjunction with the ones known from Ramnagar area (J&K), testify space, continuity and maturity of ecosystem up to late middle Miocene that set in the region during early Miocene from adjoining Dharmsala locality yielding early Miocene forms.

We report here occurrence of two carnivore taxa namely *Dissopsalis carnifex* and *Crocuta carnifex* besides describing couple of coprolites with discernible bone fragments. A lower carnassial of *C. carnifex* and stoutness of an upper third premolar referred to *Dissopsalis carnifex* help us in inferring that preys of large body size must have

Dissopsalis carnifex, a Creodont, upper right second premolar (WIF/A 1031;L-14 & W-9 mm, bar length 1 cm)

Crocuta carnifex lower left carnassial bar length 1 cm occlusal, labial & lingual views (WIF/A 1032) L-19.0 mm & W-12.0mm)

Fig. 8

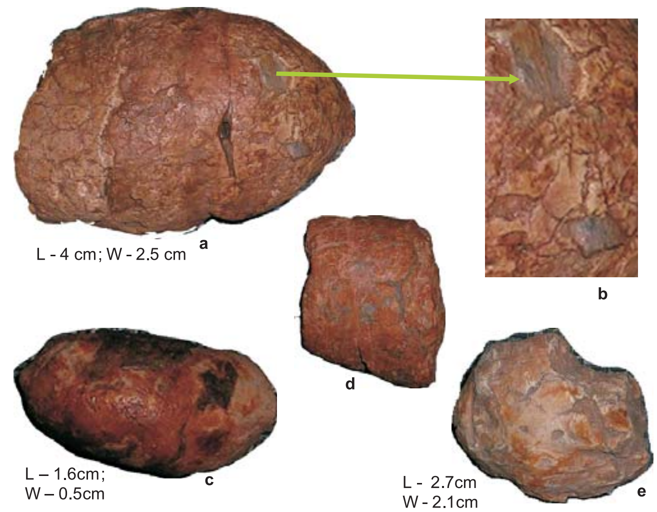

Fig. 9 a-b. Carnivoran coprolite with bone fragment, **c-e**. Other coprolites of different size and shape.

been target population of the Bharil carnivores.

In view of presence of *Paratritemnodon* from middle Eocene Subathu horizons and latest record of endemic forms from early Eocene levels from western India and Pakistan we enumerate morphological clues supporting that both Bharil taxa are descendant of native Indian subcontinent carnivore lineage. And to sum up a succinct review of evolution of terrestrial carnivore in the Himalayan foreland basins in current perspective is given.

Anagenetic evolution of Progonomys in the Siwalik Group

The most primitive murid taxon, *Antemus,* ranging from 14.3 to 11.8 Ma evolved from a south Asian Miocene cricetodontine in the Siwalik basin. Its primitive murid molar morphology anagenetically gave rise to a distinct molar configuration ascribed to *Progonomys* ca. 11.6 Ma (Barry and Flynn, 1990). It was a beginning of the Muridae in Siwalik cradle that alone constitutes more than quarter of the entire recent mammalian species of the world; let us recall that Siwalik basin represents Miocene and younger sequel to the Himalayan Orogeny and thereby brings to fore link between organic evolution and continent scale orogenic movements.

Bharil local fauna is from Lower and Middle Siwalik transitional horizons and comprises micro and mega fossil vertebrates besides host of other microfossils. Rodents are represented by isolated molars of ~ 2 mm size and are most important component of the assemblage because of their age diagnostic virtue. Murids of the local assemblage are lumped in one species namely *Progonomys hussaini* on the basis of distinguishing morphological features of the lower and upper isolated molars.

This is the first record of *P. hussaini* from an Indian Siwalik section. And on the basis of rodent biochronology-based age estimates we find that Bharil and Jalalpur assemblages are somewhat coeval.

Volcanic ash bed from the basal part of the Subathu Formation

A volcanic ash bed discovered from the basal part of the Subathu Formation exposed along the Koshaliya river in the foothills of Himachal Pradesh (Fig.10a & 10b). The find of ash bed has three-fold significance namely, i) it is the first ash bed discovered from the marine part of the Subathu Formation and the oldest from the HFB and possibly also from the entire Himalaya, ii) its stratigraphic position corresponds well with the India-Asia collision event and thus very significant for its better understanding. Its grain size varies from very fine to medium fine grained. It is soft and soapy to the touch. Its clay-rich nature and physical properties particularly the light grey colour against black coal horizons makes this ash bed conspicuous, differentiating it from the adjacent beds in the lithological section. It consists mostly of kaolinite with trace quantities of euhedral and angular quartz, K-feldspar, zircon, biotite and anatase. It has high contents of Al_2O_3 (36 to 40 wt %), loss on ignition (LOI = 10 to 11 wt %), TiO_2 (1.5 wt %) as well as high concentrations of incompatible trace elements such as Zr (735 - ppm), Nb (45 ppm), Th (69 ppm) and Y (58 ppm), and low concentrations of Na_2O (0.45 wt %), MgO (0.5 wt %) and CaO (0.11 – 0.14 wt %). The low SiO_2 and high Al_2O_3 contents, and their very low SiO_2/Al_2O_3 ratio (1.2) compared to mudstone/shale (SiO_2/Al_2O_3 ratio of 5) suggest an argillization of volcanic glass. The high contents of loss on ignition are consistent with hydration and accompanying alteration of glass and formation of clays (kaolinite). Similarly, in the absence of detrital quartz, SiO_2/Al_2O_3 are also lower for volcanic clays due to the fact that SiO_2 is lost during glass to clay conversion.

Fig. 10 **a.** Field photograph of the volcanic ash deposit at the base of Subathu Formation exposed in the Koshalia River near Kalka, Himachal Pradesh (scale is 1.5 m long).
b. Photograph of a hand-specimen of the fine volcanic ash (in scale each division equals 10 mm).

Gastropod in a pyrite nodule from the Kakara

Significant fossil finds include a tiny gastropod in a pyrite nodule from the Kakra Formation and charophytes from the lower part of the Kasauli Formation. It is expected that the Kasauli charophytes will help in fixing the lower age limit of the Kasauli beds. New sampled localities include coaly horizons of the Kakara (Ghanagu-Kog area near Darla) and Subathu formations (Kaushalya nala near Parwanoo). These are likely to yield pre-Middle Eocene mammal remains like coeval beds of Pakistan, Rajasthan and Gujarat. New fossils studied include crocodilians, whales, rodents and hyracodontids from older red beds of the Subathu Formation in the sub-Himalaya, and some lower vertebrates from western India.

3. NATURAL HAZARDS

3.1 SUB PROJECT

Geomorphological studies in the Kullu valley, Himachal Pradesh, with special reference to mass movement and environmental management.

(M.P. Sah and R.K. Mazari)

During the year analysis and interpretation of the data collected on geomorphology, geology, discharge and sediment delivery, hydrometeorology, landuse and socio-economy was carried out in order to understand the state of environment of the Kullu valley. The composite study shows that the Kullu valley embodies three major climatic zones, that is, alpine (< 4000 m), temperate (1200-4000 m) and subtropical (> 1200 m). The area above 4500 m remains under permanent snow cover. The temperate zone characterized by present day periglacial climate can be divided into cold (4000-3200 m), cool (3200-1700 m) and warm (1700-1200 m) on the basis of morpho-climatic setting. The temperate zone is most vulnerable to cloudbursts as most of the tributary valleys in their head portions form funnel-shaped morphology and are covered with thick forest which provide ideal conditions for heavy precipitation. At the peak of the cold period (ca 15,000 yr B.P.) there was a relative downward shift of all the climatic zones vis-a-vis what is presently the temperate zone was in the influence of severe cold climate as evidenced by the presence of massive relict periglacial deposits on the hill slopes especially in kullu section. Interestingly, the present day temperate zone is severely influenced by human activity and large area is under horticulture or agriculture.

In regard to discharge-sediment relationship there is heavy sediment delivery in relatively less discharge conditions as at Manali in the upper reaches of the Kullu valley (Fig. 11) which is attributed to morphological characteristics, presence of extensive incoherent Quaternary material and shifting of the climatic zone to the higher elevations where at present large area is in greater influence of rainfall than snowfall. The control of morphological characteristics on sediment delivery is obvious from the longitudinal profile of the Beas river which is 117.6/km at Manali reflecting the erosional segment of the upper Kullu valley as against 16.95/km at Bhuntar indicating depositional environment of the downstream segment. In the upper segment of the Beas topographical sinuosity is more as compared to the lower segment where hydrological sinuosity dominates. This is the reason that more lateral erosion of the river bank takes place in the lower segment of the Kullu valley as compared to the upper during the high discharge conditions.

The studies have revealed that out of 36 cloudburst events that have been reported from Himachal Pradesh during 1990-2001, 15 have occurred in Kullu valley alone which accounts for 41.7 % of the entire State. Furthermore, the studies suggest that cloudburst related mass movement generally affects the non-cohesive Quaternary material confined to the narrow valleys.

Analysis of the data suggests that significant environmental changes have taken place in the last 50 years in the Kullu valley. In 1950, the upper reaches of the Kullu valley received 353cm snowfall as against 60cm in 2001. Similarly, minimum temperature has also shown significant changes from -10°C to -4°C during the same period. With the retreat of snow cover to the higher slopes considerable changes have occurred in the hydrological system of the Kullu valley which is evident from reduced spring discharge and in many cases drying of the springs. Springs have been the potential source of potable water in the entire Kullu valley for the past several centuries. In many cases springs used to supply water to irrigate the small fields on the hill slopes. With the increasing demand it has become problematic to meet the minimum domestic needs of the area.

Of particular concern is the rapidly changing demographic character of the Kullu valley. The studies have shown that the linear growth in the agro-horticulture related economic activity and the rising tourist influx together with increasing impetus to development of infra-structure has created a wide scope for the environmental problems of the area. The total forest area in 1981-82 was 492,589 hectares which was reduced to 424,168 hectares in 2000-01 registering a decline in the forest area by 13.89% in nearly 19 years which by any reason is alarming as some portion of this has been brought under horticulture for the economic benefit against the natural balance of the area. This is also reflected in the figures which indicate that horticulture alone increased by 60.7% between 1975 and 2002. Similarly, population figures show an upward trend registering an increase by 217.65% in 100 years between 1901 and 2001. The tourist flow has grown by 241.11% between 1993 and 2001 which obviously suggests heavy demand on the development of infra-structure in the naturally constricted valley.

The overall data analysis suggests that a balanced approach is necessary for the environmental management of the area. Further studies are going on.

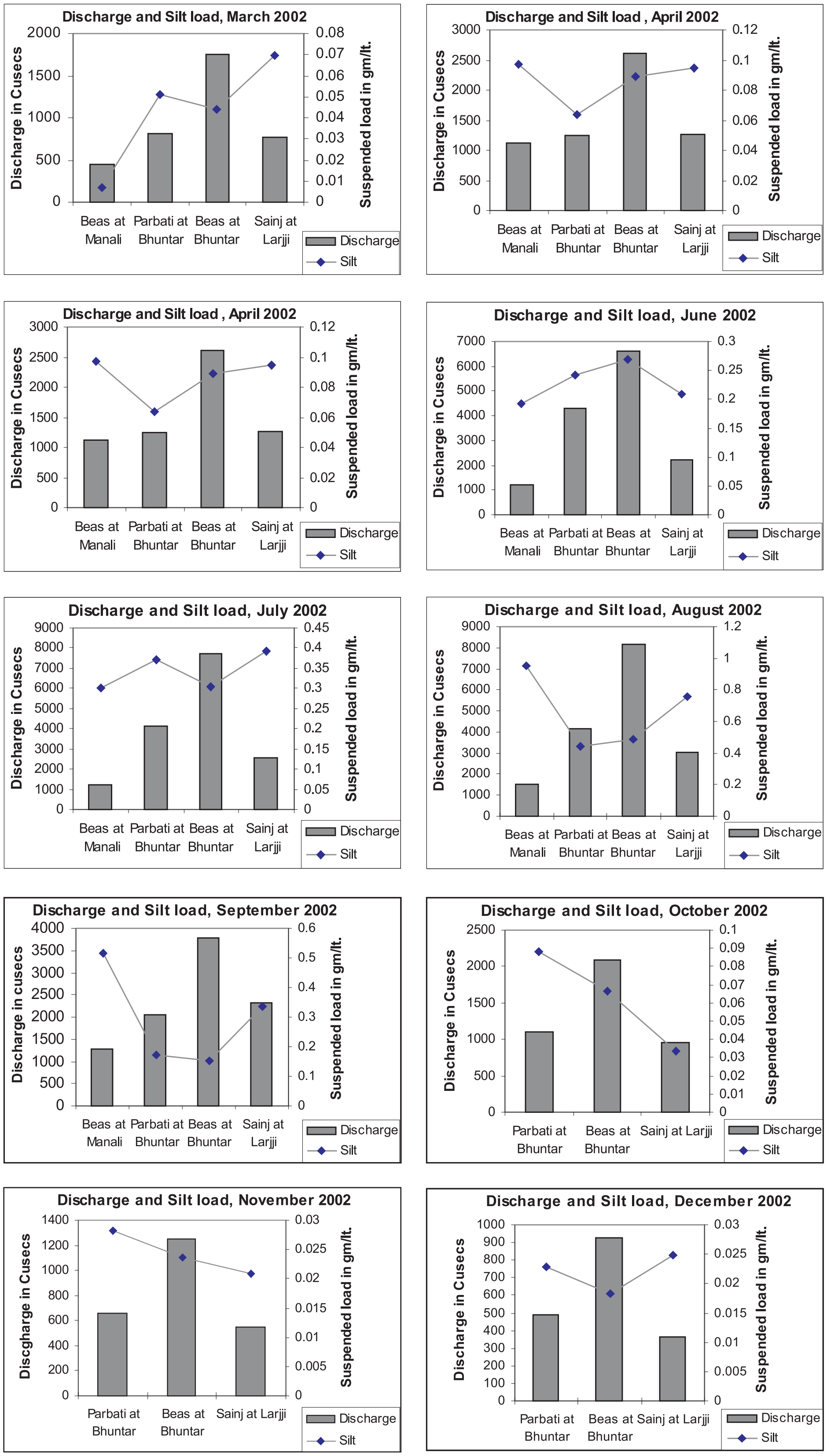

Fig.11. Discharge-sediment load trend in the various rivers in the Kullu valley for the year 2002.

3.2 SUB PROJECT

Mass movement and their relationship with the MCT Zone, Uttaranchal Himalaya.

(K.S. Bist and B.S. Rawat)

Field work was carried out to identify the mode of failure and the role of structural elements in the failure of slopes in Yamuna and Tons valleys, where the rocks exposed are the Lesser Himalayan sediments, mainly consisting of quartzite, phyllite and limestone with intrusives of metabasics of the Garhwal Group. During the field investigation, active and potential slip zones were identified and emphasis was laid mainly on the stability of the ground with reference to the geological and geotechnical parameters.

To asses the stability and potential of future rock fall along the valley sections the structural data was processed. The graphical stereo net analysis of various discontinuities at numerous sites provides the probable failure surfaces. The analysis shows that different sets of discontinuities behave differently with respect to the orientation of slope facet and the internal angle of friction of the rocks.

About one km north of Kharadi village on the left bank of Yamuna river, the highly vulnerable and active zone (300 x 250 m) of mass movement shows the slopes varying from 37° to 48° is at limiting equilibrium as controlled by the 35° residual angle operating along deep seated joint plane (slip plane of an old landslide) of Garhwal quartzite dipping at 42° due southwest into the valley. It is observed that during rains the rate of mass movement increases with the saturation of the slopes. The down slope movement has caused several radial cracks at the crown area making it dangerous to the habitat on the upper reaches of this active zone.

The comparative study of slope profiles of Khanera slide before and after the failure shows that a voluminous mass has moved due west down the valley affecting the present morphology and causing damming in the year 1980. The failure of the slope took place during the construction of the main highway to Yamnotri where site geology is quite complex with local faulting, folding and associated shear zones. The slide was a direct consequence of a construction sequence where the slip surface was day lighted at the excavation face.

3.3 SUB PROJECT

Mapping of active faults using remote sensing techniques.

(G. Philip)

Study of high-resolution satellite data in the proximity of the MBT and the HFT has brought to light numerous potential areas for the study of neotectonic activity and its influence on drainage changes and geomorphic evolution.

(i) Pinjaur Dun: Active tectonics in the Pinjaur Dun is reflected in the form of dislocation of landforms by major and minor faults in Quaternary and pre-Quaternary sediments. A number of lineaments and active fault traces have been delineated on aerospace data and also verified in the field. Five prominent active fault systems were identified at Mastanpura-Bagheri, Nangal-Jhandian, Manpura, Bari Batauli and Majotu in the Pinjaur Dun. Most of the fault traces and lineaments show a NW-SE trend, which is almost parallel to the regional trend of the MBT, Bursar and the Nalagarh Thrusts. Some stream courses are fault guided and also controlled by the lineaments. Uplifted and tilted Quaternary landforms and sediments indicate the activity along these faults. Many conspicuous tectono-geomorphic features such as warping and back tilting of fluvial and alluvial fan surfaces and fault scarplets in the Quaternary deposits are observed along these active fault traces which show basically a thrust movement with northeast side up (Fig. 12). The traces of active faults running parallel to each other traverse through late Pleistocene to Holocene alluvial-fan sediment. Wherever the faults show strike slip movement, lateral offsets of streams, offset of Quaternary terraces, linear valleys running along the fault and narrow deep gorges are common features observed.

(ii) Frontal Himalaya: A new active fault trace, which is oblique to the Himalayan Frontal Thrust, has been recognized in east of Kala Amb, the northwestern Frontal Himalaya. Topographic features indicative of long-term uplift/ deformation along the fault in the current tectonic regime and cumulative slip along the fault reflect the manifestation of normal faulting. The fault zone, to be referred to as the *Singhauli Active Fault (SAF)*, which traverses through the Middle Siwalik is exposed on the hanging wall of the HFT along the Singhauli Nala. SAF is traceable for over 4km, of which the western half trends NE-SW while the eastern half trends in E-W direction. The western half merges in the piedmont alluvium in the south while the eastern segment

Fig.12. Nangal-Jhandian active fault system (**a**) WNW-ESE trending fault scarp (FS) near Palsara Nihla village with an average height of 15m. (**b**) Backtilting of the Quaternary fan deposit by about 10° (shown by yellow arrows) along the Nangal-Jhandian fault, exposed along a tributary of Chikni Khad, southeast of the village Palsara Nihla. (**c**) One of the sagponds on the hanging wall i.e. to the north of the Nangal-Jhandian Fault near Nangal village. View towards north.

east of Singhauli Nala fades away further east in the Siwaliks. The south side up behaviour of this fault is in contrast to the prevalent north side up movement along the HFT. The fault is steeply dipping due NNW/N and has created few sag ponds to the north of the footwall zone. The fault has also caused shift of drainage channels of major and minor streams. Near its southwestern termination, north of Singhauli and Nanhari villages, another set of minor faults is also traceable for over 1km. These are WNW-ESE trending south side up normal faults dipping steeply due northeast and with well-defined fault scarps. These faults appear to be sympathetic faults developed along with the SAF. Observation along number of N-S oriented streams draining into the piedmont zone has revealed clear-cut exposures of HFT on the surface (Fig. 13). This is against the so far propagated opinion that HFT is a blind thrust and no surfacee rupture is associated with major or great earthquakes occurring along the Himalayan Front.

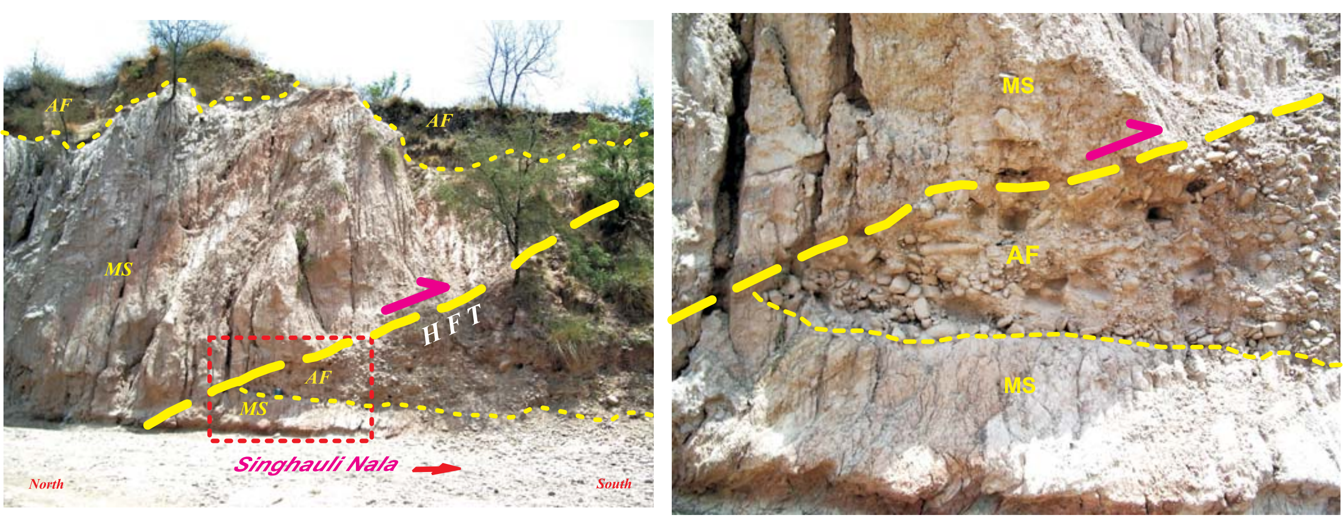

Fig.13. Himalayan Frontal Thrust (HFT) between Middle Siwalik (MS) sandstone and Quaternary alluvial fan (AF) exposed along the Singhauli Nala. Inset: Closeup of the thrust zone showing Siwalik sandstone(MS) overlain by fan gravels(AF) thrusted over by the Middle Siwalik sandstone.

3.4 SUB PROJECT

Monitoring and analysis of seismicity in NW Himalaya.

(Kamal, Sushil Kumar, V. Sriram, A.K. Mundepi, Ravinder Singh, H.C. Pandey, R.M. Sharma and S.K. Chabak)

11 digital (short period and Broad Band) and 7 analog (short period) seismic stations have been operating in the Himachal Pradesh and Uttaranchal. During the year 2005 – 2006 about 2560 earthquakes (local, regional and teleseismic) have been fed to computer for further analysis. Out of these, about 165 local earthquakes (Fig. 14) have been rechecked and analyzed (up to September 2005). The depth of these local earthquakes ranges from about 4 to 24 km. and r.m.s. ranges less than 1. ERZ and ERH vary to epicentral location of the earthquake. The earthquake lies within the network having less ERZ and ERH, whereas earthquake outside the network having higher ERZ and ERH. The seismic activity generally concentrated north of the Dhauladhar region.

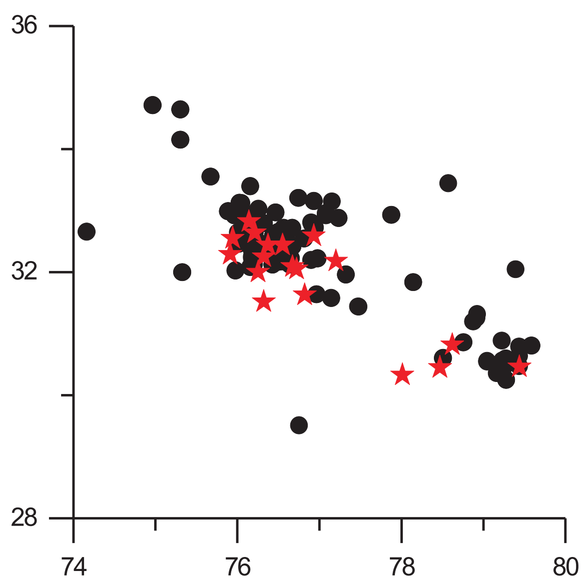

Fig. 14. Epicentral plot of earthquake from March to September 2005.

3.5 SUB PROJECT

Site response studies in major population centres in NW Himalaya.

(Kamal, A.K. Mundepi)

Microzonation is an essential step in the formulation of local land use planning, design criteria and earthquake hazard reduction planning. Importance of local site effects related to the sedimentary soft soil site, strong lateral heterogeneity or surface topography is illustrated. The Ground Ambient Noise (GAN) technique is presented as a means to estimate site effects in an urban environment and finally to illustrate the role of lacustrine / fluvial deposit on seismic response in the city.

The H/V technique has become popular for quick estimation of site's natural frequency, mainly because of its ease of operation and non-destructive nature. The technique directly provides an estimate of the predominant frequency of the local site.

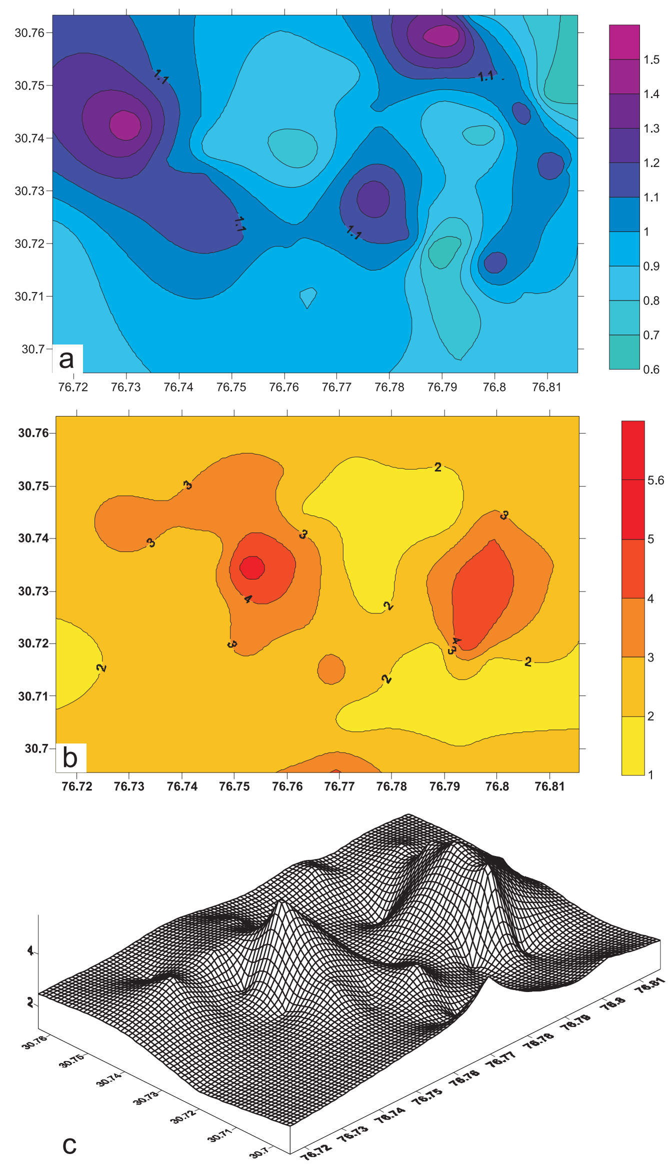

Fig.15. a. Contour map of resonance frequencies, **b**. Amplification Contour map and **c**. 3D picture of Amplification in Chandigarh city.

The field work was carried out during the year Dec. 2004 - Jan. 2005 in and around Chandigarh and Shimla region to estimate the site response of the region. The data collected during the field work was processed by user friendly SESAME software. The location of survey sites was plotted on *Google Earth* for accurate site positions.

The H/V ratio obtained by using SESAME software, the resonance frequencies and magnification of each site were calculated on the graph plotted. The resonance frequencies range 0.6 to 1.2 Hz (Fig. 15a) and amplification ranges 1.1 to 7.2 (Fig. 15b). The amplification contours are concentrated in two pockets where the resonance frequencies are at lower frequencies. It may be inferred that the soft soil thickness is higher in these pockets. The 3 –D diagram of amplification is shown in (Fig. 15c).

Results of an analysis performed in Chandigarh indicate that GAN analysis is able to identify and quantify soft soil site response to seismic waves. The resonance frequencies range between 6.0 and 10.0 Hz and amplification ranges between 1 and 3 in Shimla region which shows the rocky basement with little soil cover.

3.6 SUB PROJECT

Seismicity, seismotectonics and seismic hazard assessment of NW Himalaya.

(V. Sriram)

A simple and rapid methodology based on band limited strong motion data to obtain the double couple fault plane solution, average effective shear wave attenuation and site amplification is used to investigate the moderate sized Chamoli earthquake of 1999, and its after shocks that occurred in the central seismic gap of Himalaya. The spectra of high-energy packets observed in SH-waves are modeled in terms of Brune ω^{-2} model. The source parameters of the main shock obtained are seismic moment = $(5.03 \pm 1.7) \times 10^{25}$ dyne-cm, stress drop = 65 bars, source duration = 5.2s and moment magnitude = 6.4. The estimated stress drops for the aftershocks varies from 23 bars to 153 bars and seismic moment from 1.4×10^{23} dyne-cm to 2.9×10^{23} dyne-cm. The average values of the estimated shear wave quality factor Q_β vary from 883 ± 186 in Uttaranchal sector of Himalaya. These values of effective Q indicate that in general the curst is at low temperatures that will promote brittle behavior and conditions for episodic failure as compared to creep under the piling strains from plate collision at the Himalayan plate boundary. The site amplification factors at various recording sites are also estimated.The fault plane solution obtained for the main shock is consistent with the findings from other teleseismic studies. This method is particularly useful in the study of small earthquakes, which are recorded locally at a small number of observatories. Automation of this method using genetic algorithm is in progress.

3.7 SUB PROJECT

Local earthquake tomography for crustal and upper mantle structure of the NW Himalaya.

(Sushil Kumar)

Taking advantage of the availability of the digital broad band data from the NW Himalayan sector, the arrival time of 78 earthquakes from the Hindu Kush region (vary in depth 50-260 km) are inverted to obtain the upper mantle velocity structure. Inverted model shows a velocity 8.1 km/s to a depth of 100 km. Whereas the velocity change below 100 km is 8.3 km/s. In comparison with global model (PREM) no significant variations beneath Garhwal Himalaya is observed, however below Himachal Himalaya velocity is low (7.9 km/s).

In continuation of earlier work in which the "Upper mantle velocity structure in the NW Himalaya: Hindu Kush to Garhwal region" were estimated from travel time studies of deep Hindu Kush earthquakes, 78 Hindu Kush earthquakes recorded at the 7 stations in Himachal Himalaya were used to estimate the upper mantle structure between the Hindukush to Himachal region.

During the year many earthquakes occurring in the Hindu Kush region were picked up by the portable recording stations installed in the Himachal Himalaya for local seismicity studies. P wave readings obtained from seismograms of the seven stations were analysed. Records of 78 Hindu Kush earthquakes were found to have readable P phases on these seismograms. The necessary travel times were obtained adopting the hypocentral location and origin times of the concerned earthquakes as reported by the US Geological survey. The epicenters of the Hindu Kush earthquakes whose data are analyzed were clustered in a 90 km by 120 km area. The focal depth of these earthquakes as estimated by the USGS ranged between 50 and 260 km approximately. It was observed through ray tracing that these rays pass through the crust only once near the recording station. Moreover their travel time through the crust is a relatively small fraction of the total travel time. Hence distribution of V_p in the crust was not investigated. However, an average crustal model was assumed to obtain estimates of V_p in the upper mantle. It is suggest that the clustering in focal depth of 78 earthquakes can be grouped into three clusters, (i) Cluster I earthquakes in which 11 earthquakes in the focal depth range of 50 to 100 km fall, (ii) Cluster II earthquakes in which 35 earthquakes in the focal range of 100 to 145 km fall, and (iii) Cluster III earthquakes in which 32 earthquakes in the focal depth range of 180 to 260 km fall.

It is seen that with the Cluster I earthquakes minimum of E (V_{pl}) is observed at crustal thickness of 40 km and upper mantle V_{pl} of 7.85 km/s do yield the least total squared error, with Cluster II earthquake minimum in E (V_{pl}) is observed at depth of 100 km for the top interface of the last layer in this case. It corresponds to a V_p of 8.15 km/s, while with Cluster III earthquakes it is observed that the minimum in E (V_{pl}) is weak and acceptable value is 186 km. It corresponds to a V_p of 8.8 km/s.

It is observed that the new results of V_p are lower in the top two above layers in comparison to the results obtained previously for the Hindu Kush to Garhwal stretch. Ni and Barazangi and other workers estimated a value of 8.45 ± 0.08 km/s for P_n wave velocity in the Himalaya. Our value is 8.1 km/s discrepancy between the two results is large. All workers use data in which the ray paths between earthquakes and recording stations were not strictly in the Himalaya. In the present study, the great circles between the epicenters in the Hindu Kush and the recording stations in the Garhwal Himalaya and Himachal Himalaya do lie along the Himalaya. The determination is strictly for the Himalayan region. Some DSS results for the Kashmir region are available. In comparison with the geographic location of DSS profiles and our great circle match upper mantle V_p of 8.1 km/s is obtained again and this supports our results. Along the DSS profile the Moho has wide depth variations. Towards the great circle of interest, the Moho appears to rise towards our estimated depth of 39 km. Upper mantle V_p of 7.9 km/s is obtained when Hindu Kush earthquakes recorded at the stations in the Himachal Himalaya. This indicates some low velocity mass below the seismic array.

3.8 SUB PROJECT

Seismic Hazard and sub - surface studies using Engineering Seismograph.

(A.K. Mahajan)

Seismic Microzonation of Dehradun city

Research for improving the understanding of seismic hazard at regional level and then particularly site specific is very important for urban planning. It is well demonstrated by different earthquake occurrences that the local site condition profoundly influence all of the important characteristics- amplitude, frequency content and duration of strong ground motion. The extent of their influence depends upon the geometry and material properties of the subsurface material, on site topography and on the characteristics of the input motion. Thus, site amplification is a concern in major cities. Multichannel Analysis of Surface Waves (MASW) technique has become important to map the near surface soil properties controlling the amplification and frequency content of soil column. These studies have been initiated in Dehra Dun city and have been applied effectively to determine shear wave velocity of upper 30-40 meter soil column. The understanding of geotechnical characteristics of the near surface material are of fundamental interest in many engineering studies. It has become apparent that the structure on the unconsolidated material of young sedimentary basins can have a profound effect on the ground motion amplification. To evaluate the soil properties especially shear wave velocity, a geophysical technique such as seismic reflection using Multi-channel Analysis of Surface Waves (MASW) has been applied. Based on shear wave velocity along with other parameters like strong motion data of Chamoli earthquake, dynamic properties of soil layers etc, shake map has been prepared for different frequencies for Dehra Dun city. The amplification functions derived between free surface and the lowermost layer shows peak amplification at 3-4Hz in the northern part of the city, 2-2.5 Hz in the middle of the city and 1.5 Hz in the south and southwestern part of the city.

Shallow sub - surface studies

A seismic reflection survey using MASW technique has been conducted across the Himalayan Frontal Fault at Panchkulla, Pinjuar near Chandigarh and Lal Dang and Baleparao area near Pantnagar in Uttaranchal. This technique has been able to delineate hidden subsurface faults and has been tested in some of the sites in Chandigarh, Ram Nagar area and Lal Dang area.

A shallow surface wave survey using Multi-channel Analysis of Surface Waves (MASW) technique was conducted across the Himalayan Frontal Thrust at number of sites in an attempt to determine the existence of fault which has been identified at very shallow depth (3-4 meters) during paleo-seismological investigations by different workers. The basic idea of this survey is to identify shallow faults near the Himalayan Frontal Thrust (HFT) and to appraise the resolving power of MASW technique in the Himalayan region. Two to three reflection profiles were acquired at each site using an 8kg sledge hammer energy source and 24 channels engineering seismograph using roll along technique. The field parameters were designed to optimize the recording of subsurface structures and geological units in the 30-40 meters depth range. This survey enables us to identify blind

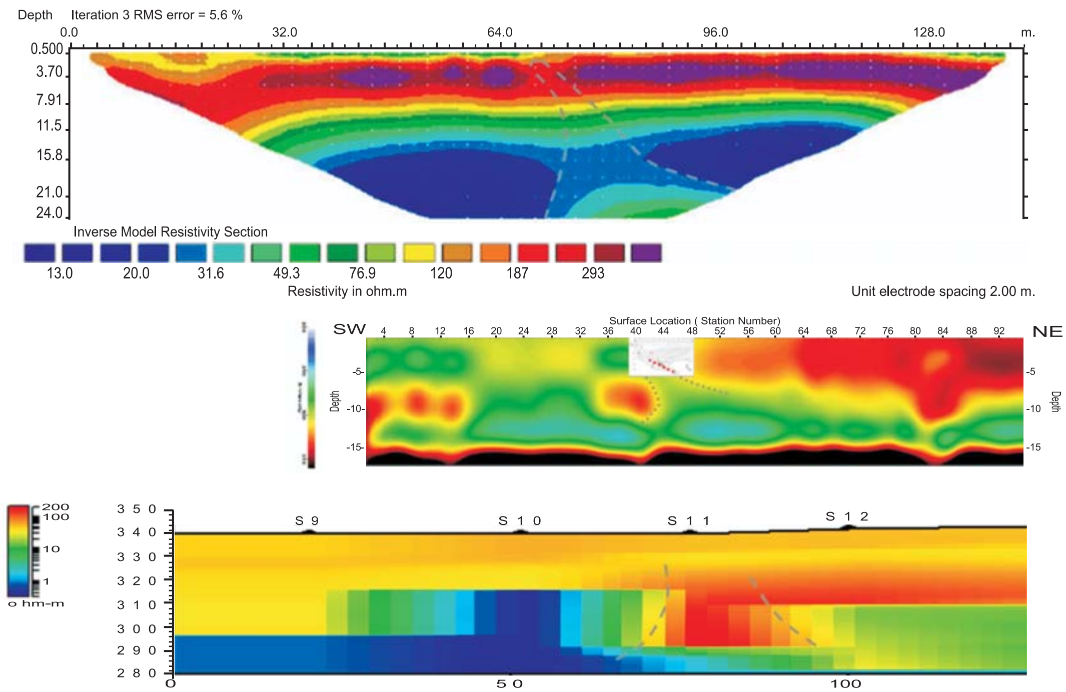

Fig. 16 **Inverse model resistivity 2D section shows a layered structure (top) down to a depth of 12 m with a higher resistivity compared to the bottom depth. From 16 m onwards, there is low resistivity zone up to 24 m depth with a break in the resistivity value which indicates the possibility of displacement of blocks at these depths with a slight tilt of the formation bed and it also shows that the bed may have a deep origination. In seismic section (middle) the displacement in shear wave velocity below location number 36-44 having shear wave velocity of the order of 350-400m/sec have been observed. The break in velocity extends up to depth of 15 meters which corroborated with the break in resistivity 65 meters location imaging section(Top) , thus indicate the presence of fault. The same features have been noticed in Time domain electromagnetic profile at the same location but with little accuracy.**

faults/thrusts related to the Himalayan Frontal Thrust system. This technique has been effectively applied for delineating shallow faults and associated deformation associated with paleo-seismic event identifies by various workers. Further to strengthen our data, a joint experiment has been designed under the guidance of Prof. B.R. Arora in collaboration with National Geophysical research Institute (NGRI), Hyderabad and International Institute for Geo-information and Earth Observations (ITC), Enschede Netherlands by using three different approaches namely Multichannel analysis of surface waves, multichannel-electrode resistivity imaging and the Time domain electro-magnetic methods to map the shallow strcutres in terms of shear wave velocity and electrical resistivity. From the seismic data and resistivity imaging we were able to identify a fault at a depth of around 08 meters with a displacement of 6-7 meters striking NW-SE and dipping northeast in Panchkulla site across the Himalayan Frontal Fault. The results are compared to geologically documented trench which has been dug 40 m in length and 5 m in depth east of the geophysical line with a NE-SW orientation (Fig. 16). The data collected form the basis for future efforts to study blind thrusts along the Himalayan foot hill region and to evaluate the activity of blind thrust/ faults underlying in urban areas.

The dividing sedimentary sequences of the fore-deep basin of the Himalaya in terms of lithological transitions and to unravel deformations are critical for tracing basin evolution, establishing tectono-climatic relations and to find evidences of the palaeo-seismological events. The proposed MASW and Electric Resisitivity tomography studies are effective modes for shallow surface studies. The proposed study can provide an important tool for seismic hazard, palaeo-seismological and sedimentary evolution studies.

3.9 SUB PROJECT

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

(P. Banerjee)

Two permanent GPS stations were installed at Uri and Keran (Kashmir) immediately after the October 8, 2005 Kashmir earthquake. A major part of GPS data was processed to study the coseismic and post-seismic deformation related to the December 26, 2004 Sumatra-Andaman earthquake, and March 27, 2005 Nias earthquake. In collaboration with Prof. Roland Burgmann of UC-Berkeley, data was collected from Malaysia, Indonesia, Sumatra, Burma as well as from all Indian Permanent GPS stations, and obtained the co- and post-seismic deformations in the near-field as well as far-field region of the source zones of these two earthquakes in the eastern plate boundary of Indian plate. The data was processed from all permanent GPS stations in India and that of surrounding countries and working on interaction of India plate motion with surrounding plates on all borders, with special emphasis on the Himalaya.

India-Sunda plate boundary earthquakes: Coseismic Studies

The December 26, 2004 Sumatra earthquake produced significant static offsets at continuously operating GPS stations located at distances up to 4500 km from the epicenter. We also utilized estimated offsets on the Andaman and Nicobar Islands from campaign GPS measurements. A coherent pattern of surface motions has been found that is roughly directed towards the earthquake rupture at distances as large as 4500 km from the epicenter (Fig. 17). Sites in southern India moved eastward by as much as 25 mm, decaying to 2-4 mm in the northwest Himalaya. Motions swing in a clockwise sense from southeast Tibet across China towards a southwesterly trend for sites in Korea and Taiwan. Displacements of sites just to the south of the rupture in Sumatra are small and mostly towards the east. Estimated motions in Australia, on the Seychelles Islands, and in Eurasia north at about 40° latitude are insignificant. In collaboration with Geodetic & Research Branch, SOI, data has also been computed for the near-field coseismic offsets of the 2004 Sumatra earthquake, and are currently working on post-seismic deformation.

Mechanical modeling of an earthquake of this dimension requires consideration of the Earth's shape and depth-varying rigidity. The standard approach of modeling the surface motions from an earthquake using an elastic half-space approximation of the Earth is inappropriate for an event of the magnitude and dimensions of the Sumatra earthquake. We model the event using PREM. Static deformation in a spherical geometry is evaluated using the method of Pollitz (1996). We define the geometry of our earthquake rupture based on constraints provided by the distribution of aftershocks and independent seismic source

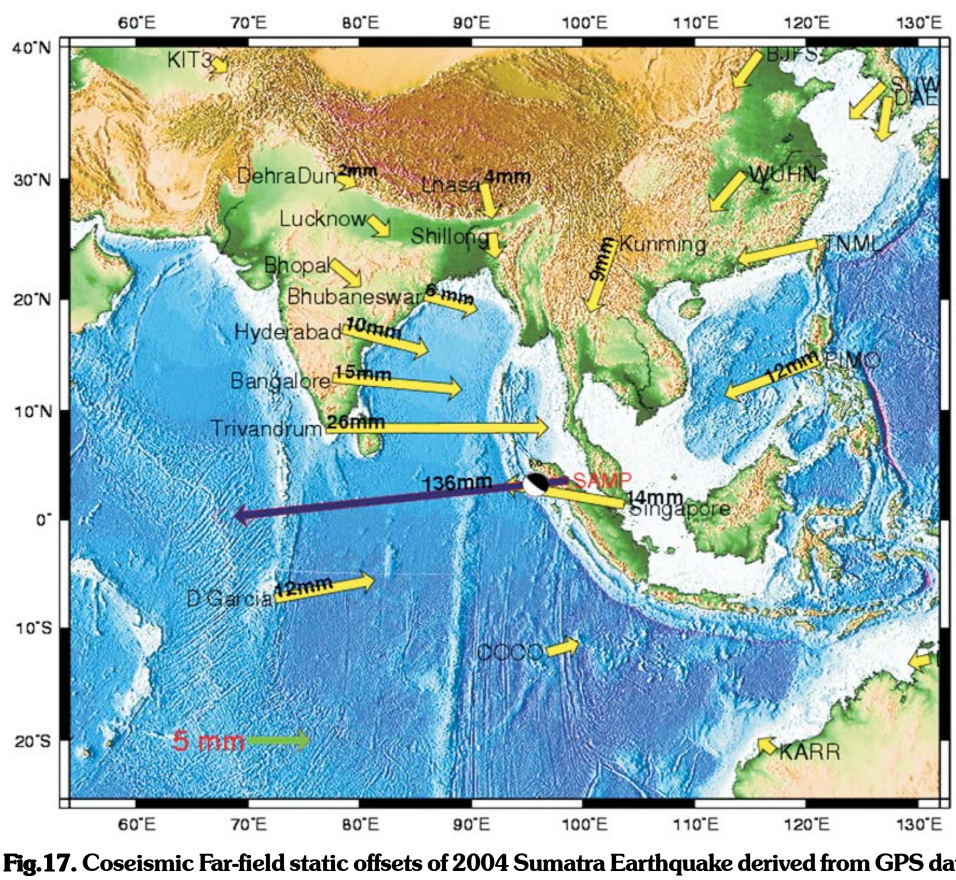

Fig.17. Coseismic Far-field static offsets of 2004 Sumatra Earthquake derived from GPS data.

studies. Forward model comparisons of the Sumatra earthquake show that surface motions calculated with a homogeneous spherical model greatly exceed surface motions of the layered spherical model at very large distances. The magnitudes of the far-field displacements are highly sensitive to fault dip, and each segment is therefore subdivided into two sub-segments in order to capture the first order dip increase with depth.

We determine > 5 m of average slip along the full >1200 km length of the 130-200 km–wide rupture, including the ~650 km-long Andaman segment of the megathrust. Comparison of the source excitation derived from the far-field static offset with seismically-derived estimates suggests that as much as 25-35% of the total moment release occurred at periods greater than one hour.

Post-Seismic studies

The Mw=9.2 December 26, 2004 Sumatra-Andaman and M=8.7 March 28, 2005 Nias earthquakes, which collectively ruptured approximately 1800 km of the Andaman and Sunda subduction zones, are expected to be followed by vigorous viscoelastic relaxation involving the asthenosphere and underlying mantle. Both afterslip and viscoelastic relaxation may contribute to the postseismic displacement field. Our study explores the latter process using models of oceanic lithosphere and mantle rheology on a self-gravitating compressible Earth. We present new coseismic slip models of both earthquakes based on compilations of continuous and campaign GPS data from four different regional networks, and we implement them as source models for coseismic and time-dependent postseismic deformation fields. For simple layered viscoelastic models which include a low-viscosity asthenosphere, we predict substantial postseismic effects over a region several 100s of km wide surrounding the eastern Indian Ocean. We compare observed GPS time series from ten regional sites (mostly in Thailand and Indonesia), beginning in December 2004, with synthetic time series that include the coseismic and postseismic effects of the December 26, 2004 and March 28, 2005 earthquakes. A viscosity structure involving a bi-viscous (Burghers body) rheology in the asthenosphere explains the pattern and amplitude of postseismic offsets remarkably well.

October 2005 Kashmir Earthquake

Immediately after the October 8, 2005 Kashmir earthquake, two continuously GPS stations were installed on LOC with Pakistan, at Keran and Uri, to study the post-seismic deformation of the Kashmir event. The data collected from these instruments are being processed. Uri station stopped working after few days because of problem in the instrument which is quite old. The Keran station is still working and is being maintained by the army.

3.10 SUB PROJECT

Geological controls on radon emanation and its role in environmental pollution assessment and earthquake studies.

(V.M. Choubey and S.K. Bartarya)

Radon concentrations in groundwater and soil-gas along with the gamma radiation dose rate have been measured in the different geological formation of Kumaon Himalaya. Radon concentrations were found to vary from 1 Bq/l to 392 Bq/l with a mean of 50Bq/l in water 398 Bq/m3 to 25.8 kBq/m3 with a mean value of 5.867 kBq/m3 in soil-gas. The radium content in groundwater samples from the study area was found to vary from 0.11 Bq/l to 0.75 Bq/l with a mean value 0.35 Bq/l. The terrestrial gamma radiation dose rate and uranium content in soil were found to vary from 21.67 μR/h to 57.50 μR/h with a mean value of 36.15 μR/h and 0.8 ppm to 15.3 ppm with a mean value 3.4 ppm, respectively, in the different lithotectonic units. The emanation of radon in groundwater and soil-gas are found controled by the geological formation of the area. It was also found controled by the tectonic structure of the area. Radon level was found higher in the area consisting of granite, quartz porphyry, schist, phyllite, slate and lowest in the area having sedimentary rocks, predominantly dominated by quartzite rocks. The terrestrial gamma radiation dose rate in the area was found positively correlated with radon concentrations in groundwater and soil-gas. A strong positive correlation was observed between uranium content in soil and terrestrial gamma radiation dose rate. Soil-gas radon concentration was also found positively correlated with the uranium content in the soil. However, a weak correlation was found between uranium content in soil and radon concentrations in groundwater samples from the study area. No correlation was observed between radon concentrations in groundwater and soil-gas. Beside this we have also measured soil radon across different thrusts in Alaknanda, Bhagirathi and Bhillangana valleys.

3.11 SUB PROJECT

Geological, geomorphological and geotechnical investigation of Pawari and Nathpa slide zone and upgradation of existing landslide inventory of Sutlej valley, Himachal Pradesh.

(Vikram Gupta and M.P. Sah)

The study was aimed at updating existing landslide inventory and detailed mapping of Pawari and Nathpa landslides in the Satluj valley. It has been observed that the frequency of landslides particularly in the upper stretch of the valley has increased which may be related to the climate change in the area. In the years 2000 and 2005, the study area has witnessed two major flash flood events due to breaching of the landslide lakes (Landslide Lake Outburst Floods) that were created in the Tibetan region, consequently damaging the entire ecosystem lying all along the Satluj river and creating unstable zones at a number of places.

The analysis of average daily discharge data for the Satluj river available during the years 2000-2002 and 2004-2005 for Khab, at its confluence with the Spiti river suggests constant water level during the period January to March. It began to rise from April or the beginning of May and reached its maximum during July-August each year which is related with the snow melt. At the end of August water level began to fall. The mean flow per year was 2191 m^3/s, the peak discharge is in the month of July or August and is about 4600 m^3/s. The maximum daily discharge not related to flood event was 318 m^3/s. The mean daily flow was 24.1 m^3/s for April, 67.0 m^3/s for May, 137.2 m^3/s for June and 158.3 m^3/s for July and 159.8 m^3/s for August. The minimum discharge for most of the year is in the month of February where it is as low as 7.5 m^3/s (Fig. 18).

During 2000 and 2005 flood events, the maximum daily discharge measured at Khab was about 1733.80 and about 1900 m^3/s (after that no discharge was measured as the discharge site has been submerged by the rising water).

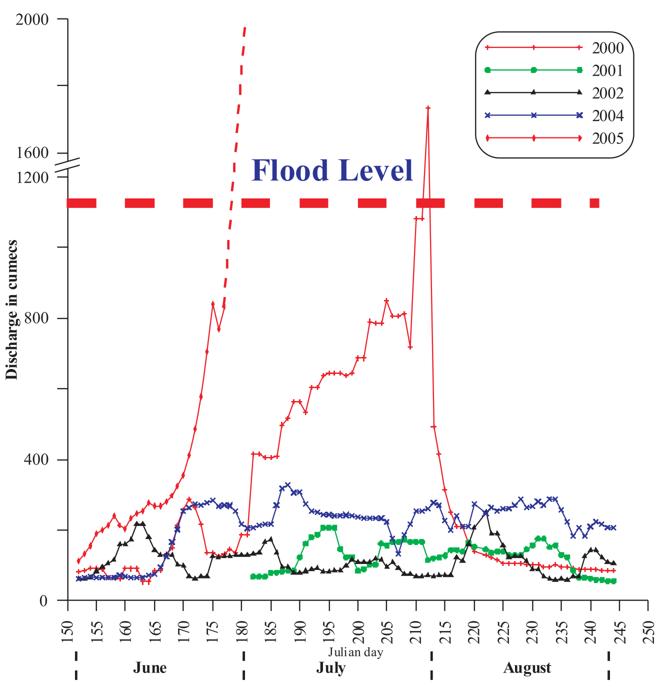

Fig.18. Daily average discharge for river Satluj at Khab for June, July, August for the years 2000-2005. The flood level in the valley based on the present study is interpreted to be about 1100 m^3s^{-1} and is marked on the figure.

Mapping of the Quaternary sequences all along the Satluj river confirms that the area has had a history of blockades and consequent flooding in the past. However, the recurrence interval of these flood is yet to be established.

3.12 SUB PROJECT

Monitoring of Geophysical and Hydrologial changes due to impounding water.

(B.R. Arora, Kamal, V.M. Choubey, S.K. Bartarya, A.K. Mundepi, Gautam Rawat, Rajesh S.)

Seismic Component

Since the period of installation of seismic network, data up to February 20, 2006 has been analyzed and 7 local earthquakes have been identified and located. The locations of these local shocks are mainly concentrated around Garurganga station and Indo-Tibet border region. Earthquakes observed around Garurganga station have epicentral distance of 7 to 15 km. The signatures of these earthquakes are absent in other stations. The data collected will help to establish the background seismicity and to track the level of induced seismicity due to impounding of reservoir.

Other Geophysical Component

Over Hauser Magnetometers, Campaign mode GPS, Fluxgate Magnetometer, ULF induction coils were procured this year under different DST sponsored projects. These units will be used for monitoring various parameters in repeated campaign mode survey. One ULF induction coil magnetometer for recording induced magnetic field in ULF band has been installed at MPGO site at Kopardhar.

Radon and Water discharge measurements

Daily measurements of water radon in one of the perennial springs located in the Tehri campus of Garhwal University was carried out. Besides radon we have also recorded water discharge of the same spring every day during the year 2005. Radon concentration in water varies from 238 Bq/m3 to 13525 Bq/m3 with an average of 4503 Bq/m3 during the period January to December, 2005. Whereas, the water discharge of the spring for the same period varies from 2.8 l/min. to 10 l/min. with an average of 5 l/min.

The radon and spring discharge data shows some relationship i.e. with increase in spring discharge the radon also increases due to larger surface area contributing to discharge. Similarly, the larger surface area allows more water to interact with the catchment lithology that increases the radon along with water discharge. Work is in progress to include the micro-seismic data of this area along with radon and water discharge variation.

4. GLACIOLOGY AND NATURAL RESOURCES

4.1 SUB PROJECT

Geohydrological investigations and water quality assessment in headward region of Kumaun and Garhwal Himalaya with emphasis on identification of hill aquifers.

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

The study area is drained by the tributary streams of the Kali, Ramganga and Pindar rivers. Although these rivers originate from the glaciers in the Higher Himalaya, their catchment area and sub-tributaries, particularly those present in the Lesser Himalaya are dependent predominantly on the subsurface and groundwater for their flows. An attempt has been made to understand the discharge variation of the spring and groundwater flow pattern using the discharge data of the springs, drilling chart of the handpumps and water chemistry data.

Discharge variation of Springs

Fluctuations in the discharge of springs are primarily due to variations in rainfall, more precisely, due to variations in the quantum of rainwater that is able to infiltrate the ground. A balanced precipitation causes uninterrupted adequate discharge of water in the months of July, August, and September, and a gradual decrease and deficit in summers. Melting of snow in the upper reaches of the catchments causes local recharge and slight increase in water discharges during winters. The alternation of recharge and discharge is the cause of seasonal, local and short-term fluctuations. The springs related to secondary permeability show a marked response to rainfall variations, indicating a rapid inflow or infiltration of rainwater to the groundwater reservoir. Springs fed by subsurface water are subject to greatest fluctuations, even to the extent of complete disappearance of springs at certain times. However, the springs fed by groundwater have more or less steady supply, even though their discharges vary seasonally, depending on seasonal changes in the hydro meteorological conditions. Among different types of springs, the springs emanating from sand – gravel deposits and fractured and jointed limestone of the Gangolihat formations have the largest discharges.

The base flow estimations (permanent groundwater flow) of the spring discharges have been made by the hydrograph separation method (separation of storm flow from the base flow). The structurally controlled springs related to fracture joint show 20-40% of the total discharge as base flow, the colluvium – related show 47-60%, the fluvial related springs 45-65% and the karst related springs show 22-37%.

Few hot springs were also observed in the Goriganga valley. These springs are associated with Munsiari Thrust and Goriganga Fault zones present in the Goriganga valley. The springs are formed due to deep circulation of meteoric water in the thermal regime of regional heat flow. The relatively low temperature (37^{0}C) of water is because of the low magnitude of the regional heat flow and relatively shallow depth of circulation of water. However, temperatures are often strongly influenced by the admixture of cold surface waters to the ascending thermal water.

Groundwater flow

It has been observed that three ground water flow paths are present in the study area: a shallow, a moderate and and a relatively deep ground water flow path. In the Ramganga and Goriganga valley, the hydraulic conductivity is confined to the upper and middle layer of the first system and much of the groundwater follows shallow to moderate flow paths. A combination of the flow patterns of the two systems exists in the lower reaches. The springs and seepages draw water from shallow and moderate flow paths, handpumps/ borewells draw water from moderate to deep flow paths and hot water springs have deeper circulation. This flow pattern is evident from the water chemistry data. The water from handpumps/borewells shows relatively higher conductivity, TDS and major ions in comparison to springs (results of shallow ground water flow path) present in the close vicinity.

Hydrochemistry

The chemical analysis of waters of the study area reveals that the major elements in groundwaters/subsurface waters of Kumaun region are low in the majority of the samples compared with groundwater of the peninsular region. This signifies rapid infiltration and quick outflow of the rainwater, and thus low residence time of water, because of the steep slopes in the Himalayan region.

The average equivalent ratio of (Ca+Mg)/(Na+K) and the $Cl+SO_4$ contents of only 15-20% do not represent a contribution from soil salts. The low Mg:Ca ratio (0.1–0.4) and high bicarbonate content suggest the possibility of carbonate precipitation between the upper part of the catchments and discharge location. The prevalence of Ca over Na (except localized excess over calcium) reflects in weathering of calcite in fractures or of calcic plagiocalse present in granite gneiss and schist rocks. Excess Ca could also have been provided from net forest – floor leaching in old growth forest stands. The excess Na over Cl, low Mg:Ca ratio and increased silica in spring and borewell water in the Champawat area suggest input from weathering of aluminosilicate minerals (mainly Na-a nd K- feldspar and quartz) of metamorphic rocks (granite, gneiss, mica schist and weathered quartzite) of the Almora Group. The high SO_4, low silica and the low Na : Cl ratio reflect the dissolution of pyrite and gypsum present in carbonaceous slates and dolomitic limestone of Tejam Group (Deoban and Mandhali formation) present around Pithoragarh. The dissolution of aluminosilicate minerals is of minor importance, consistent with the sedimentary rocks of the drainage sub-basin. The chemical composition of groundwater in Pithoragarh area serves as a good indicator of weathering of dolomite and other carbonate rocks, as Ca, Mg and HCO_3 account for over 85% of the cation-anion balance. As alkalinity serves as a good tracer for carbonate weathering, SiO_2 and Na+K together could be used as an indicator for weathering of crystalline rocks with a high Na and K content.

4.2 SUB PROJECT

Glaciological studies of Dokriani Glacier and Chorabari Glacier, Garhwal Himalaya.

(J.T. Gergan, R.K. Chaujar, D.P. Dobhal, P.S. Negi and Renoj J. Thayyen)

Ground Penetrating Radar studies were conducted at Dokriani glacier in October 2005 including investigation of a sole thrust at lower ablation zone of the glacier. The cross glacier profile generated at 4300 m a.s.l. shows good bedrock reflections and shows different flow regimes of the glacier. Surface slope profiles of GPR sounding lines were generated by EDM for topo-correction. Maximum thickness of glacier ice along this profile was 80-85 m. (Fig. 19).

One of the important aspects of glacial runoff in many parts of Garhwal Himalaya is the presence of monsoon at the time of peak ablation in the month of July and August. Understanding the role of monsoon in glacial runoff processes is an important aspect to be dealt with prior to attempting glacial runoff modeling. We tried to separate the monsoon component from bulk glacier runoff and studied its influence on determining the hydrograph characteristics. Monsoonal component in glacial discharge during 1999 and 2000 ablation period increased to 26% from 10% in 1994 and 1998 (Fig.20). This increase resulted mainly due to the variations in rainfall distribution pattern over the glacier rather than the variations in rainfall depth. Correlation between discharge and rainfall during monsoon months is found to be a bad tool in analyzing the influence of rainfall on glacier discharge. Both the variables have increasing trend in the peak ablation months. However increase in glacier discharge during monsoon months resulted from increased glacier melt due to higher temperatures in summer rather than from rainfall contribution. Daily and diurnal glacier hydrograph response to the rainfall is inconsistent and weak especially in monsoon months, which coincides with the crest of the ablation hydrograph. This is due to the complex interrelationship with the temperature, rainfall intensity, duration and distribution of rainfall, distribution of sunshine hours in a day and efficiency variation of glacier drainage network during the ablation season. This study has very clearly highlighted the need for in depth evaluation before attributing various hydrological characteristics of Himalayan glaciers to monsoon precipitation.

The annual monitoring of Chorabari glacier during 2005 by means of ground survey, stake network and topographical mapping has been carried out. In order to obtain its annual mass balance, snout recession, snow-cover mapping, transition snow line fluctuation, glacial discharge measurement and meteorological parameters were collected and analysed. The summary of the results is as follows:

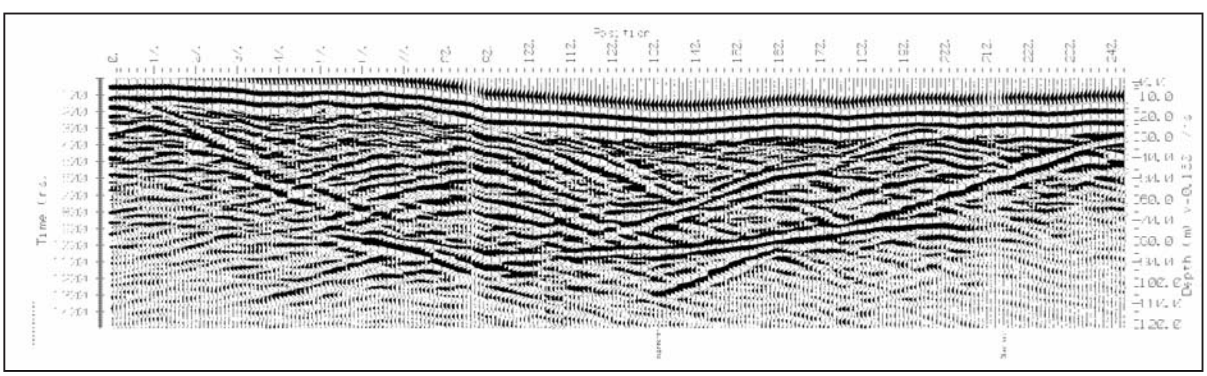

Fig.19. Glacier cross profile by GPR.

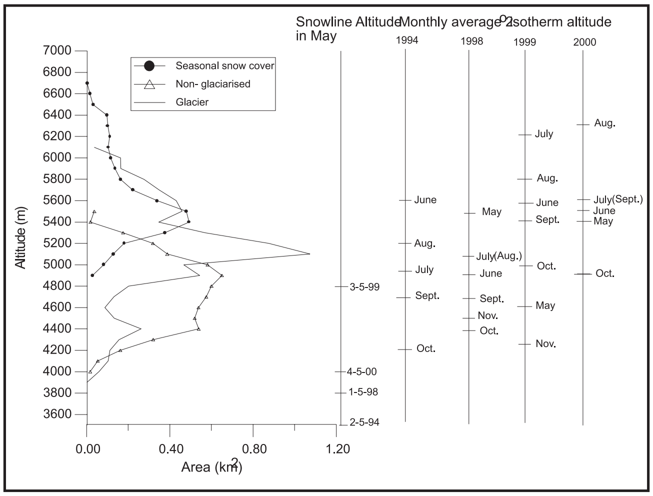

Fig. 20. Variation of two degree isotherm distribution over the glacier during the study period.

- **During the period 2004-05, net annual balance was calculated negative amounting to (-) 5.2x10^6 m^3 of water equivalent with specific balance of (-) 0.84 m.The glacier snout retreated by 12 m in the central part and 8 m and 10 m in the marginal parts of both sides of the glacier.**

- **The surface ice-thickness loss in the lower part of the glacier (June-October) shows less thickness as compared to other middle ablation zone due to the thick debris cover. Maximum loss is observed between 4300 m and 4740 m which registers about 50% of the total ablation of the glaciers. The ELA found at an altitude of 4900 m compared to ELA altitude 4950 m in 2004 (Table 1).**

Discharge from the Chorabari glacier was estimated for one month from 7 June to 30 June in 2005. The discharge was estimated by area velocity method. The total discharge for the observation period was 5.95 x 10^6 m^3 with an average of 0.24 x 10^6 m^3/d. The discharge increased near the end of June. The maximum and minimum daily discharge calculated was 0.45 x 10^6 m^3 and 0.09 x 10^6 m^3 on 30th June and 11th June 06 respectively. The peak and lowest discharge were 5.9 m^3/s at 1700 hrs on 30th June and 0.98 m^3/s at 800 hrs on 11th June 2006, (Fig. 21).

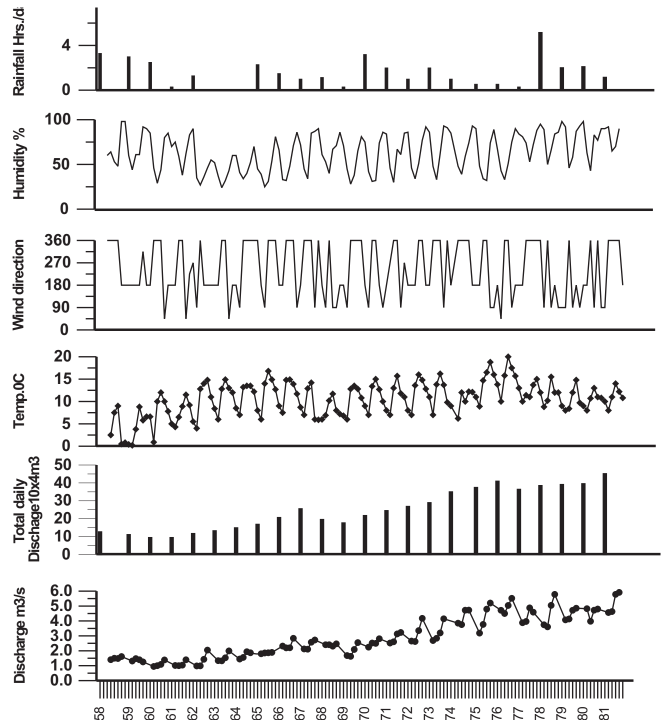

Fig. 21. Meteorological and discharge scenario of Chorabari glacier during the period June 2005.

Meteorological observations were carried out in Chorabari glacier catchment, from 7 June to 30 June 2005. Meteorological parameters include temperature (minimum and maximum), rainfall, wind direction and humidity. The average maximum minimum (m) relative humidity (RH) was recorded at 98% and 27% respectively.

Lichenometric studies were carried out to establish chronological affinity with glacier melting.To date glacial activities of advance and retreat, growth rate of lichens was calculated by remeasuring some of the selected lichens after a gap of three years. Growth rate was calculated as 0.66mm/year. But colonization delay, i.e., the time gap lichens took to start growing on the surface after their exposure to the atmosphere, could not be established as no lichen with known date was available in the surrounding area. Indirect method was applied by locating a bridge of about 72 years old having no lichen grown on its sides/walls. It could be

Table 1. Mass Balance parameters of Chorabari Glacier, 2004-05.

Elevation extension	Abl. area km^2	Accu. area km^2	Net abl.x 10^{-6} m^3	Net acc. x10^{-6}m^3	Net Bal. x10^{-6}m^3	Sp. Bal m	AAR	ELA m
3860-6000	3.15	3.01	-7.40	1.56	-5..2	-0.84	0.48	4900

presumed that a minimum of 72 years were taken by the lichens in the region to grow. The diameters of largest lichens on these loops were measured and Table 2 show their age.

Table 2. Size of largest lichen with growth rate of 0.66 mm per year and a colonization delay of 72 years.

Stage	Largest Lichen	Age (Size/Growth Rate+ Colonization delay
I	160 mm	160/0.66=242+72=314
II	144 mm	144/0.66=152+72=224
III	58 mm	58/0.66=87+72=159
IV	48 mm	48/0.66=72+72=144

In addition to measurement of conventional *Rhizocarpon geographicum*, two other Himalayan species such as *Lobaria* and *Lecanora* , have been recommended for sampling due to their uniform growth pattern and spatial distribution. Earlier indirect sampling studies from Himachal Pradesh show variability in growth with direct sampling studies in and around Chorabari glacier in Garhwal Region (Table 3).

Table 3. Specific lichens growth rate variation in Garhwal and Himachal regions.

S.N.	Name of species	Himachal region	Garhwal Pradesh
1.	*Lobaria* sp.	0.78 mm / year	0.84 mm / year
2.	*Lecanora* sp.	0.67 mm / year	0.74 mm / year

This variation is attributed to the diverse microclimatic scenario in both the area of study. It is widely accepted, especially in the context of Himalaya that refine knowledge of lichen ecology is likely to improve, accuracy and reliability of technique. During earlier studies it was investigated that by virtue of habitat ecology, *Alanus nepalensis* manifest as a precursor for unstable hill slopes. Its ecological dynamics is corroborated with decreasing value of factor of safety due to high shear stress and low shear resistance along slip surface in order to develop temporal affinity with instability/landslide along any slope. Growth rate of 102 saplings of *Alanus nepalensis* was measured for three years at three experimental sites. The annual growth rate was determined at 145 cm. The girth of sapling is also measured and being calibrated with height for onward development of logical correlation co-relation with slope instability.

4.3 SUB PROJECT

Geochemical investigations of active stream sediments and preparation of reference rock standards from Himalayan orogenic belt.

(M.S. Rathi, P.P. Khanna, N.K. Saini, K.K. Purohit, and P.K. Mukherjee)

About 150 stream sediments collected in March 2005 from Ramganga-Kosi catchment were analyzed for major, minor and trace elemental abundances, and present day background values have been estimated for each element on sub-catchmentwise and whole area basis. Additionally, some representative samples (28 nos.) from the Garhwal region were also analyzed for REE abundances.

Radioactive mineralization: Evidence from Geochemical mapping

Unique systematic increased variation of radioactive element abundance (U+Th) is observed from Proterozoic metasedimentaries of the Garhwal Group to MTC zone through prophyroides (Devguru Formation). This is also consistent with the REE abundance. However, the zirconium abundance departs considerably from the expected positive correlation with REEs and radioactive element. Thus, the anomalous zones characterized by high U+Th and relatively low Zr and High REEs are of special interest and are most potential for mineralizations.

Mineralogical evaluation of stream sediments: Evidence for 'Schelite mineralization'

Sample processing of some heavy mineral (HM) pre-concentration was done by hydraulic separation using a gold-pan at few sampling sites to evaluate the heavy mineral assemblages. These heavy mineral fractions were further fractionated into different magnetic fractions (Ferromagnetic-Paramagnetic-Diamagnetic and non-magnetic) using hand-held magnet and iso-dynamic separator.

The preliminary examination of different magnetic fractions reveals presence of scheelite mineral in as many as 7 samples out of 16 samples collected from Eastern Kumaon. This was confirmed by UV lamp under which it gives a bright blue fluorescence. Thus the potentiality of tungsten mineralization is very high in this region that needs further detailed study.

Himalayan geoanalytical reference standards

Updating of Working Values for DG-H

A total of 2500 units of data contributed by as many as 44 laboratories of international repute for about 50 constituent elements was subjected to rigorous statistical treatment for better characterization of the granitic standard i.e., DG-H. Some new and improved working values were assigned for several elements. The updated compilation of working values is being sent for publication.

Homogeneity Test and New Compilation for Derivation of Working Values for AM-H

Contributed data from 28 laboratories for the AM-H, an amphibolite from Jeory, in Satluj valley, has also been compiled. Inter-laboratory agreements of data are excellent, suggesting proper homogenization of the bulk sample. This is further verified by using standard homogeneity test procedures and deriving F-ratios for ten major oxides. Working values have been assigned for all the major oxides, 35 minor and other trace elements including REEs. The certified values for many major and trace elements unique or uncommon, may prove useful for bridging the concentration gaps in available basic geostandards. Notably the proposed standard has lower Ti, alkalies, Ba, Nb, Zn, Zr that are characteristic of deformed metamorphosed basic rocks of the Himalayan terrain. Surprisingly, the Cr content is exceptionally high at 707 ppm and hence may be used as high-point calibration standard. The compilation is ready to be sent for publication.

5. PALAEOCLIMATE AND ENVIRONMENT

5.1 SUB PROJECT

Late Quaternary vegetation history and climate changes with respect to SW monsoon in Garhwal Himalaya.

(N.R. Phadtare)

The high-resolution multi-proxy paleoclimate records (pollen, phytoliths, diatoms, total organic matter, and magnetic susceptibility) elucidating the past 3500-year climate history of the Uttaranchal Himalaya, are retrieved from a well-dated 1.24-m thick Dhakuri peat deposit of the Kumaon Higher Himalaya. Century-scale climate records indicate that the Pinder valley was predominantly cool between ~3500 and 1600 cal yr BP, with two distinct dry episodes during 3300 - 2300 and 2100 - ca. 1600 cal yr BP, separated by 3500 - 3300 and 2300 - 2100 cal yr BP periods of relatively moist conditions. Except for a centennial cold/dry event of 740 - 640 cal yr BP (~1260 - 1360 cal AD), the climate shows progressive increase in wetness until the present, with higher temperatures for 1600 - 740 cal yr BP (~ 400 - 1260 cal AD), 640 - 460 cal yr BP (~1360 - 1540 cal AD), and 270 - 57 cal yr BP (~ 1730 - 1940 cal AD) intervals, and relatively cold conditions during intermittent periods. These climatic events are at variance with the late Holocene climate records from Bangong Co and the Sumxi Lake of western Tibet, but show good correspondence with contemporaneous records from the Dunde Ice cap, Central

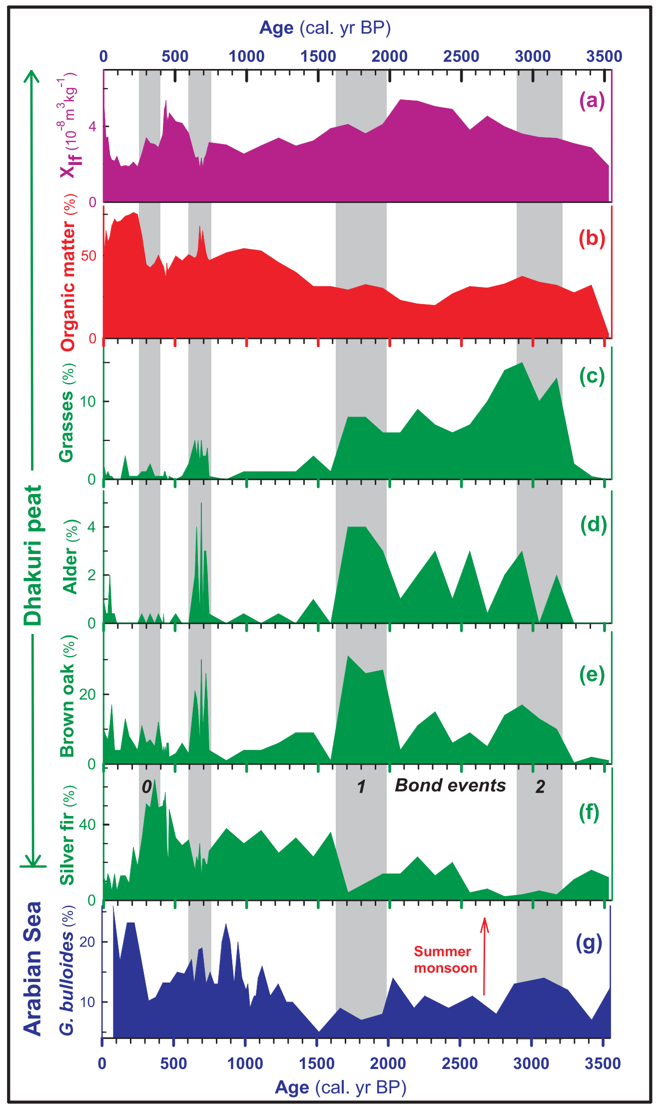

Fig. 22. Correlation of the climate proxy records from the Dhakuri peat sequence with the *G. bulloides* (%) record from the Arabian Sea ODP Site 723A. Time series **(a)** magnetic susceptibility of the detrital influx, **(b)** organic matter content, **(c)** grasses, **(d)** Alder, **(e)** brown oak, **(f)** silver fir of the Dhakuri peat profile; and **(g)** *G. bulloides*. The vertical gray bars indicate intervals of decreased summer monsoon in Himalaya and corresponding *Bond events* in Greenland ice core record.

Nepal, the Ganga Plain, the Thar Desert and the Arabian Sea.

The direct correlation of Himalayan dry climate episodes with the Indian summer monsoon (ISM) record of the Arabian Sea, established for the first time (Fig. 22), revealed that the 3200-2900 cal yr BP dry event of the Kumaon Himalaya, unexpectedly, corresponds with the improved monsoon episode of the Arabian Sea. The younger dry events (2000 – 1600, 740 – 640, and 400 – 250 cal yr BP), however, are closely comparable with weak monsoon episodes of the Arabian Sea.

5.2 SUB PROJECT

Geo-Database for Uttaranchal : an information system for environmental management and monitoring of Himalayan Geo-Resources.

(D. Pal, B.P. Sharma and A.K.L. Asthana)

Pithoragarh District lies between 29°4' to 30°3" N latitude and 80° to 81° E longitude in the eastern part of the Uttaranchal state. The Indo-Tibetan water divide in the north and the Kali river forms a continuous border with Nepal in the east. Pithoragarh District is surrounded by Almora, Champawat, Bageshwar and Chamoli districts and covers an area of 7,169 sq. kms.

The district is divided into five Tehsils viz Munsiari, Dharchula, Didihat, Gangolihat and Pithoragarh having its headquarters at Pithoragarh and the Kumaun commissionary head quarters at Nainital. There are 8 developmental blocks, 3 towns, 64 Nyaya Panchayats and 651 Gram Sabhas in the district. There are 1635 villages out of which 1568 are inhabited. As per 2001 census, total population of the district is 4,62,289 out of which 2,27,615 are males and 2,34,674 females. Literacy rate of the district at present is 61.4%.

Geologically, Pithoragarh district comprises four main geological units which are separated by different thrusts/ faults. These are Almora–Dudatoli Crystallines in southernmost part of the district (to the south of Saryu), calc zone of Tejam–Pithoragarh in the central parts (Jhulaghat–Pithoragarh-Bans–Gangolihat), Askot Crystallines to the north of calc zone of Pithoragarh (Askot and Muwani areas), and further north repeat of calc zone in Nachni-Didihat and Tejam-Kapkot areas. This entire sedimentary sequence of Lesser Himalaya is in direct contact with the Central Crystallines along the Main Central Thrust (MCT) passing through Chiplakot and Loharkhet. The Central Crystallines form Higher Himalaya and are mainly covered by glaciers and their snow melt gives birth to the perennial streams like Kali, Ramganga and Saryu. The northernmost part of the area exposes sedimentary sequence of Tethyan Himalaya starting from Pre- Cambrian to Eocene in Malla Johar area. Thus, the area has a unique geological entity exposing the Lesser Himalaya, Crystalline nappes, Central Himalaya and the Tethyan Himalaya. The Central Crystallines are dated around 1800 my, Lesser Himalaya exposing one of the most extensive stromatolitic sequence and the Tethyan Himalaya sequences are richly fossiliferous. The sedimentary sequence of Dewal Thal, Chandok and Gangolihat are quite rich in magnesite deposits and Askot Crystallines are quite rich in base metal mineralization as seen near Askot.

Pithoragath is quite rich in water resources, firstly the perennial streams coming down from the glaciers in the north and secondly several gads and natural springs oozing/ originating in the calc zone of Pithoragarh. Main stream pattern is linked to the three sets of joints/fracture pattern (1), NNE-SSW trending streams like Kali following typical tear faults in the Himalaya, (2), Rivers following the strikes WNW-ESE of the beds in the central parts (Saryu river from Kakrighat–Rameshwar-Ghat-Pancheshwar) and (3), perfect north-south trend (Ramganga and several third order streams in central parts. Availability of water throughout the year has become source of hydropower in Tanakpur-Banbasa, Goriganga (Jauljibi) projects and proposed mega project at Pancheshwar on Kali River.

Geomorphologically, Thal Kedar and Berinag form the highest areas dissected by streams like Ramganga and Saryu, glaciated region in the northern part forming higher Himalayan region (Panchuli, Milam and Nandadevi) and cold desertic Tethyan Himalaya of Lapthal and Lipulekh.

Seismically, this area has experienced of moderate to major earthquakes and their epicenters are falling on two lineaments firstly along Kali in Tanakpur, Lohaghat and Dharchula areas trending NNE-SSW and, secondly, along the Himalayan trend in Loharkhet, Girgaon Darma, Milam and Munsiary glaciated areas trending NNW-SSE.

Uttaranchal has a population of 84.49 lakhs. It has 13 districts and Champawat district is least populated with a population of 2.24 lakhs i.e. 2.64% while Pithoragarh district has a population of 462289 which is 5.45% of Uttaranchal. While highest population density is in Hardwar district i.e. 613 persons/sq km while Pithoragarh has 65 persons/sq km as per 2001 census.

Table 4. Yearwise literates and literacy rate in Pithoragarh.

Year	Literates			Literacy in Percentage		
	Male	Female	Total	Male	Female	Total
1971	98680	26640	125320	48.16	12.67	30.1
1981	141182	50015	191197	58.10	20.3	39.0
1991	137574	72504	210078	80.3	42.4	61.3
2001	172696	127102	299798	90.57	63.14	76.48

Blockwise literates and literacy rate in Pithoragarh District

Blocks	Literates			Literacy in Percentage		
	Male	Female	Total	Male	Female	Total
Munsiari	12647	4702	17349	70.2	27.4	49.4
Dharchula	15270	5493	20763	74.4	29.8	53.3
Berinag	14391	8122	22513	79.0	41.5	59.6
Didihat	10574	6149	16723	81.2	43.0	61.2
Kanalichhina	14566	9364	23930	84.2	48.1	65.1
Gangolihat	18581	8434	27015	72.2	30.6	50.7
Pithoragarh	20506	10837	31343	86.3	50.4	69.3
Munakot	15212	9349	24561	87.4	47.2	66.0
Total	**121747**	**62450**	**184197**	**79.0**	**39.6**	**59.1**

Literacy in women has increased considerably in the last 10 years as 2001 census data shows 63.14% women literacy in the District (Table 4).

The sex ratio (No. of female per 1000 males) of the state exhibits an impressive figures (964) which is increasing further. The sex ratio of Almora district is maximum (1146) while Hardwar recorded the lowest (868) in the State. Pithoragarh recorded sex ratio at1031 in 2001 census.

SUB PROJECT

Tectono-climatic studies in Alakhnanda valley near Deoprayag.

(Pradeep Srivastava, Jayant K. Tripathi, R. Islam, Manoj K. Jaiswal)

To understand the relative role of changing climate and tectonic conditions in the Himalaya, fluvial terraces preserved along the Alaknanda river in Uttaranchal Himalaya were investigated and the one located at Deoprayag were studied in greater detail. At Deoprayag in Alaknanda valley development of three major terraces namely T_0, T_1 was observed. Where T_0 is the present day riverbed and flood inundation level. T_1 is located 112 m above the channel. Recent to sub-recent flood deposits overlie unconformably over the slopes of T_1 terrace. Sedimentological analysis of the terrace deposits suggests that the terraces are made up of three major lithofacies *viz.*

1. Matrix supported gravel
   a) Matrix supported rounded boulders
   b) Matrix supported angular boulders
2. Yellow micaceous fine sand
3. Alternating sand-slit

Matrix supported rounded boulders are the deposits of river bed aggradation which matrix supported angular boulders are the debris flows or slope wash deposits. Yellow micaceous fine sand is channel bar deposit formed over the gravel bed during the waning floods. Alternating sand silt facies represents paleoflood deposits and are the archives of the past flood intensities.

Luminescence dating of the T_1 terrace deposits indicates that this phase of aggradation started before 21 ka and continued after 10 ka. This indicates that the major part of aggradation took place during the increased aridity of the Last Glacial Maxima (LGM) and incision took place due to increased precipitation after LGM. However tectonic upliftment along the splays of MBT or local fault might have created the accommodation space and higher river gradient to facilitate the incision. The chronology of the flood deposits indicated two phases of high flooding in Alaknanda at 300-200 year BP, 2.5-1.2 ka, and strath formation took place around 5.3 ka.

Weathering is required to dislodge the mineral grains from rocks for erosion and sedimentation processes. The extent of weathering defines the nature of the sediments, which is controlled by the climate and tectonics of the hinterland. Chemical Index of Alteration (CIA) of the sediments is a measure of the extent of chemical weathering. A-CN-K plots give insight into the weathering trends and therefore tectonic and climatic stability of the provenance. Using these parameters from the geochemistry of the sediments from different surfaces of Deoprayag terrace, it is indicated that the physical erosion of phyllite with high CIA value (75) is locally and dominantly contributed material and the chemistry of channel sediments shows predominantly the distal contributions. The CIA values also indicated that the floods responsible for the deposition of younger flood sequence were originated in the upper cathment of Alaknanda.

5.4 SUB PROJECT

Evolution of Late Quaternary deposits in the NW Himalaya.

(N. Suresh, Rohtash Kumar and S.J. Sangode)

The Late Quaternary alluvial fans and fluvial terraces in the tectonically active Pinjaur Dun were studied to unravel the tectonic and climatic control on their evolution. A series of alluvial fan deposits were observed in the area between Pinjaur in the east and Kiratpur in the west. The eastern sector of the valley is narrow (between Pinjaur and Nalagarh) than the western sector (between Nalagarh and Kiratpur). The alluvial fans are deposited in the footwall of the Nalagarh Thrust (NT), an imbricate thrust of MBT, and are oriented in the NE-SW direction. The hanging wall of NT is characterized by Tertiary rocks and streams originating from these Tertiary mountains is presently dissecting the fans from apex to toe. The alluvial fans are segmented into first order (Qf1) and second order (Qf2) fans with Qf1 at higher level from the modern stream than the younger Qf2. The first phase of fan lobe was dissected during the subsequent stream incision from the fan head and second phase of fan lobe was deposited below the intersection point in the medial zone of first phase of fan lobe. The cessation of second order (Qf2) fan deposition was followed by stream entrenchment interrupted by short depositional phases. These depositional fluvial surfaces are flat and not areally extensive and consist of a thin veneer of gravels and sandy sediments above the eroded fan remnants. Three levels of fluvial depositional terraces were deposited in the incised streams and they occur below the Qf2 surface. The multi-levels of fan and of terrace surfaces indicate the depositional phases are interrupted by incision phases. In the hanging wall of Nalagarh Thrust, small patches of these deposits are observed and are occurring at higher elevation than the alluvial fans in the footwall. The stratigraphy of these fan and terrace deposits was established using vertical logs constructed on the exposed cliff sections on the banks of the transverse flowing entrenched streams, roads and irrigation canal cuts. These sections provided longitudinal views from apex to toe and valley parallel fan exposures for the lateral and vertical variation in sediments (Fig. 23). The litho facies were identified and are broadly grouped into gravel, sand and mud and are divided into sub-facies based on clast or grain-size, degree of organisation, stratification, colour and bedding geometry. The ten lithofacies i.e., disorganized matrix-supported (G1), disorganized matrix- to clast- supported (G2), crudly stratified (G3) and cross-stratified (G4) gravels; pebbly (S3), medium to fine-grained, stratified (S1) and fine-grained, massive (S2) sand; massive silt to clay grade (M1), pedogenic (M2) and clay grade thinly laminated (M3) mud have been identified from the alluvial fans. In case of gravels, maximum, mean and model size of the clast, matrix-clast ratio, nature of matrix, sedimentary structure and composition of clast were noted. The fan profiles are constructed using Survey of India toposheets at 20 m contour interval. The alluvial fans in the eastern sector have higher elevation than the fans in the western sector. In the eastern sector the concavity and elevation of each fan gradually decreases from east to west, whereas in the western sector it gradually decreases from west to east. The depositional slopes of alluvial fans vary between 0.7° and 4.2° with multiple slopes representing two depositional lobes and are observed in both the eastern and western sectors. The chronostratigraphy of fans and terraces was established using optically stimulated luminescence (OSL) dating technique.

Chronostratigraphy of these deposits by quartz optically stimulated luminescence dating indicates that the Qf1 aggradational phase initiated well before 96.5±25.3 ka and stopped after 83.7± 16.3 ka. The Qf2 depositional phase initiated at 72.4±13.4 ka and continued till 24.5±4.9 ka. The terraces were deposited at 16.3±2.1 ka, 4.5 and 2 ka. The segmentation of fans suggests the depositiuonal phases are separated by incision phases and the Qf1 entrenchment occurred between 83.7± 16.3 ka and 72.4±13.4 ka and is coinciding with enhanced SW monsoon precipitation. The subsequent development of the Qf2 and its progradation till 20 ka suggest erosional unloading of the hanging wall during tectonically quiescent phase of NT. The toe cutting and recession of Qf2 around 45 ka and deposition of fluvio-lacustrine facies indicate basinward shift of the axial river due to base-level changes in response to the reactivation of NT. The calcrete bearing mud at the top of the Qf2 surface suggests the cessation of sedimentation occurred under arid climate during LGM. The prolonged stream incision since the cessation of Qf2, with minor depositional phases at 16.3±2.1, 4.5 and 2 ka, is resulted

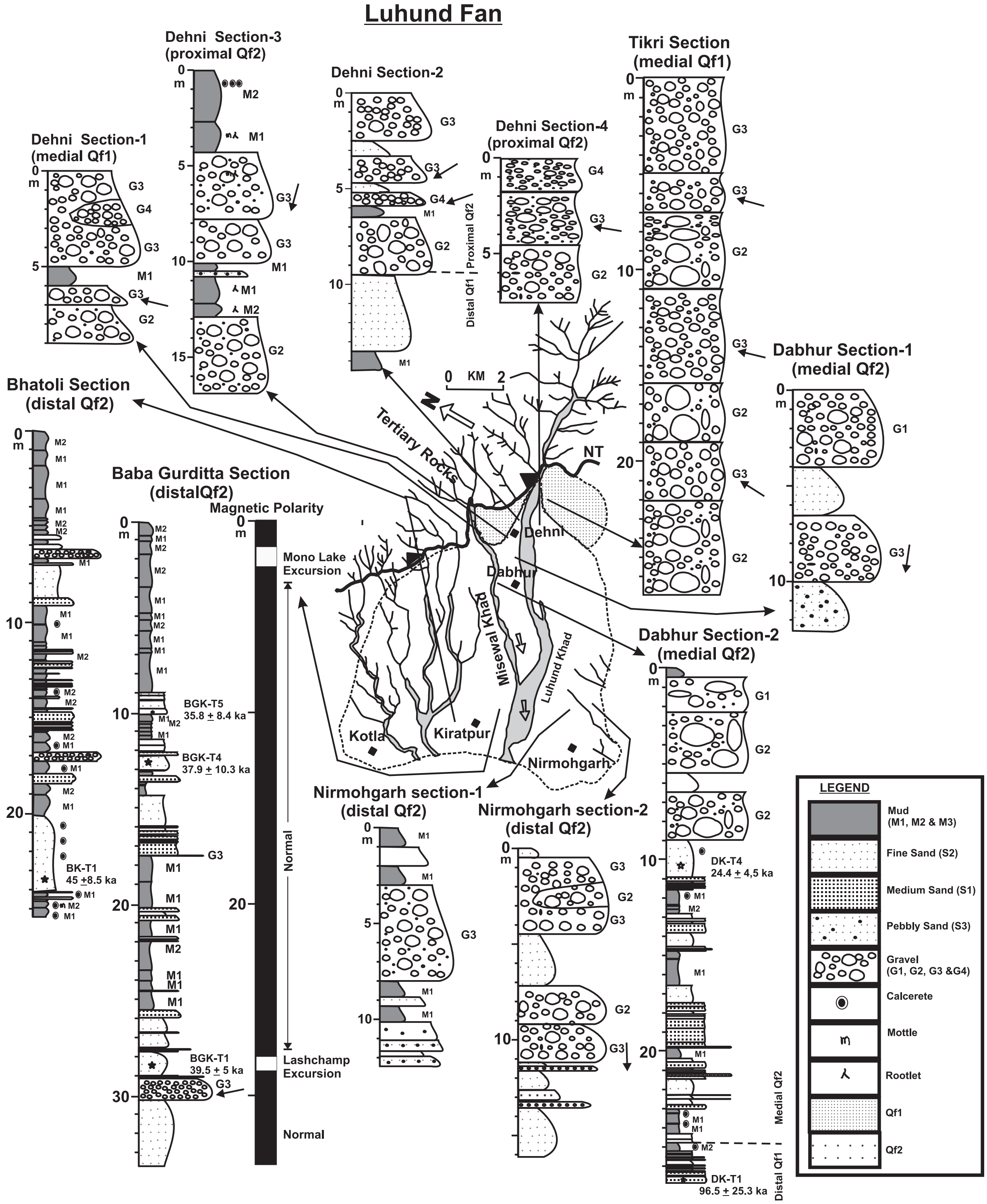

Fig. 23. Measured vertical sections with quartz luminescence ages for the Luhund Fan. The facies distribution shows the Qf1 is dominated by gravel facies whereas the Qf2 is dominated by gravel in the proximal fan to sand-mud-gravel in the medial fan to mud-sand in the distal fan region. The patchy outcrop of distal Qf1 facies are exposed beneath Qf2 with erosional contact in stream section (Dehni section-2 and Dabhur section-2). Palaeoflow directions are shown by arrow on the right of the logs. Magnetic polarity stratigraphy for the Baba Gurditta section shows two excursions.

from high water discharge and low sediment input during interglacial period intensification of SW monsoon. The stratigraphic evolution of alluvial fans and terrace deposits of the Pinjaur Dun suggests although tectonic processes exerted the dominant control on fan building pattern before and until 72 ka, climatic fluctuations with minor tectonic events may have been the most important factor since 72 ka for building the landscape of alluvial fans and terraces.

6. NORTHEAST HIMALAYA

6.1 SUB PROJECT

Kinematic history of the thrust sheets and metamorphic evolution of the crystallines of Western Arunachal Pradesh.

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

Field and lab studies of the various structural fabric elements reveal that the rocks of eastern Arunachal Pradesh have undergone three phases of deformation. The first phase of deformation has produced small-scale tight isoclinal folds which are intrafolial and rootless at the exposure level and can be best observed under the microscope. This phase of deformation has thickened the Himalayan mass of rocks. The second phase of deformation has produced isoclinal to slightly open types of folds, which are intrafolial in nature and exposed in mesoscopic scale. The third phase of deformation has produced the regional scale, broad open type of folds (eastern syntaxis) trending NNW-SSE, and along the axial plane of this folds minor as well as major faults have started to develop (Bame fault). During this phase of deformation, the eastern part of the eastern syntaxis has started moving towards NW due to the push from the SE block of Myanmar and as a result all the F_2 folds are dragged in nature. In the syn- to post- D_3 phase of deformation the eastern part of the eastern syntaxis has started to move up with respect to the western part of the eastern syntaxis. In this phase a set of strong stretching lineation trending NNW has been produced on a regional scale and can be observed in the central part of the eastern syntaxis, especially in the Siyom valley. In the eastern part of the syntaxis (Lohit and Dibang valleys) the stretching lineations are trending towards NE and near the Walong Thrust they are reflected in the NNE direction due to the northwestward movement of the southeastern block.

Four samples of quartzite have been analysed under 3 axis Universal stage for the c-axis orientation. The quartzite samples were collected from the western part of the syntaxis, viz., Siyom valley. In the field they are white in colour and shows a set of strong mineral lineation, which at places show minor undulations. In the XZ section they show mesocopic folds of second generation, which are mostly tight, asymmetric in nature and are sheared. Under the microscope, they exhibit medium grained, granular texture with partly formed elongated quartz ribbons. Quartz is the most predominant mineral present in the thin section with minor amount of muscovite and plagioclase as primary minerals. Weak to moderate development of schistosity is observed. Nearly 300-350 grains of second-generation quartz has been analysed from each sample. The results of the poles of quartz have been plotted in the lower hemisphere of equal area net. The stereo diagram of the samples show slightly elongated asymmetric maxima and can be cut by great circle, exhibiting monoclinic symmetry. The maxima are slightly oblique to the foliation plane, with a high density of c-axis in the center of the pole. The flexering of stereographic projection towards northern sector indicates a sense of movement from top to North.

Additional samples were collected from the Higher Himalayan Crystallines of Siyom valley to evaluate the metamorphic P-T conditions. Petrographic studies reveal the development of symplectitic corona of cordierite and quartz around garnet in the hanging wall of the MCT due to decompression reaction:

Garnet+Quartz+Sillimanite=Cordierite

The development of sillimanite is related to low to medium pressure-high temperature M2 metamorphism that overprints the early M1 kyanite bearing assemblage. The development of cordierite is related to the exhumation of HHC due to movement along MCT during M2 phase of metamorphism. Since the M2 metamorphism has affected the whole sequence, the P-T data across the HHC is highly variable. Detailed thermobarometric studies are in progress.

The geochemistry of the volcanic rocks and dykes that are associated with the ophiolitic mélange that are exposed in Siang (Tuting area), Dibang and Lohit valley sections of eastern Arunachal Pradesh have been analysed to understand their composition and to evaluate their source characteristics and environment of generation. The rocks of the ophilitic mélange occur as a tectonic unit between the HHC in SW and the subduction related Lohit Plutonic Complex (LPC) in the NE. The early thrust contact (Lohit Thrust) between the ophiolite and the LPC at present behaves as a dextral strike-slip fault. The ophiolitic mélange comprised of slices of serpentinised ultrabasic rocks, basic volcanics with minor acid volcanics (dacites), basic dykes, hornblende pegmatites and sedimentary rocks and out of these the basic volcanics dominate. The sequence is highly deformed and metamorphosed under green schist facies conditions. The HFS element concentrations and their ratios, along with the REE suggest that the volcanics from the ophiolitic mélange from the three sections show both island arc and MORB affinity. It is difficult to ascertain the tectonic setting of the ophiolite lavas, however, they represent an evolving oceanic crustal section in a subduction zone environment probably on the edge of the immature arc and the young arc like volcanics are superimposed on the ocean floor crust, thereby the MORB related sequence and the overlying island arc sequence were contiguous. This is attested by the field relationship; for example in Dibang valley section the ophiolitinc mélange consists of a basal peridotite,dunite intruded by basic dykes representing the mantle section that is overlain by volcanics of island arc affinity associated with dacites and sedimentary rocks. The dacites are the common feature in island arc environment. Since the whole sequence is highly deformed and imbricated the serpentinised peridotites occur as tectonic slices at different structural levels.

6.2 SUB PROJECT

Lithotectonic terranes and neotectonic features between the valley of Kameng and Siang rivers, Arunachal Pradesh.

(D.K. Misra and Trilochan Singh)

Geological mapping in the Kameng and Subansiri valleys of western Arunachal Pradesh reveals the existence of five thrust bound tectonostratigraphic units. From south to north these are : 1. Siwalik Group, 2. Gondwana Group, 3. Miri Group, 4. Bomdila Group and 5. Sela Group. The Siwalik Group comprises predominantly sandstone and shale which override the Brahmaputra alluvium along the Himalayan Frontal Thrust (HFT) and is overthrust by the rocks of the Gondwana Group along the Main Boundary Thrust (MBT). The Gondwana Group consists mainly of shale, sandstone and diamictite. It is overthrust by quartzite and carbonate association of the Miri Group along the Miri Thrust. The Miri Group is overthrust by the Bomdila Group, which consists of low to medium grade metamorphics and foliated micaceous quartzite. High grade metamorphics of the Central Crystallines (Sela Group) of Higher Himalayan Zone overlay the Bomdila Group along the Main Central Thrust (MCT). Field studies coupled with interpretation of topographic maps resulted in the identification and delineation of NW-SE trending active faults. Movements along these faults are responsible for abrupt rise of mountain front, occurrence of planar scarp and triangular facets, recent landslides, uplifted fluvial terraces and pounding of streams. Along the tectonic contact (HFT), there is an abrupt rise of 2000 m high mountain from a flat area of the Brahmaputra alluvial plain. The south facing slope of the mountain is uncommonly smooth and cut by multiple landslide scars and ungullied fresh triangular fault facets devoid of vegetation. The junction between flat plain area and mountain front is almost straight. All these evidences and facts indicate neotectonic activity along the Himalayan Frontal Thrust.

In the Kameng valley, a major 10 km long transverse active fault namely Bhalukpong Fault has been recognized. It is responsible for 90 m uplift of the western Bhalukpong Block towards the footwall side of the fault. At Bhalukpong there are four prominent levels of the river terraces. The older T_1 (220 m above m.s.l.) has been raised by 90 m, the T_2 (210 m above m.s.l.) by 80 m, the T_3 (200m above m.s.l.) by 70m and T_4 (160 m above m.s.l.) by 30 m with respect to Kameng river bed (130 m above m.s.l.). This indicates that the western (Bhalukpong side) block across the fault has been lifted up by 90 m in four pulses. Recent movements along the fault are also responsible for existence of fresh landslide devoid of gullies and vegetation on the eastern side of the fault.

In the Subansiri valley, there is another 10 km long Hawa Camp Fault which trends NW-SE and follows the straight course of the Panyar river. It is responsible for 20 m uplift of fluvial terrace and recent unfurrowed landslide towards the eastern side of the fault. In the central part of the Subansiri valley, the 16 km long NW-SE trending Joram Fault lies within the Bomdila Group. Movements in the geologically recent time on this fault have caused blockade of the Kale river and resulted in the formation of a lake at Ziro. The lake has now vanished due to revival of the neotectonic activity. The NNW-SSE trending palaeolake contains 50 m thick deposists at an altitude of 1600 m above m.s.l. These sediments extend for nearly 15 km in length and has a width of about 5 km.

6.3 SUB PROJECT

The terminal Proterozoic-Lower Palaeozoic sedimentation, palaeo-biological and carbon isotope events in the NE Lesser Himalaya.

(V.C. Tewari)

Field work was done in the month of November 2005 in the Rangit window around Namchi and Namchi–Wak sections of the south and west Sikkim Lesser Himalaya. Each studied section is briefly described below.

Reshi- Kehlu Road Section

This section is about 500 m thick and well developed in the Rangit valley. Buxa Dolomite is exposed along the road.

The dolomite is massive, bedded, stromatolitic, cherty and intraclastic- oolitic in nature. There are various types of stromatolites (columnar Conophyton type stratified, columnar branching type and domal forms). There is change in morphology from the base to top of the sequence, and, in sequence stratigraphic concept, each buildup shows a sequence boundary separated by a surface of discontinuity/ short break in sedimentation. Detailed lithologs were prepared and systematic samples were collected for laboratory studies.

Namchi – Sallebugh Road Section

This road section from Namchi town to Sallebugh village shows good outcrops of the Lower Gondwana Formation (Namchi Sandstone and coal beds with black shales) which bears a tectonic contact with the Buxa Dolomite (Meso-Neoproterozoic). The purple, pink limestone and shale sequence of the lower part grades into dark bluish cherty dolomite. The dolomite is about 500 m thick. Lithologs were prepared and samples of dolomite and chert were collected for laboratory investigations.

Namchi – Wak Section

A well developed large size *Conophyton* buildup (typical of Middle Riphean) is observed in the Lower part of the Buxa bluish grey dolomite. The diameter of the transverse section ranges from 10cm to 70cm. This is a very large buildup not recorded so far from the Buxa Dolomite anywhere in the eastern Himalaya. The transverse section is typically augen shaped characteristic of *Conophyton garganicus*. The stromatolitic laminae are also cherty. The chert has also yielded cyanobacterial remains of filamentoue and cocoidal palaeobiological forms.

Carbonate, chert and stromatolite samples collected in the field were processed in the laboratory. Thin sections, thick sections and polished samples of the carbonates and stromatolites were studied for petrography, mineralogy, biota and stromatolite morphological variations. Microfacies analysis of limestone, dolomite, allochemical constituents (oolites, intraclasts, pellets, coated grains etc. Fig. 24a) were carried out. X-ray diffraction study of the calcite, dolomite, siderite, quartz minerals has been done. Stained sections with Alizarine Red S and KCN were studied for mineralogy and ferron dolomite determination. The biota recognized in petrographic thin sections include *Obruchevella eomycetopsis, myxoccoides* (Fig. 24b). The various types of oolites have been studied for diagenetic alteration and depositional environment. Depositional model of the buxa dolomite has been reconstructed on the basis of variation in the sedimentary facies, microbialites, oolites and sedimentary structures in the field (Fig. 25).

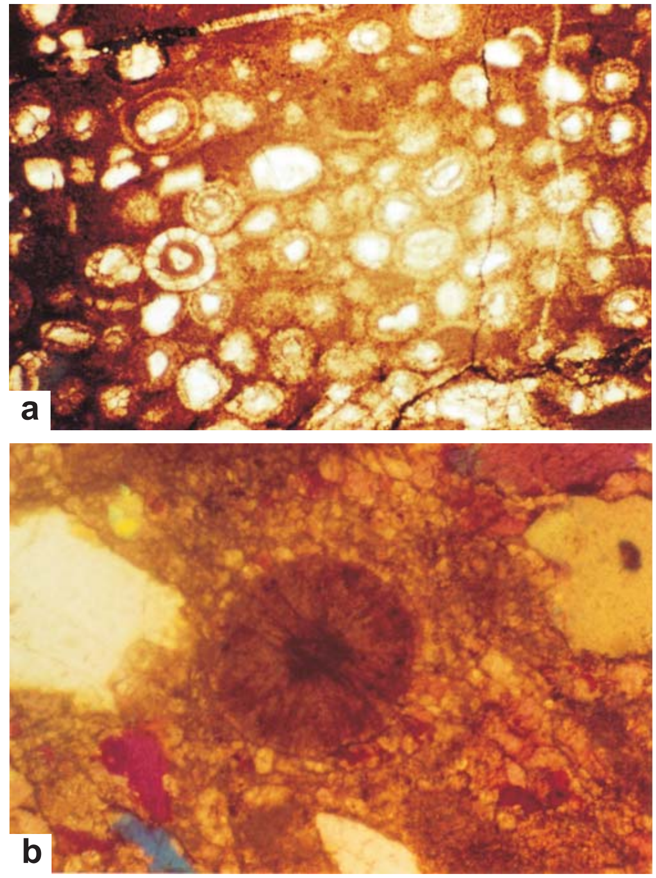

Fig. 24. a. Concentric and radial oolites in the Buxa Dolomite, Ranjit Window, Sikkim. **b.** Enlargement of a concentric cum radial oolite showing diagenetic replacement in the outer margins.

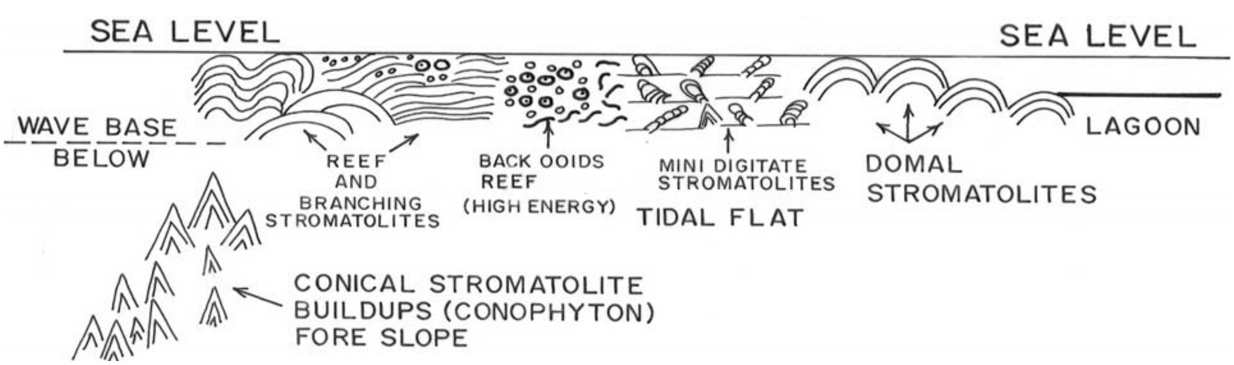

Fig.25. Depositional environment of the Stromatolitic Buxa Dolomite, Sikkim.

PROGRESS IN RESEARCH PROJECTS

6.4 SUB PROJECT

Geochemical characterization and petrogenetic studies of Abor volcanics in Arunachal Himalaya.

(A. Krishnakanta Singh)

The core of the Siang Window of Eastern Himalayan Syntaxial Bend exhibits the presence of thick pile of volcano-sedimentary sequences. The mafic volcanic rocks are dominated by basalt with subordinate basaltic andesite and agglomeratic basalt. The pyroclastics present a range varying from coarse agglomerates to volcanic bombs, lapillies and coarse ash. The pillows are predominantly associated with the basal parts of the basaltic flows and the sizes of individual pillows are varying from 8 cm to 80 cm in diameter. The presence of spherical bomb and lapillies indicate that the liquid bled are sufficiently fluid when the molten lava was ejected (Fig. 26a). Sub-aqueous and violent eruption nature of volcanism are indicated by the presence of pillow structures and pyroclastics, respectively (Fig. 26b). The relatively higher proportions of pyroclastics at places are indicative of a violent and abrupt explosive activity. At places, the volcanics contain interflow sediments comprising quartz arenite, shale and dolomitic limestone which is suggestive of quiescent periods during the volcanism. The metamorphism and deformation are generally of low intensity.

The basaltic rocks are predominantly of subalkaline-tholeiitic affinity with minor alkaline affinity. Petrographically, tholeiitic basalt exhibits subophitic, glomeroporphyritic, intergranular, intersertal and trachytic textures and consists of plagioclase (An_{57}-An_{43}), pyroxene (augite-pigeonite), Fe-Ti oxides (magnetite, ilmenite) and volcanic glasses, whereas alkaline basalt is characterized by the presence of alkali feldspar phenocrysts and absence of plagioclase phenocryst; groundmass is composed of clinopyroxene, plagioclase, alkali amphibole, apatite, titanite, feldspar, epidote, Fe-Ti oxides exhibiting intergranular to intersertal and variolitic textures with occasionally sub-ophiolitic texture. The tholeiitic basalt is enriched in large ion lithophile elements (LILE), light rare earth elements (LREE), depleted in high field strength elements (HFSE) and REE fractionated nature [$(La/Yb)_N$ = 3.01-7.47)] along with insignificant Eu anomaly which illustrate close similarity with low-Ti basalt (Ti/Y <500) (Fig. 26c). Alkali basalt shows significantly high value of TiO_2, P_2O_5, K_2O, Rb, Sr, Ba, Zr, Th; depleted in SiO_2, Na_2O, Al_2O_3 and Fe_2O_3 which is identified as high-Ti basalt (Ti/Y >500). It has extremely enriched in REE [ΣREE (515-779.29)] with strongly fractionated REE abundances [(La/Yb_N) = 26.34-44.10] (Fig. 26c). Enrichment of incompatible elements and LREE in alkaline basalt suggest that the source

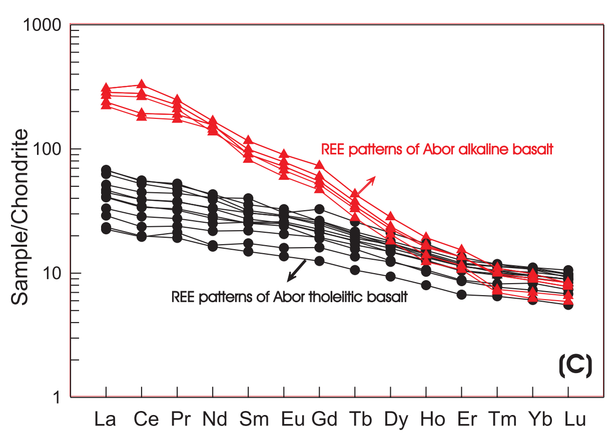

Fig.26. **Field photographs of Abor volcanics, Arunachal Himalaya (a). Lapilli bed overlain by massive basaltic flow near Dite Dime (Lat. 28021/ & Long. 95002/) (b). Pillow lavas near Dite Dime (Lat. 28^0 23 & Long. 95^0 04') (c). Chondrite normalized REE patterns of Abor tholeiitic and Alkaline basalt.**

was affected by a melt phase enrichment and compatible with H_2O or CO_2 rich fluid phase metasomatism in the mantle. Similarity in immobile trace element compositions together with their ratio (rock)/ratio (PM) and normalized multi-element abundances reveal their cogenetic nature. Geochemical and petrogenetic studies suggest that they might have generated from enriched mantle source by multi-stage metasomatic processes with varying degrees of partial melting and they display clear cut continental setting in its geological set up.

6.5 SUB PROJECT

Foraminiferal Biostratigraphy and Paleoecology of the Tertiary sediments of parts of Nagaland, Mizoram and Arunachal Pradesh.

(Kapesa Lokho)

A detailed foraminiferal biostratigraphy and paleoecology studies have been carried out on Upper Disang Group in the south-central part of Nagaland. 54 foraminiferal species belonging to 29 genera, 23 families, 17 superfamilies and 5 suborders have been identified. Of the total species, 16 are planktic and 38 are benthonic forms. Three foraminiferal biozones have been established based on the first appearances and last occurrences of marker species and their ranges. They are *Globigerinatheka semiinvoluta* Zone (Zone P15), *Cribrohantkenina inflata* Zone (Zone P16) and *Turborotalia cerroazulensis* Zone (Zone P17).

Haq *et al.* (1988) suggested a global drop of sea-level around 80m during Late Eocene. The deeper part of upper bathyal setup during upper Disang was due to rapid subsidence. Literature on the geology of Mizoram reveals that not much work has been carried out so far. It may be due to inaccessibility of the terrain and lack of ready to take economic mineral content. Field studies were carried out along Aizawl-Champhai and Aizwal-Kolasib road sections and within the Aizwal town. Samples collected were processed for various laboratory investigations. The present work report the findings of planktonic foraminifera along with a few ostracodes from a shale bed of Bhuban Formation of Mizoram for the first time. Identification, foraminiferal biostratigraphy and paleoenvironment studies are under process.

6.6 SUB PROJECT

Neotectonic investigation of a part of Arunachal Himalaya between MBT and HFF in East and West Sinag Districts, Arunachal Pradesh.

(S.S. Bhakuni and Khayingshing Luirei)

In the frontal part of the Eastern Syntaxial Bend (ESB) structure, Arunachal Pradesh, the MBT and HFT represent the folded structures. The major part of the ESB forms the NNW plunging Siang antiform along the Siang River valley. The imbricate zones of the MBT and HFT are characterized by active brittle thrusts, normal and strike-slip fault systems. Hanging wall bed rotation along these later thrusts/faults has caused significant variations in attitudes of bedding planes. The trace of the HFT between the Sub-Himalaya and the Brahmaputra alluvium is not very clear in the field. This contact seems to be rather tectonic geomorphic boundary. Along the basal parts of the hanging walls of the MBT and HFT the rocks show superposed deformation. The MBT is offset by active transverse N-S trending tear faults.

The steeply dipping brittle normal faults are the latest gravity collapse structures, which have developed after the thrust movement has locked. River terraces show up warping due to active fault propagation folding in bedrocks of hanging wall of the MBT. The extensional tectonics has played on important role in the development of sites for the deposition of the Quaternary sediments. The implication of this active tectonics is that this process seems to have reduced the transportation of sediment flux, being eroded from the Himalaya, into the Bay of Bengal.

The study area is criss-crossed by a number of lineaments, which have pronounced impact on the geomorphology. The lineaments fall into two maxima, one falling between N30°E and N60°E and the other between N 60° W and W. The values of mountain front sinuosity index have been calculated by using 1:50,000 topographic map of Survey of India for a length of 25 km between Bote and Sileng rivers. These values range between 1.114 and 1.657, which along with the incised vertical valley-slopes of streams suggest the recent tectonics along the HFT.

Along Pasighat-Roing section five levels of fluvial terraces rest over the inclined beds of the Upper and Middle Siwaliks. The incision of the fan deposits and steep scarps suggest that not only the recent tectonic activity has played an important role but the climate is also responsible for their development. Soft sediment deformational structures are preserved in the lacustrine deposits at Soro village in the Ziro valley in Lesser Himalaya. These structures seem to be developed by the change of state of sediments from grain supported to fluid supported matrix due to application of the external tectonic force. The earthquake-induced liquefaction process is proposed for the origin of these structures.

SPONSORED RESEARCH PROJECTS

PROJECT

Field, model deformation, petrofabric and magnetic strain studies along frontal and oblique ramps of the western Himalaya.

(DST-SERC-Earth Sciences)

(A.K. Dubey)

A great earthquake of Mw = 7.0 magnitude occurred in the Kangra region on April 4, 1905. The triggering mechanism of the earthquake was regarded as thrusting along the MBT. Middlemiss (1910) prepared a detailed report on the earthquake in which the isoseismals showed two zones of relatively high intensity. The maximum intensity was reported near Kangra and Dharamsala (i.e. frontal ramp of the Kangra Recess; Dubey *et al.*, 2004) and minor intensity around Dehra Dun (i.e. oblique ramp of the Dehra Dun recess). However the intervening area of the Kangra oblique ramp did not suffer much devastation. The report was later analyzed by Molnar (1987) but what he missed in the report was the hard core ground fact that in sharp contrast to the Kangra region, the Dehra Dun region underwent normal faulting. The precision leveling measurements by the Survey of India, immediately after the earthquake, clearly showed coseismic uplift of Dehra Dun (i.e. footwall of the MBT, south of the fault) by an amount of +0.44ft (=13.41cm) as compared to Mussoorie (i.e. hanging wall of the MBT, north of the fault). The observation was later confirmed by Rajal et al. (1986) based on the precision leveling data for the Doon valley collected during pre (up to 1904) and post (May 1905) Kangra earthquake. The data revealed that the fault displacement was undoubtedly of normal fault type along the Dehra Dun oblique ramp. The conclusion is further supported by the present study compelling for an interpretation of the earthquake based on combination of thrusting and normal faulting. Bilham and Wallace (2005) have described the Survey of India leveling data as untrustworthy because it contains incontrovertible correlation between height change and elevation and they inferred that after taking account of the vertical errors in the leveling data, "no significant vertical deformation remains". Perhaps they meant vertical displacement by the term "vertical deformation". The geological observations are in favour of normal faulting as the youngest event although they do not provide the precise age data. Presence of normal faults in the un-indurated terrace sediments of the foothill belt confirms normal faulting as the youngest event (Rautela and Sati, 1996; Kandpal et al., 2006). Srivastava and John (1999) have also reported vertical extensional master joints and conjugate set of normal faults trending nearly parallel to the trend of the oblique ramps. These faults were described as younger than the thrusts. The dynamic analysis of these faults revealed subvertical maximum compression and subhorizontal minimum compression. The conclusion is also confirmed by the present studies and this compels us for an interpretation of the earthquake based on a combination of thrusting and normal faulting. Notwithstanding the dilemma of reliability of the Survey of India data, three options remain; (i) normal faulting along the Dehra Dun Recess was simultaneous with thrusting at Kangra; (ii) Kangra and Dehra Dun (1905) were two different earthquakes (Hough *et al.* 2005). The Kangra earthquake destabilized the region and the accumulated strain on the Dehra Dun oblique ramp were released by normal faulting, or (iii) no significant vertical displacement took place in Dehra Dun region during the earthquake because the stress orientation at the adjacent MBT oblique ramp was suitable for normal faulting and not for thrusting. The present study demands a continuous monitoring of seismicity around the region because increase in intensity of the superposed deformation can lead to normal faulting and another great earthquake in the Kangra Recess (Dubey 2004).

PROJECT

Petrogenesis and Tectonic Significance of Igneous Rocks Associated with Permian Argillites of southeast Karakoram.

(DST-Deep Continental Studies)

(H.Rai, D.R. Rao)

The Aq Tash Formation is exposed along the upper Shyok valley in the southeast Karakoram of Ladakh district. This is a volcanic dominated formation where rocks range in composition from basalt to dacite. Eruptions were underwater and accompanied by sedimentation which is evident from the pebbles to boulders within the volcanic flows and clastic deposits measuring 1-3 m within different flows. Clast composition is dominated by limestone; however, clasts of quartzite, sandstone and volcanics are present in different proportions at different places. Clasts are stratified, angular to subrounded and floating in the carbonate dominated matrix. The basin developed as a trough adjacent to the Saser Brangsa Formation (Carboniferous) as indicated by the dominance of clasts derived from this formation (Carboniferous is the oldest sedimentary sequence in Karakoram). The development of trough may be representing the Permian rifting as there was no orogeny at that time along the southern margin of Eurasia due to southward migration of Gondwana land. From the studies carried out it is concluded that (i) The Aq Tash formation has nearly 90% carbonate clast. Most of the clasts are rounded to subrounded, indicative of high energy and near source, (ii) The association of carbonate rocks, red shale and conglomerate suggest shallower depth of the basin as compared to black argillite sequence of Permo - Carboniferous age, (iii) Volcanic signatures point to a within-plate eruption, and (iv) The basin developed in response to a rift phase along the southern continental margin of Eurasian Plate during the opening of Neo-Tethys.

PROJECT

Ultrahigh-Pressure Metamorphism in Tso-Morari Region, Ladakh Himalaya: Implications for Deep Crustal Processes in Himalaya.

(DST-Deep Continental Studies)

(H.K. Sachan)

The detailed mineralogy and mineral chemistry of host rock is carried out. The preliminary study indicates that the gneissic rock along with the basaltic material have converted into eclogite and eclogitic metasediments. The interpretation of mineral chemistry data is in progress. For the first time presence of phengite in host rock of eclogite in thin section has been noticed and also confirmed by EPMA. The zircon inclusion mineralogy is also giving indication of the presence of high–pressure mineral. The geochemical signature indicates that the protolith of UHP eclogite are basic dyke which were traversing through th northern margin of Indian Plate.

PROJECT

Biostratigraphical study of the Upper Palaeozoic–Mesozoic Succession of the Eastern Karakoram and its Correlation with Adjacent Regions.

(DST-SERC-Earth Sciences)

(K. P. Juyal)

The detailed biostratigraphic work was carried out in the lower and upper Shyok areas. The summary of the work is given below.

Lower Shyok Area: (Hundiri Formation : Aptian – Albian)

Biostratigraphic work was carried out in three sections of the Hundiri Formation (Aptian-Albian), namely, Dosam, Sukur Nala and Hore Sostan. Former two sections did not yield Orbitolina fauna. The arc sequence in the lower Shyok area comprises volcanics (Shyok Volcanics) and intra-arc basin sediments (Hundiri, Saltoro Flysch and Saltoro Molasse formations). Biostratigraphic investigations indicate that this lithounit contains several Aptian-early Albian orbitolinids comprising *Mesorbitolina, Orbitolina, Praeorbitolina, Palorbitolinoides, Palorbitolina, ?Neorbitolinopsis* and *Paracoskinolina*. The orbitolinid taxa from the Shyok tectonic belt are comparable with those known to occur in Ladakh, Chitral, Burzil Pass (Indo-Pak region), Afghanistan, South Tibet and Myanmar. The fossil data suggests the existence of transgressive Neo-Tethys sea during Early Cretaceous times north of the Indian Plate.Besides these larger foraminiferal taxa, algae as well as smaller foraminifera, bryozoans, corals and rudist (molluscs) were also encountered.

After the deposition of the Hundiri Formation, the sea regressed towards the south in the ITS zone from the area due to tectonic activity. This was followed by deposition of the molassic Saltoro Formation in the post-Albian times. The data suggests that India-Asia collision took place along the Shyok Suture after the deposition of marine Hundiri and Saltoro Flysch formations in the terminal part of Albian times (93.5 Ma).

In the Shyok tectonic belt, the earlier phase of magmatism is related to late Triassic-early Cretaceous subduction. The site of subduction shifted to the Indo-Tsangpo Suture Zone in which the subduction continued up to early late Ypresian times (50 Ma).

Upper Shyok area : (Burtsa Formation: Rhaetian - ? Maastrichtian)

From perusal of fossil assemblages from the Burtsa Formation in eastern Karakoram, it appears that from Carnian-Rhaetian times, sediments were deposited on shallow marine carbonate shelf of Karakoram microplate, which formed a part of North Tethys margin facing towards the south. Similarly, the carbonates were also being deposited at the south Tethys (at the edge of northern margin of the Indian plate). The faunal evidence indicates that the North and South Tethys margins were well connected by shallow sea routes permitting migration of fauna. Further from Lias to ? Campanian times, there was a continuous sedimentation on the carbonate shelf of eastern Karakoram. Faunal similarity existed during early Liassic time between eastern and western Karakoram. Fauna of eastern Karakoram does not compare with that of the Indian passive margin during Jurassic - ? mid-Maastrichtian interval. It suggests that the two plates were perhaps far from each other during this time. However, from late ? Maastrichtian onwards, fossil assemblages of the Tethys Karakoram became similar to that of the Zanskar Tethyan zone. It appears that during this time the Indian plate came very close to the Karakoram microplate.

PROJECT

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

(DST-SERC Studies)

(S.K. Parcha, Shivani Pandey and S. V. Sabnis)

During this period the faunal data collected earlier from the Parahio and Pin sections of the Spiti region were scanned and among them one trilobite genus was selected for detailed morphometric analysis. Thirty cranidial variables were measured which are yet to be measured through the software in order to create multi-parametric data for statistical analysis.

PROJECT

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

(NSF-National Science Foundation,USA)

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

The Cambrian Parahio Formation in the Zanskar valley consists of dominantly siliciclastic marine Cambrian deposits. The Cambrian succession is capped by a dominantly siliciclastic upward coarsening unit that is overlain by a regionally extensive unconformity and overlying Conglomerate of early Ordovician. Trilobite bearing limestone beds represent thin transgressive system tract deposits developed over marine flooding surface. Paleocurrent data for marine and fluvial facies of the Parahio Formation of the Zanskar and Spiti valleys to the south indicate northeast sediment transport. The nature of the Cambrian–Ordovician boundary unconformity is yet unresolved.

PROJECT

Mineralogical and Geochemical Studies of Sediments from the Kakara-Subathu Succession (Paleocene to Middle Eocene), NW Himalayan Foothills.

(DST-SERC-Earth Sciences)

(N. Siva Siddaiah)

Berthierine/chamositic ironstones have been found at the base of the Subathu formation in Dogadda area. The berthroid ironstone is about 3 m wide, fine-grained and highly indurated. The ironstone is composed of mostly berthierine/ chamosite. Berhierine/chamosite occurs both as ooids as well as groundmass. It also consists of very coarse-grained highly angular crystals of quartz. It consists dominantly of Fe_2O_3 (38.48 to 59.61 wt %), Al_2O_3 (12.36 to 15.48 wt %), and SiO_2 contents are relatively low (13.23 to 33.47 wt %). The ironstone units have 340 ppm of total REE. Variation in the total amount of the REE is generally small. The chondrite-normalised REE patterns show a pronounced negative Eu anomaly (Eu/Eu*=0.6) and an enrichment of LREE. The mineralogy and geochemical data suggest that the berthierine/chamositic ironstone contains a part of the volcanic origin. The stratigraphic position of the ironstone unit is very significant, since volcanic ash beds have been found in the coeval beds elsewhere in the foreland basin. The berthierine ironstones developed in shallow water in brackish to proximal marine environments on sediment-starved shelf areas.

PROJECT

Active Faults and Neotectonic Activity (with reference to Seismic Hazards) in Parts of the Frontal Himalaya and the Piedmont Zone Between Satluj and Yamuna (AFNAH)

(DST-Seismicity Programme)

(N.S. Virdi and G. Philip)

Research activity under the project focused on the following three aspects:

i. **Mapping of active faults and neotectonic features in the western Doon valley, Pinjaur and Soan Duns and, along the Himalayan Front adjacent to the HFT using remote sensing supported by field investigations.**

Emphasis was laid on the Nahan Thrust (= Markanda Thrust) and its extension in the northern Doon valley where the active nature is reflected by thrusting of Lower Siwalik sandstone and mudstones over the Quaternary Doon gravels, and river terraces cut on the fans. At the thrust base in the footwall, the terraces at Malonwala, Bhur villages in the Markanda valley and at Phandi, Jamunwala, Maihar and Doiwala villages in the Bata valley are tilted towards north by 10-15°. The Nahan Thrust is displaced by a number of tear faults in the Bata valley and due to this the width of the basin is 3-4 km in the east as compared to 0.5 to 1km in the west. The Bata fault reported by us earlier is now traced eastward up to Augiala and Khara. The fault has caused uplift of the northern block by 25-30m.

Another interesting feature mapped by us is a piggy back basin containing Quaternary material and riding over the Markanda Thrust around Parduni. The basin covering an area of 12 km^2 approximately is bound by Marhar (dextral) and Chandpur (sinistral) tear faults. The basin fill rests with a profound unconformity over the Siwalik sandstone and mudstone dipping NE. The northern margin is also tectonic with Siwaliks thrust over the fans and terraces. North of Parduni and Jamunwala the terraces of Nimbuwala and Panchbhaya Khalas are tilted 15°-20° due NNE or NE. Parduni basin is now isolated from the main Doon basin due to uplift along the Markanda Thrust and Bata Fault and is well displayed on the satellite images (Fig. 27).

ii. Apart from reassessment of earlier recorded case histories of neotectonic activity and its control on drainage changes e.g. Giri at Renuka, Amlava at Kalsi, we have recorded eight more sites and include diversion/capture in the Giri, Bata, Markanda and Sirsa valleys. At all the sites neotectonic activity has played a significant role not only in controlling the new channels but also caused uplift/subsidence of terrain, creation of wind gaps and water gaps.

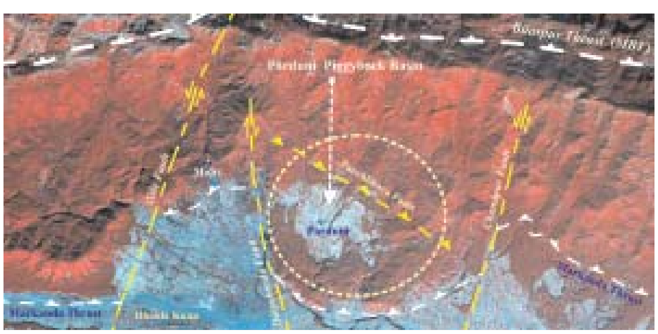

Fig. 27. IRS-LISS-III image showing the Parduni piggyback basin and its relation with major tectonic features in the Bata river valley.

iii. Tectonic tilting of drainage basins of Bata-Markanda inferred on the basis of topographic features and drainage pattern has been quantified by calculation of geomorphic parameters such as Basin Asymmetry Factor (AF) and Transverse Topographic Symmetry Factor (T) and ratio of valley floor width to valley height (V_t) for these two valleys. AF and T values have also been calculated for Sirsa, Ghaggar, Jhajra and Soan basins (Table 5).

Table 5. Morphometric parameters of different drainage subbasins in the Frontal Himalaya.

	Basin	Flow direction	AF	T
i	Bata	East	25.69	0.77
ii	Markanda	west	89.34	0.67
iii	Ghaggar	west	86.65	0.75
iv	Jhajra	east	8.6	0.80
v	Sirsa	west	88.00	0.76
vi	Soan	east	38.00	0.40

The overall pattern of AF and T values indicates tilting of all the basins to the SSW i.e. almost perpendicular to the Himalayan strike or the axial streams. This is further confirmed by the longer tributary streams flowing from north to south then those flowing due north.

PROJECT

Inventory of Glaciers and Glacial Lakes and Identification of Potential Glacial Lake Outburst Floods (GLOFs) Affected by Global Warming in the Mountains of Uttaranchal Himalaya.

(WIHG-ICIMOD Project)

(M.P. Sah and G.Philip)

Wadia Institute of Himalayan Geology (WIHG) and International Center for Integrated Mountain Development (ICIMOD, Nepal) jointly prepared an inventory of Glaciers and Glacial Lakes of Uttaranchal Himalaya. A digital database of glaciers and glacial lakes for all the eleven river basins of Uttaranchal State was prepared on the basis of Landsat-7 ETM+ satellite images of October and November

SPONSORED RESEARCH PROJECTS

2003 and other ground surveyed maps. For the glacier inventory, the methodology developed by the Temporary Technical Secretariat (TTS) for the World Glacier Inventory (Muller *et al.* 1977), and for the glacial lake inventory the methodology developed by the Lanzhou Institute of Glaciology and Geocryology (LIGG) (LIGG/WECS/NEA 1988) was used with some modification. Glaciers and glacial lakes were digitized on geo-referenced satellite images using Ilwis 3.2 software package. The glacier inventory was prepared for all the eleven river basins identified in Uttaranchal. The present study indicates that there are 1439 glaciers inventoried within the Uttaranchal State, which cover an area of 4060 sq km besides 127 glacial lakes with a total area of 2.49 sq km. Although there are no major GLOF events documented in the historical past in Uttaranchal, few supra-glacial lakes are in the threshold of development in some of the glacier tongue.

PROJECT

Neotectonic-Active tectonics of 1905 Kangra earthquake meizoseismal region in Kangra and Soan Dun in Himachal Pradesh, NW Himalaya.

(CSIR Emeritus Scientist Scheme)

(V.C. Thakur)

Reconnaissance study of Kangra, Dharamsala and Soan Dun areas was undertaken and training was imparted to 2 research students working in the project on geological mapping in Siwalik and post-Siwalik late Quaternary sediments. In the 1905 Kangra earthquake meizoseismal region, several northwest-southeast trending active faults were mapped. The Kangra valley is partially developed, half Dun made of Siwalik of the Kangra-Jawalamukhi range to the south and the Dhauladhar range spur to the north comprising Dharamsala Formation. The Siwalik strata dip northeast and are overlain by post-Siwalik late Quaternary sediments. The late Quaternary sediments constitute the Dharamsala fan trending north-south. The late Quaternary sediments are composed of unassorted gravels with matrix of clay to sand fractions, with pebbles and boulders of Dharamsala sandstone, phyllite and Dhauladhar granite. Lithostratigraphy of the post-Siwalik Bhagsu Formation has been established and structural framework has been worked out to explain the evolution of half Dun. In Soan Dun area, geological mapping was undertaken across the Janauri anticline and Soan Dun syncline. The Soan Thrust demarcates the northern boundary of the Soan Dun separating the sand and conglomerate of the Siwalik from the post-Siwalik Una Formation of late Quaternary age. The Janauri anticline is a broad open fold plunging southeast. The Soan Dun and Frontal Siwalik Range show active deformation features.

PROJECT

HIM-SCOPE (Himalayan School Observation Programme) in Earthquakes under Mission Mode Project on Seismology-An Awareness Programme.

(DST-Mission Mode Programme on Seismology)

(A.K. Mahajan)

The Department of Science and Technology, Government of India has initiated a project on Himalayan School Earthquake Laboratory Programme (HIMSELP) under Mission Mode Project in Seismology for Northwest Himalaya and Northeast Himalaya. The Wadia Institute of Himalayan Geology has been the nodal agency for implementing this project in NW Himalaya and Delhi area. The main objective of the programme is to make the students aware about the earthquake and to inculcate the culture of prevention among the younger generation. Towards this, the science teachers in the schools have been trained in basics of seismology. Under this programme 25 instruments have been installed in Uttaranchal. We have been able to record the Kashmir earthquake successfully at three locations, where instruments were installed before the triggering of the earthquake. The work of installation is in progress in Himachal. Recently five schools have been selected from Delhi area and five schools in Jammu region under this programme.

PROJECT

Palaeobiology and Biosedimentology of the Buxa Dolomite, NE Lesser Himalaya.

(DST-Seismicity Programme)

(V. C. Tewari)

Buxa dolomite and Miri quartzite from Garu–Daring–Igo–Basar–Along–Panging–Yinkiong section in Siang and Sododoke-Daporijo–Taliha section in Subansiri areas of Arunachal Pradesh were petrographically studied for facies analysis, mineralogy, diagenesis, microstructures and microbial assemblages. The microbiota has suggested terminal Proterozoic age for the Buxa dolomite. The sedimentary structures and ichnofossils *Skolithos* from the

Nikte/Miri quartzite suggest shallow marine environment and early Cambrian age for the quartzite. Field evidences suggest that the Miri quartzite is not the integral part of the Gondwana sequence in Arunachal Lesser Himalaya. The Gondwana diamictites are of Permian age and suggest glacial environment.

Systematic sampling of Buxa limestone, dolomite, chert, stromatolites , sandy units associated with the dolomite and Namchi sandstone was done. Lithologs were prepared in the field showing various facies variations, stromatolitic buildups and sedimentary structures. In laboratory, petrographic thin sections were stained and studied for the carbonate microfacies and mineralogy. Chert thick sections were scanned for the recovery of microbiota and the assemblage was identified. Polished sections of the stromatolites have been studied. The taxa recognized are, *Conophyton garganicus, Kussiella kussiensis, Baicalia, Gymnosolen, Minjaria, Tungussia, Jurusania, Collumnaefacta.e.*

PROJECT

Hazard Zonation and Risk Assessment of the Landslide Affected Areas between Banderdewa-Gohpur in Itanagar Capital Complex, Arunachal Pradesh, using GIS and Remote Sensing Techniques.

(DST-SERC Project)

(Trilochan Singh)

Itanagar Capital Complex, which came into existence only in 1981, has reached a critical state of human settlement and development. A number of lineaments and active faults have made the area more vulnerable to landslides, which are occurring not only along the roads but also in the urban agglomeration area in the Itanagar Capital Complex. Detailed inventory of these landslides has been prepared, which includes both old and presently active slides.

Various geologic and geomorphic features indicate that the area is geodynamically active. In this situation, slope cutting and blocking of natural drains in an unscientific manner for construction of multistorey concrete buildings are making this area prone to landslide hazard.

The risk assessment has shown that most of the Itanagar urban agglomeration falls under the Low to Moderate Risk category with a few isolated areas of this agglomeration falling under High to Very High Risk category. The road between Banderdewa and Itanagar mostly falls under low to moderate risk, whereas the road between Chimpu and Solangi falls under High to Very High Risk category.

PROJECT

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

(DST - SERC, Fast Track Young Scientists Scheme)

(A. Krishnakanta Singh)

The preliminarily field work and petrographical studies indicate the Manipur ophiolite complex predominantly consists of harzburgite, lherzolite, dunite and serpentinite. At places, these dismembered ophiolitic bodies are associated with pillow lavas, volcano clastic sediments, ore deposits (chromite) and have tectonic contact with sedimentary rocks of the Disang Group. The presence of limestone and chert indicates their association with pelagic sediments. The ultramafic rocks are usually cut across by serpentinised shear zones of variable width and the original primary structures and mineral outlines are obliterated by serpentinisation. Slickensides and irregular foliation is an important feature developed in these rock units; however foliation/cleavage is generally oriented in a haphazard manner.

The principal mineral constituents of the ultramafic are olivine, orthopyroxene, clinopyroxene, Cr-spinel, magnetite (Fig. 28a). They are partially or completely altered to serpentine. They exhibit xenoblastic, porphyroblastic or hypidiomorphic and mesh texture. The effect of metamorphism may be broadly treated under the process of serpentinisation (Fig. 28b). These rocks are also marked by penetrative schistosity showing parallel alignment of fibrous minerals and sometimes development of kink bands in pyroxenes. Partial chloritisation and amphibolitisation are also occasionally observed.

The ultramafic rocks are characterized by high MgO; low K_2O, Na_2O, HFSE (Ti, P, Nb, Zr, Y) and LILE (Rb, U, Ba, Pb). They display restricted variation in SiO_2 (40.49 - 48. 21 wt. %) and show alkaline (Nb/Y = 1.07-4.66) to tholeiitic (Nb/Y = 0.35- 0.93) affinity. They are strongly enriched in Ni (1983 - 3901 ppm), Cr (2572 - 3907 ppm) and Co (84 - 203 ppm). The high Mg # (91.40 - 93.35) with enrichment of Cr, Ni, Co and strong depletion Ti suggests that the rocks were refractory residual fragments separated out from mantle derived magma and high Mg # reflecting rather primitive character of these rocks. The HFSE display comparable abundances with MORB and pronounced variation in LILE reflecting influence of oceanic hydrothermal alteration on their concentration.

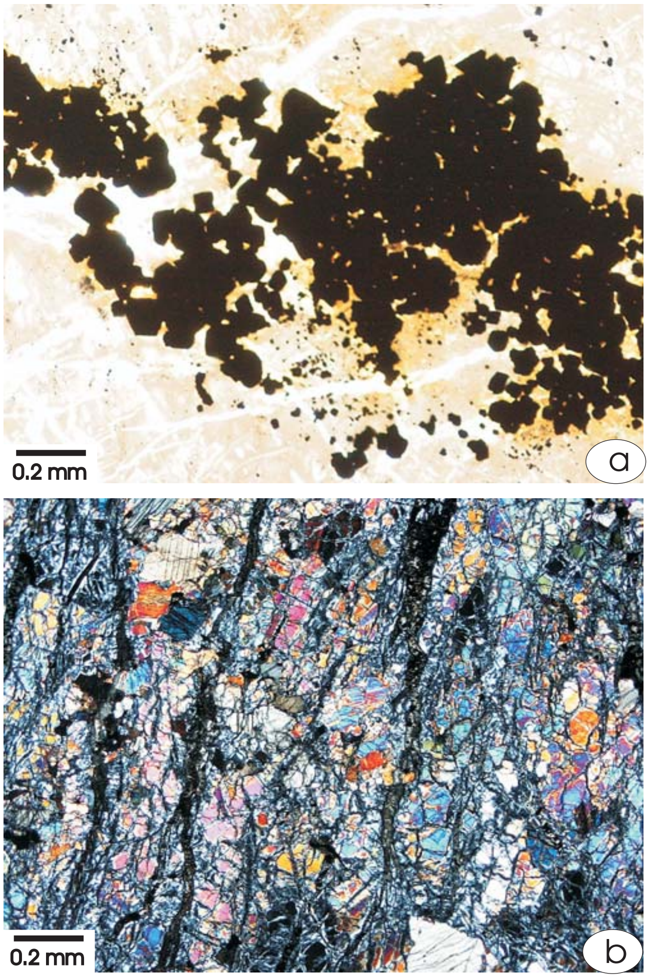

Fig. 28. Photomicrographs of ultramafic rocks from Manipur ophiolitic complex (**a**) Cr-spinel as cumulate layer in Sepentinite (**b**) Olivine grains are replaced by serpentine in Harzburgite and exhibiting mesh textures.

PROJECT

Neotectonics with special reference to delineaton of active faults in the foothills of Papumpare district in Arunachal Pradesh

(DST- SERC, Fast Track Young Scientists Scheme)

(R.K. Mrinalinee Devi)

Lineament map of the project area was prepared using the satellite imagery (Fig. 29). Lineament analysis was done for part of the foothills of Papumpare district. From the analysis, it has been observed that major trends are found to be along the ENE-WSW and NNE-SSW. Rose diagram of the lineaments are shown in the left corner of the lineament map.

Some findings of active faulting from the present study area are as follows :

- Displacement of Quaternary deposits by faults in the Gohpur-Ganga hillock section reveals the recent tectonic activity related to the movement of thrust fault trending NE-SW passing through the hillock. Evidence of thrusting by the displacement of pebbly layer in the Quaternary deposits and triangular facets through which the fault passes has also been observed. Lineaments trending NE-SW and ENE-WSW to E-W represented by scarps have also played an important role in the uplift of the section. Recurrence of landslides has taken place within a span of 2 to3 years in this section after the rains. Tilting of Quaternary terrace and presence of wind gaps of an abandoned active channel is also observed in the section.

- In the Julie-Naharlagun road fault scarp trending ENE-WSW has witnessed recurrence of landslides with road cutting on the scarp enhancing the problem. Sandstone and siltstone banded rocks are tilted 48^0 towards north. Triangular facets are also present. This zone has witnessed movement along a fault striking in ENE-WSW direction. Further study is going on around the area.

- In the Julie-Naharlagun road near Birup Stream a thrust dipping 60^0 SE and having a displacement of 20 cm, has been observed in an actively sliding scarp trending NE-SW. Near Habya stream bridge a triangular facet through which an active fault trending NE-SW has been observed in the unconsolidated rock type of sand, silt, sandy and silty sandstone.

- At the Yupia road, an abrupt tilting of unconsolidated sandstone and pebbly beds showing steep tilting and upright bedding has been observed signifying the tectonically disturbed nature of the area. The tilted beds of sandstone and pebbles juxtapose the upright beds of sandstone and pebbles at 72^0 towards SE.

- On Yupia road about 1 km from NH 52A, an actively sliding scarp has been affected by a vertical fault displacing fine grained unconsolidated sandstone rocks by 20cm and the hillock is also sliced by numerous joint planes.

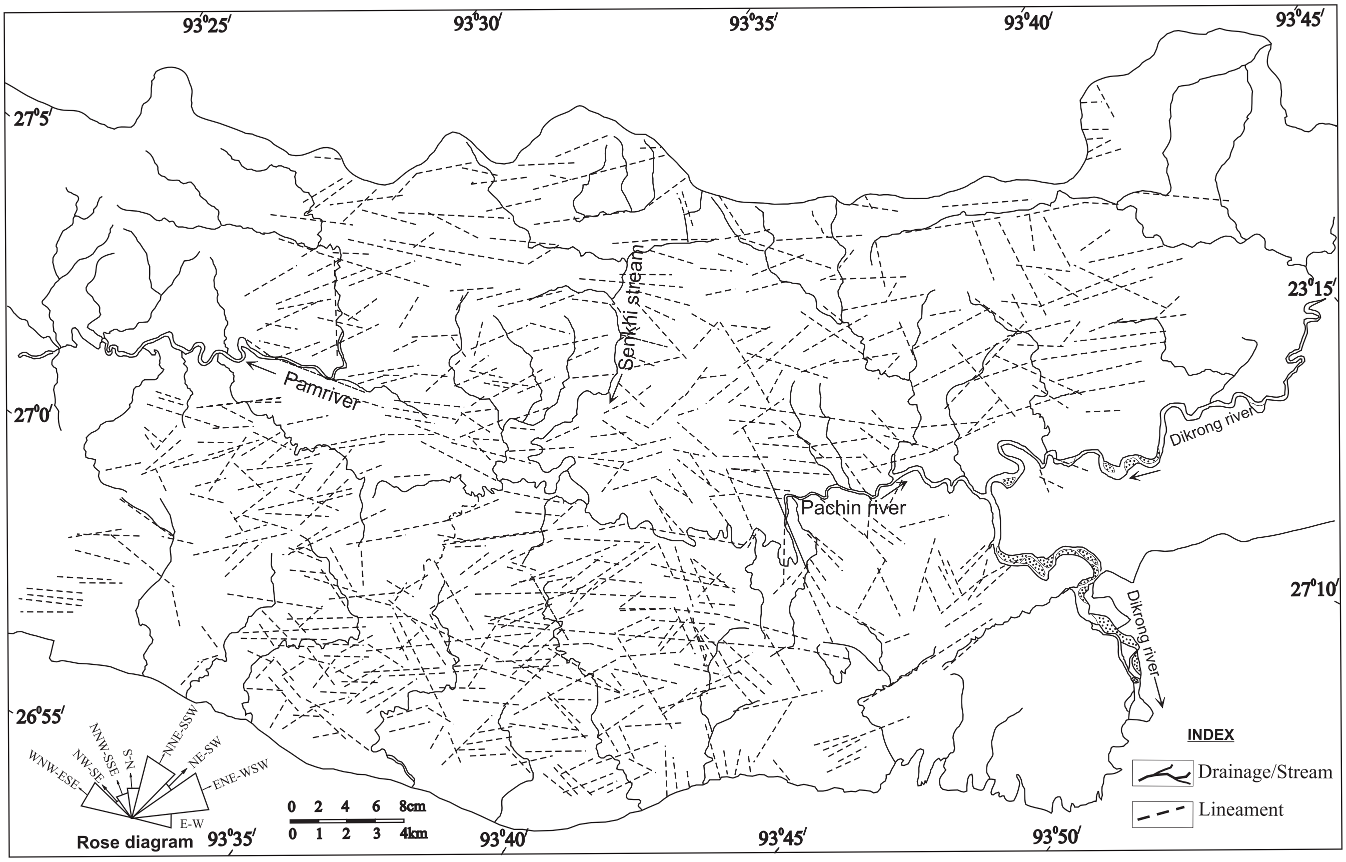

Fig. 29. Lineament map of the study area, around the Itanagar Capital Complex, Arunachal Pradesh.

- Along the NH 52A, nearby Naharlagun town, a fault zone comprising normal fault dipping 20^0 SE and thrust faults dipping 45^0 NE and 56^0 SE are observed displacing the pebbly and sandstone beds .
- At the Karsingsa landslide the NE-SW trending scarp through which a fault trending E-W pass through is currently an active fault zone. Slicing of the scarp face is enhanced more by the toe cutting of the Dikrong river and National Highway remains reoriented frequently due to road sliding.

PROJECT

Rock Properties Laboratory–A National Facility

(DST- Earth System Science)

(Vikram Gupta and Ruchika Sharma)

With the diminision and subsequent extinction of surface and shallow surface natural resources supplemented by the ever increasing requirements, the need for precise interpretation of geological and geophysical data has been well realized in recent years. Precise value of the rock properties would result in a more realistic and accurate results on the subsurface characteristics. Realizing the limitations and the specific expertise required in the determination of rock properties, a national facility to determine seismic wave velocities in rocks in lab conditions has been proposed to be established at the Wadia Institute of Himalayan Geology. This facility apart from the Institute users, will be available to all other research workers from universities and professional organization.

PROJECT

Creation of District Database Centre, Champawat District, Uttaranchal

(DST- NRDMS)

(B. Sharma, A.K.L. Asthana and Manu Sharma)

The Champawat District is a newly created district which was carved from Pithoragarh and Udham Singh Nagar districts. The Champawat District has four development blocks, namely, Pati, Lohaghat, Barakot and Champawat. Administratively Chamapawat is formulated in four Tehsils i.e. Pati, Lohaghat, Tanakpur and Champawat. This district constitute of 24 Nyaya panchayat, 283 Gram Sabha, 691 Revenue Villages. The geographical area of the District is 1955.26 km^2. The total literacy of the district is 71.1%.

Geologically this district lies in the Almora Crystallines of Almora Dudatoli synform. It has North Almora Thrust on the northern margin along Saryu river and South Almora Thrust through the central part. Other main feature is the Main Boundary Fault, which separates Siwalik ranges along Ladhiya river. The granitic terrain shows a well marked ridge line from Champawat to Devidhura and schists show moderate to gentle slope in Champawat, Lohaghat and Khetikhan areas. This district does not have any glaciers.

Various thematic maps have been prepared on 1:50,000 scale of both Block. Data collection for secondary sources (socioeconomic) is prepared at village level. Data is stored in D-Base format. Digitized maps of geology, drainage, forest, land use, infrastructure, road, wasteland, village boundary of each village have been prepared in GIS environment.

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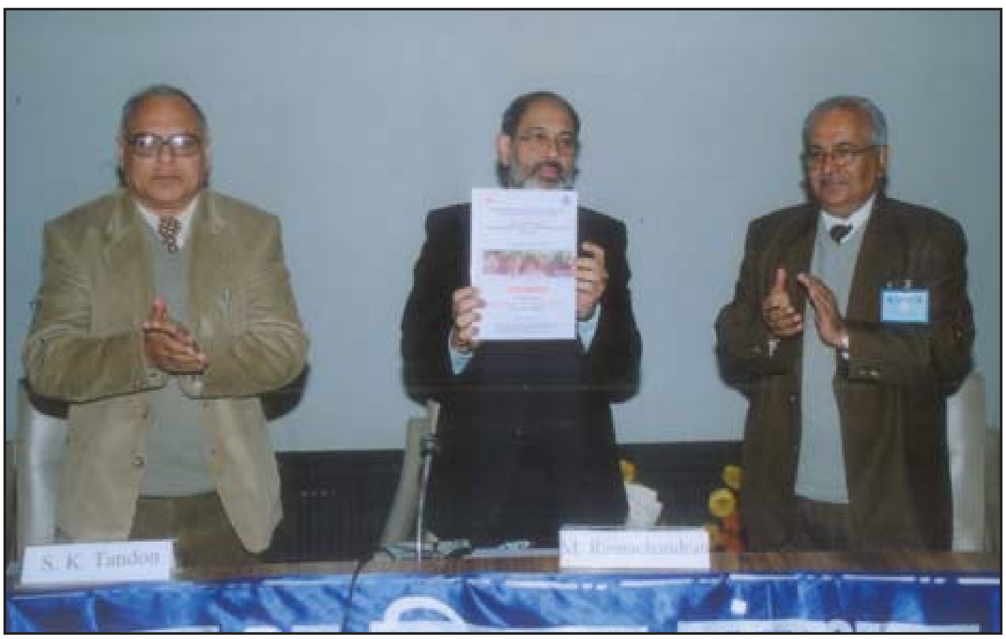
SEMINAR/SYMPOSIA/WORKSHOPS ORGANISED

a) XXII Convention of Indian Association of Sedimentologists (IAS-2005)

Wadia Institute of Himalayan Geology organized the XXII Convention of Indian Association of Sedimentologists (IAS-2005) from December 21 to 23, 2005. The focal theme of the Convention was "*Sedimentary Basins of the Himalaya: Challenges for the Future*". The Sub-themes of the Convention were; *Himalayan Sedimentary Basins, Foreland Basin Systems, Proterozoic-Phanerozoic Sedimentary Basins, Responses of Sedimentary Systems to South Asian Monsoonal Shifts; Applications of Sedimentology to Geohazards, Petroliferous and other Energy Resources Sedimentary Basins-Challenges, Sedimentology–other related aspects.* Shri M.Ramachandran, Chief Secretary, Uttaranchal Government, inaugurated the Convention. The Convention was, jointly sponsored by Department of Science and Technology and Oil & Natural Gas Corporation and was attended by about 100 participants from various institutions/organizations of the country. The participants were from universities, Banaras Hindu University, Delhi University, Nagaland University, Jadavpur University, Aligarh Muslim University, Lucknow University, Andhra University, Jammu University etc. Delegates from IIT Kharagpur, Kanpur and Roorkee also participated. Apart from this, eminent research institutions/organizations like WIHG, BSIP, ICFRE, ISM, Indian Statistical Institute, Kolkata, National Institute of Oceanography, Goa, ONGC and GSI also participated in IAS 2005 Convention. 106 abstracts were received for presentation.

In the Convention emphasis was placed on recent disastrous events due to nature's fury such as tsunami, earthquakes and global climate change. The frequency of these disasters has geared up the geoscientists to fight these natural calamities with the tools of science & technology. On the conclusion of the Convention it was felt that sedimentologists should strive towards consolidating their role in understanding the process as of the earth-ocean-atmosphere system and must continue in the quest to augment the nation's energy resources.



Chief Guest Sh. M. Ramachandran, Chief Secretary, Uttaranchal Government releasing Abstract volume during IAS-2005 XXII Convention.

b) Workshop on Himalayan School Earthquake Laboratory Programme (HIMSELP)

The Department of Science and Technology, Government of India, has initiated a project on Himalayan School Earthquake Laboratory Programme (HIMSELP) under Mission Mode Project in Seismology for Northwest Himalaya and Northeast Himalaya. To provide training to school teachers in earthquake processes and instruments, the first workshop of school teachers from different schools identified under this programme was organized from September 29, 2005 to October 4, 2005 at Wadia Institute of Himalayan Geology, Dehra Dun. The main objective of the workshop was to bring awareness to the students through teachers about the earthquake and to inculcate the culture of prevention among the younger generation. Towards this the science teachers in the school have been trained in basics of seismology who can impart that knowledge to the children. This will also provide an opportunity to school children for participatory and interactive learning, and attaining higher levels of conceptual development in earthquake science education. 45 teachers participated in the programme and who showed keen interest in learning the physics of the earth and instrumentation.

c) Workshop on Inventory of Glaciers and Glacial Lakes and the Identification of Potential Glacial Lake Outburst Floods (GLOFs)

Wadia Institute of Himalayan Geology (WIHG) and International Center for Integrated Mountain Development (ICIMOD, Nepal) jointly organized a workshop on "Inventory of glaciers and glacial lakes and the identification of potential glacial lake outburst floods (GLOFs) affected by global warming in the mountains of Uttaranchal Himalaya, on 14 July 2005 at Wadia Institute of Himalayan Geology. During this workshop a digital database of glaciers and glacial lakes for all the eleven river basins prepared of Uttaranchal state, based on Landsat-7 ETM+ satellite images of October and November 2003 was released in CD. For the glacier inventory, the methodology developed by the Temporary Technical Secretariat (TTS) for the World Glacier Inventory and for the glacial lake inventory, the methodology developed by the Lanzhou Institute of Glaciology and Geocryology (LIGG) (LIGG/WECS/NEA 1988) was used with some modification. The digital database of glacier inventory indicates that there are 1439 glaciers inventoried within the Uttaranchal State, which cover an area of 4060 sq. km besides 127 glacial lakes with a total area of 2.49 sq. km.

CD containing database of glaciers and glacial lakes for Uttaranchal prepared under joint program between WIHG and ICIMOD being released at the Workshop organized at the Institute.

d) National Field Workshop on Sub-Himalayan Palaeogene Sediments in the Context of India-Asia Collision

A National Field Workshop on the Sub-Himalayan Palaeogene sediments in the context of India-Asia collision was organized by Wadia Institute of Himalayan Geology, in the Shimla Hills near Jabli on Kalka-Shimla Highway during March 24-26, 2006 to highlight the uniqueness and wealth of information that these sediments hold in the context of India-Asia collision. The focus was on the stratotype sections of the Subathu and the Dagshai formations in Himachal Pradesh. The Sub-Himalayan Palaeogene was witness to distinct episodes of withdrawal of the Tethys Sea during the India-Asia convergence and the onset of continental deposition and therefore has great potential for information on wider consequences of collision including palaeontologic, sedimentologic, geochemical, tectonic, palaeoclimatic, orographic and sea level changes that need to be recorded and interpreted in terms of geodynamic models. The workshop was held with a view to motivate an integrative approach to address these aspects and to encourage formulation of multidisciplinary and multi-institutional projects to study these successions of great interest and importance.

20 geoscientists specializing in various sub-disciplines of Geology including stratigraphy, palaeontology, magnetostratigraphy, sedimentology, structural geology, geochemistry, palynology and coal geology attended the workshop. A few experts/ resource persons who have studied the sub-Himalayan Palaeogene for many years were specially invited to share their knowledge and experience. The participants were from various university departments/organizatons like: Departments of Geology, Panjab University, Delhi University, Lucknow University, Jammu University, Mizoram University and Banaras Hindu University, Birbal Sahni Institute of Palaeobotany, Oil & Natural Gas Corporation, Department of Science & Technology and Wadia Institute of Himalayan Geology.

A team of experts participating in the Field Workshop on Sub-Himalayan Palaeogene Sediments organized by WIHG.

VISITS ABROAD

- Dr. B.R. Arora, Dr. A.K. Dubey and Dr. S.J.Sangode participated and presented papers in the 21st Himalayan-Karakoram-Tibet Workshop held at Cambridge University, U.K. on March, 29-31,2006.
- Dr. Rohtash Kumar & Dr.Sumit K.Ghosh participated in Asia Oceania Geoscience Society 2nd Annual Meeting held at Suntec City, Singapore from 20-24 June, 2005.
- Dr. S.K. Parcha participated and presented papers in the 4th International Symposium on the Cambrian system held at Nanjing, China from Aug. 16-25,2005.
- Dr. P. Banerjee visited Topcon, Singapore to attend GPS training course Sept. 13-18, 2005.
- Dr. P. Banerjee visited Research Institute, University of Tokyo, Japan, and presented paer in Memorial Conference during Dec.14-17, 2005.
- Dr. V.C. Tewari participated and presented a paper in the 14th International Conference on the Origin of Life, Beijing, China on June 19-24, 2005.
- Dr. N.K. Saini visited Panalytical Application Laboratory, Almilo, The Netherland, to attend XRD user training course on Nov. 7-17, 2005.
- Dr. D.P. Dobhal visited Institute of Research and Developments (IRD) Montpellier, France from Nov. 20-26, 2005.
- Dr. H.K. Sachan visited Department of Earth and Planetry Sciences, MIT. USA for colloborative research work from April 25-May 15.2005.

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEE

Name of the Scientist	Status	Prestigious Committee/s Outside WIHG
B.R.Arora	Member	Editorial Board of the Journal Geophysics
A.K. Dubey	1) Fellow 2) Member	Geological Society of India, Bangalore Indian Geological Congress, Roorkee
G. Philip	Member	ISRO-NNRMS-Sub Committee on Geology
V.Gupta	Member	Bureau of Indian Standards (BIS) for preparing draft standards on guidelines for preparation of Landslide Hazard Zonation maps on meso- and micro- scale

AWARDS AND HONOURS

- Dr. A.K.Dubey was awarded National Mineral Award for the year 2004 for his significant contribution in the field of Experimental Structural Geology.
- Dr. S.J.Sangode was given best research paper award for his paper entitled " Pedogenic transformation of magnetic minerals in Plio-Pleistocene paleosols of the Siwalik Group, NW Himalaya" for the year 2005.
- Dr. P. S.Negi was given award for Best Scientific Research Work in Hindi for the year 2005 (under Government of India Scheme).
- Dr. S. J. Sangode received C. Radhakrishnamurthy Award 2005 from the Geological Society of India, Bangalore.
- Dr. P. Banerjee received best paper presentation award in International Conference: GRATICULE-2005, for Surveying+Positioning+Locational at Hotel Taj Palace, New Delhi.

Dr. Ashok Kumar Dubey, receiving the National Mineral Award from the Honourable Minister of Mines, Shri Sisram Ola.

Ph.D. THESES

Name	Supervisor/s	Title of the Thesis	University	Awarded/ Submitted
Priti Verma	Dr. Rajesh Sharma	Gensis of barite mineralization and the environmental impact of its exploitation in the Tons valley,Lesser Himalaya	HNB Garhwal University	Awarded
Kapesa Lokho	Dr.R.Venkatachalpathy	Foraminiferal biostratigraphy, paleoecology and the boundary events of Paleogene sediments from parts of Kohima and Phek district, Nagaland.	Nagaland University Kohima	Awarded
Subhajit Sinha	Dr.Rohtash Kumar Dr. S.K. Ghosh	"Magnetostratigraphy and Sedimentology of the Neogene succession in the Himalayan Foreland Basin, Ravi Re-entrant"	HNB Garhwal University	Submitted
B.P.Singh	Dr. S.K. Parcha	"Paleontology and biostratigraphy of the Cambrian Successions in the Zanskar region of the Ladakh Himalaya".	HNB Garhwal University	Submitted
Ajay Kumar	Dr. Rajesh Sharma	Genesis of magnesite deposit in Panthal, District Udhampur, J&K	Jammu University	Submitted
Lakshmi Narasimhan	Dr. S.J.Najafi	Rock magnetic and palaeomagnetic studies on the western part of Indian Subcontinent	University of Mumbai	Submitted

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOP/TRAINING COURSES

Seminar/Symposia/Workshop

- **14th International Conference on the Origin of Life ,Beijing , China , June 19-24, 2005**

  Participant : V.C.Tewari

- **Seminar on Natural Resources of Uttaranchal, organized by Department of Geology and Mining, Uttaranchal State at Wadia Institute of Himalayan Geology, Dehra Dun, June 26-27, 2005.**

  Participants : Rajesh Sharma, Vikram Gupta

- **Workshop on "Inventory of Glaciers and Glacial Lakes and the Identification of Potential Glacial Lake Outburst Floods (GLOFs) Affected by Global Warming in the Mountains of Uttaranchal Himalaya, at Wadia Institute of Himalayan Geology, Dehra Dun, July 14, 2005.**

  Participants :R.K.Mazari, G.Philip, M.P. Sah, S.K.Bartarya , Vikram Gupta, D.P. Dobhal A.K.L. Asthana, P.S. Negi, R.J.Thayyen

- **2nd NIAS-DST Course' on 'Multidisciplinary perspectives in Science and Technology, held at National Institute of Advance Studies, Bangalore, July 25 - August 6, 2005.**

  Participant : D. R. Rao

- **4th International Symposium on the Cambrian System at Nanjing, China, August 17-21, 2005.**

  Participant : S.K. Parcha

- **10th International Coference of the Cambrian Stage Subdivisions, Nanjing, China, August 22-24, 2005.**

  Participant : S.K. Parcha

- **National conference on advanced characterization techniques on nanomaterials at Institute Instrumentation Centre, Indian Institute of Technology, Roorkee, August 24-26, 2005.**

  Participant : T.N. Jowhar

- **DST sponsored contact programmed on *'Lithofacies Mapping in sedimentary Terrains, K-G Basin, A.P'* organised at Sattupalli-Rajahmundry, by Geological Survey of India, Training Institute, Hyderabad, August 24-31, 2005.**

  Participant: Kapesa Lokho

- **Conference on Brand Uttaranchal is Green organized by CII (Confederation of Indian Industry) Uttaranchal State Office at ICFRE, Dehra Dun, August 26, 2005.**

  Participant : N.K.Saini

- **Short training course on larger foraminifera from Prof. P.K Sarawasti, IIT Powai, Mumbai, September 2-13, 2005.**

  Participant: Kapesa Lokho

- **National Conference on 'Arunachal Pradesh: Tradition in transition linking Ecology, Economics and Ethics' organized by UNESCO at Nirjuli, September 13-16, 2005.**

  Participant : T. Singh

- **Workshop on Accelerator Mass Spectroscopy, organized at IUAC, New Delhi, September 23, 2005**

  Participant : N.R. Phadtare

- **Workshop on "Ganga Dialogue" organized by Eco- Friends, Kanpur at Wadia Institute of Himalayan Geology, Dehra Dun, September 28, 2005.**

  Participants: P.K. Mukherjee and D.P. Dobhal

- **Training programme on " conflict management and negotiating strategies at Administrative Staff College of India (ASCI), Hyderabad, October 3-7, 2005.**

  Participant: R. Islam

- **National Contact Training program in "Geochemistry" sponsored by Department of Science and Technology, Govt. of India at JNU, New Delhi, October 6-7, 2005.**

  Participant: N. Siva Siddaiah

- **Workshop on "The role of the Public, Private and Civil Sectors in Sustainable Environment Management: a search for Balance in Uttaranchal", organized at RLEK, Rajpur Road, Dehra Dun , October 14-15, 2005.**

  Participants: D. Pal, A.K.L. Asthana and P.S. Negi

- **XX Indian Colloquium on Micropalaeontology and Stratigraphy, at Department of geology, Andhra University, Visakhapatnam October 24- 26, 2005.**

  Participants : Kapesa Lokho

- **National Seminar on Geology and Energy Resources of NE India and Perspectives, organized by Deptt of Geology, Nagaland University, Kohima, November 8-9, 2005.**

  Participants: A.K. Dubey, N.S. Gururajan, V.C. Tewari, B.K. Choudhuri, D.K. Misra, S.S. Bhakuni, A.K. Singh, Kapesa Lokho, Khayingshing Luirei

- **Seminar on Vison 2010 – Analytical Techniques and Instrumentations for Industrial Research and Automatics" Organized by IIP, Mokhampur, Dehra Dun, November 11, 2005.**

  Participants: M.S.Rathi, P.P.Khanna and P.K.Mukherjee

- **Annual General meeting of the Geological Society of India, organized at Nagaland University, Kohima, Nagaland, November 11, 2005.**

  Participants: V.C. Tewari, A.K. Singh, S.S. Bhakuni, Kapesa Lokho and Khayingshing Luirei

- **Diamond Jubilee National Conference at Birbal Sahni Institute of Palaeobotany, Lucknow, November 15-16, 2005**

  Participant: Meera Tiwari

- **National conference on "Geochemical and Isotopic Evolution of Continental Crust" Organized by IIT, Roorkee, Nov. 18-19, 2005.**

  Participant: P.K. Mukherjee

- ***International Seminar on "Climatic and Anthropogenic impacts on water resources variability" organized by IRD, HSM, Hydro Sciences University of Montpellier, Montpellier, France, November 22-24, 2005.***

  Participant: D.P. Dobhal

- **XXVII IGC (Indian Geography Congress).Organized by Deptt. of Geography and Geo-informatics ,University of Bangalore, Bangalore, December 2-4, 2005.**

  Participant: P.S. Negi

- **14th Indian Geological Congress organized at Delhi University, Delhi, December 3-4, 2005.**

  Participants: R.S.Rawat and R.K.Chaujar

- **International Seminar on Northward Flight of India in the Mesozoic-Cenozoic: Consequences on biotic changes and Basin Evolution" organized by the Department of Geology, University of Lucknow and Palae. Soc. of India, at Lucknow December 7-9, 2005.**

  Participants : B.R. Arora, V.C. Tewari, B.N.Tiwari

- **Seminar on Sedimentary Basins of the Himalayas: Challenges for the future and XXII convention of Indian Association of Sadimentologists (IAS 2005) during December 21-23, 2005 at Wadia Institute of Himalayan Geology, Dehra Dun.**

  Participants : R.K.Mazari, R.S.Rawat, V.C.Tewari, Rohtash Kumar, S.K.Ghosh, Rajesh Sharma, R.Islam, S.J.Sangode,B.N.Tiwari, Vikram Gupta, G.Perumal, D.K.Misra

- **Fundamental training course on ArcGIS organized at Wadia Institute of Himalayan Geology, Dehra Dun, January 2-6, 2006.**

  Participants : K.S.Bist,R.K.Chaujar, M.Tiwari, G.Philip, P.K.Mukherjee, S.K.Paul, Kesar Singh, P.S.Negi, A.K.L.Asthana, Vikram Gupta, R.J.Thayyen, G.Perumal

- **93rd proceedings of the Indian Science Congress held at Acharya N.G. Ranga Agricultural University, Hyderabad, January 3-7, 2006.**

  Participant : T.N. Jowhar

- **Workshop-cum-Interactive meet on Characterization and Gainful Utilization of NE Coals, organized by Regional Research Laboratory, Jorhat at Gauwhati, Janaruary 10, 2006.**

  Participant : T. Singh

- **Workshop on Disaster Management and Remote Sensing and GIS applications in the context of northwestern region at Panjab University, Chandigarh, February 2-3, 2006.**

  Participants : M.P.Sah, Vikram Gupta

- **Consultative Workshop for Review of Suggested Amendments to Development Control Rules, The Ministry of Home Affairs, Govt. of India, Master Plan Regulation and Building Bye-Laws in local Bodies of Uttaranchal. Organised by Uttaranchal Government, Hotel Aketa, Dehra Dun, February 8, 2006.**

  Participants : R.K. Mazari and M.P. Sah

- **International Workshop on "Geology and Natural Hazards of the Eastern Himalaya Syntaxis, Indo-Burmese Arc and Adjoining Regions" organised at Itanagar (Arunachal Pradesh), February 9-11, 2006.**

  Participants: T. Singh, V.C.Tewari and A.K. Singh

- **Proceedings of the "Indian Council of Official Language's - National Conference", Goa, February 16-18, 2006.**

  Participant : Dr. D. R. Rao

- **International symposium on Quaternary studies, organized at PRL, Ahmedabad, March 2, 2006.**

  Participant : N.R. Phadtare

- **DST sponsored 2nd Brain Storming Session 'National project on paleoclimate studies' at PRL, Ahmedabad, March 3, 2006.**

  Participants : N.R.Phadtare

- **Workshop on Scientific and Technical Terminology. Organized by Commission for Scientific and Technical Terminology, Government of India, New Delhi at I.I.T. Roorkee March 3-4, 2006.**

  Participant: P.S. Negi

- **Workshop on Remote Sensing and Chandrayaan -1 Data Analysis" organized by PLANEX group at PRL, Ahmedabad, March 6-7, 2006.**

  Participant: P.K. Mukherjee

- **International workshop on Seismic Hazard and Risk Assessment at India Habitat Center, New Delhi, organized by NORSAR, Norway and IIT, Roorkee, March 8, 2006.**

  Participant : A.K.Mahajan

- **Workshop/discussion on "Study of Himalayan Glaciers and water Resources, organised by IRD, Hydro sciences Montpellier, France, at WWF India, Lodi Road, New Delhi , March 22-23, 2006.**

  Participant: D.P. Dobhal

- **National Field workshop on Sub-Himalayan "Palaeogene Sequences" in the context of India-Asia Collision, sponsored by Department of Science and Technology, Government of India around Dharampur-Kasauli-Subathu areas, March 24-26, 2006.**

  Participants : Rohtash Kumar, S.K.Ghosh, B.N. Tiwari, N. Siva Siddaiah, Kishor Kumar, S.J.Sangode, Kapesa Lokho

- **21st Himalayan –Karakoram-Tibet Workshop, Cambridge, UK, March, 29-31, 2006**

  Participants: B.R.Arora, A.K.Dubey, S.J.Sangode

LECTURES BY VISITING SCIENTISTS

Name and Address	Date	Topic
Dr. H.K. Gupta Secretary, Dept. of Ocean Development New Delhi	8.4.05	Early Warning System for Oceanogenic Disasters in Indian Ocean (Tsunami and Storm Surges): The Indian initiative
Dr. H.K. Gupta Secretary, Dept. of Ocean Development New Delhi	16.4.05	Triggered Earthquakes
Shri S.N. Maurya Dy. Director, Software Technology Parks of India, Dehra Dun	11.5.05	Last Mile Connectivity for Broad Band Services
Dr. S.A. Jafar Consultant, ONGC, Dehra Dun	27.5.05	Chasing a Ghost in Lesser Himalaya: Deciphering a Natural Stratigraphic Order
Prof. C. Leelanandam Emeritus Professor, Osmania University, Vishakhapatanam	8.6.05	Mineral studies and Mountain Belts
Dr. R.S. Tolia Chief Secretary, Government of Uttaranchal, Dehra Dun	29.6.05	Endeavours for making a Self-reliant Mountain State
Dr. Barun Mukherjee JSPS Post Doc, Tokyo Institute of Technology, Tokyo, Japan	5.7.05	*Microdiamonds from Himalaya: appraisal for Ultra High Pressure study*
Prof. A.K. Sinha Ex-Director, BSIP, Lucknow	27.9.05	Tectonic Framework of the Himalaya: some gaps and questions
Dr. Ragnar Stefansson Iceland Meterological Department, Iceland	21.11.05	Multiparametric Geophysical Observations. Earthquake Premonitory (Prediction) Studies in India
Dr. Pierre Chevallier Director, Institute of Research in Water and Environment, France	30.11.05	Climate Change Impact on Water Resources from the Mountains of Peru
Prof. Nibir Mandal Dept of Geological Sciences, Jadavpur University, Kolkata	1.12.05	Numerical Modeling and Modern Techniques in the Structural Geology

Name and Address	Date	Topic
Dr. Valeri Gitis Institute for Information Transmission Problems RAS, Moscow	16.12.05	GIS Technologies for Spatial and Spatio-Temporal Data Mining
Dr. Alexey Lyubushin Institute of the Physics of the Earth, Moscow	16.12.05	Multidimensional Geophysical Monitoring Time Series Analysis
Prof. Nibir Mandal Jadavpur University, Kolkata	1.1.06	Continuum modelling of flow: geological implications
Prof. Somnath Dasgupta Department of Science, Jadavpur University, Kolkata	17.1.06	Petrology and geochemistry of the inverted metamorphic sequence across the MCT zone in Sikkim Himalaya and their Tectonic significance
Dr. Vineet Kumar Gupta Consultant Psychiatrists, Dehra Dun	28.2.06	Stress management: a scientific approach
Dr. Joy Routh Stockholm University	8.3.06	Organic Geochemistry Molecular Fossils in the Environment
Dr. Jagdish Bahadur, Ex. Director, DST New Delhi	27.3.06	Role of Himalyan Snow and Glaciers

LECTURES DELIVERED BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
S. J. Sangode	IIT, Kanpur	28-30.3.05	Series of lectures in the School on Conepts in Quaternary Geology, Palaeomagnetic and Rock Magnetic Applications and Techniques in Orientation Course at WIHG.
T. Singh	Bomdila	15.4.05	Preparedness for earthquake disaster
A.K. Dubey	GSI, Dehra Dun	21.4.05	• Thrust tectonics with special reference to the Himalaya. • Development of the Leopargial Horst
A.K. Mahajan	Survey of India, Dehra Dun	14.5.05	Seismic Microzonation of Dehra Dun city
P.K. Mukherjee	Allahabad University Allahabad	2-5.5.05	Series of lectures on Geochemistry and Igneous petrology
Vikram Gupta	WIHG, Dehra Dun	19.5.05	Natural Hazards with particular reference to landslides in Uttaranchal
P. Banerjee	WIHG, Dehra Dun	7.6.05	Kinematics of the Great 2004 Andaman-Sumatra Earthquake
T.N. Jowhar	WIHG, Dehra Dun	31.5.05	Basic concepts of Thermodynamics
Vikram Gupta	ITBP, Mussoorie	5.7.05	Natural Hazards and their management in the Himalaya
A.K. Mahajan	Ordinance factory Institute, Dehra Dun	16.7.05	Importance of preparedness for Disaster Management and Protection Scheme
N. Siva Siddaiah	JNU, New Delhi	6.10.05	Geochemistry of Noble metals and analytical techniques
Kapesa Lokho	WIHG, Dehra Dun	7.10.05	Foraminifera, from Dizang Group of Nagaland, Eastern Himalaya-Implications on paleoenvironment, age and hydrocarbon exploration
T. Singh	Itanagar	27.10.05	Earthquake disaster in context of Arunachal Pradesh: Facts, consequences and preparedness
A.K. Mahajan	IIRS, Dehra Dun	28.10.05	Seismic Hazard and seismic Microzonation using MASW technique
S.K. Parcha	Dept. of Physics, BHU, Varanasi	29.11.05	On structure and characterization of physical, Chemical, bio and geo materials
Rajesh Sharma	Dept. of Geology, Jammu University, Jammu	5.12.05	Evolution of the ore fluids for the sulphide mineralisation in NW Himalaya

Name of Scientist	Venue	Date	Topic
Rajesh Sharma	Dept. of Geology, Kumaun University, Kumaun	8.12.05	Series of lectures on some aspects of melt and fluid phases in diverse natural environments
A.K.Mahajan	Rangarao Agriculture University, Hyderabad	6.1.06	Shear wave velocity profiles of surficial deposits in Dehradun city using Multichannel Analysis of Surface Wave Method (MASW)
T.N.Jowhar	Dept. of Geology, Delhi University, Delhi	6-10.2.06	Special invited lectures to M.Sc. students "Computer applications in geology & fundamentals of computer programming"
V.C.Tewari	Geological Society of India, Bangalore	22.2.06	Mass Extinction due to Large Bolide Impact on Earth and its Astrobiological Implication
R.K. Mazari	Chunakhan, Ramnagar	23.2.06	Global warming and its impact in the Himalaya
M.P.Sah	Chunakhan, Ramnagar	23.2.06	Glacier and glacial lake inventory in Uttaranchal
P.S.Negi	IIT, Roorkee	3.3.06	Identification of unstable slopes through bioengineering-A case study along MCT in Himalaya
D.R.Rao	WIHG, Dehra Dun	23.3.06	Electron Probe Micro Analyzer (EPMA): instrument, technique & its applications
P.K.Mukherjee	WIHG, Dehra Dun	23.3.06	Geochemical mapping in Uttaranchal: Some implications
B.R.Arora	WIHG, Dehra Dun	24.3.06	Seismic Hazard Potentials of the Frontal Himalaya

FOUNDATION DAY CELEBRATIONS

The Foundation Day of the Institute was celebrated on 29 June 2005. Dr. R.S. Tolia, Chief Secretary, Government of Uttaranchal was the Chief Guest. He delivered the Foundation Day Lecture on "Endeavours for making a Self-reliant Mountain State". On this occasion awards were given for the best research paper as well as for the best scientific work carried out in Hindi. First prize was given to Dr. S.J.Sangode for research paper entitled " Pedogenic transformation of magnetic minerals in Plio-Pleistocene paleosols of the Siwalik Group, NW Himalaya" published in Palaeoecol, Palaeoclimate, Palaeoecology. The second award was given to Dr. P.S.Negi for his Hindi article "Jalwayu pariwartan evam uske viswavyapi prabhaw-ek vigyanic vishleshan". The best worker awards were given to Sh. Rambir Kaushik, Technical Assistant, Sh. S.K.Chhetri, UDC, Sh. S.K.Srivastava, UDC and Sh.S.K.Thapliyal, FCLA for the good work carried out by them during the year 2004-05.

Dr. R.S. Tolia, Chief Secretary, Uttaranchal Government delivering the Foundation Day Lecture.

NATIONAL TECHNOLOGY DAY

The Seventh National Technology Day was celebrated by the Wadia Institute of Himalayan Geology on May 11, 2005. The Institute observed an Open Day by keeping Museum and other Laboratories open for the general public and for the school and college students. On this day a special lecture was delivered by Shri S. N. Maurya, Dy. Director, Software Technology Parks of India, Ministry of Communication and Information Technology Government of India on "Last Mile Connectivity for Broad Band Services"

NATIONAL SCIENCE DAY CELEBRATIONS

The National Science Day week was celebrated by the Institute by organising the Science Quiz and Hindi Essay Competition for school children from 22-28 February 2006. The various educational institutions of Dehra Dun were invited for participation in the Science Quiz and Hindi Essay Competition. Inspite of Annual Board Exams in Schools, a number of educational institutions participated in these competitions. The title of the Hindi Essay was "Himalayee Pariyavaran - Samasyayay Evam samadan" in which 28 schools participated. Winning students were given certificates and awards. In addition to these the scientists of the Institute delivered lectures in the different schools in and around the Doon valley.

A popular science lecture on "Stress management -A scientific approach" was delivered by Dr. Vineet Kumar Gupta a renowned psychiatrist of Dehra Dun. A huge crowed of students and general public attended the lecture. Also on February 28, 2006, an Open day was observed for students and general public to visit Museum and Laboratories of the Institute. More than 2000 school children and a large number of general public from far off places as Haridwar, Rishikesh, Sailakui, Mohakampur, Sahastradhara and Vikas Nagar visited the Institute.

School children interacting with Scientist on National Science Day.

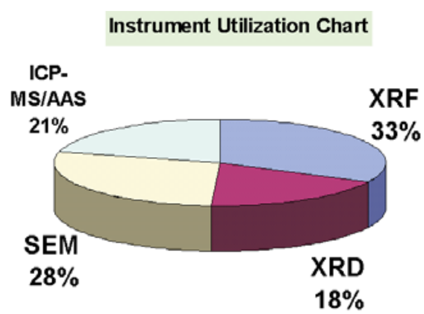
School children participating in the Hindi Essay competition during National Science Week.

TECHNICAL SERVICES

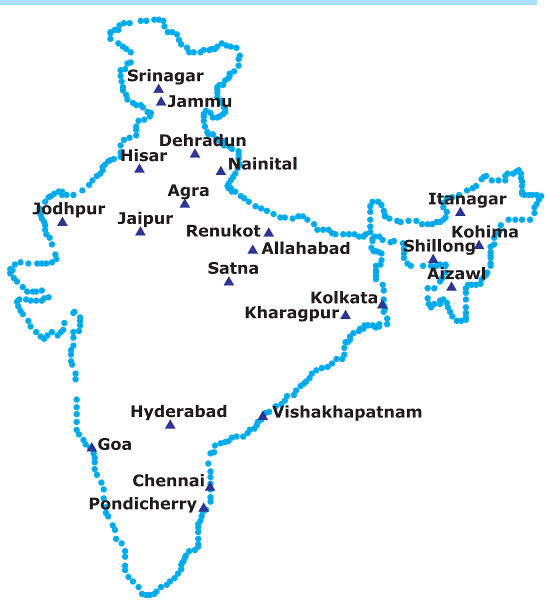
Analytical Services

Central Facility Laboratories

The broad scope of Central Facility Laboratories (CFL) is to develop techniques to feed the analytical needs of researchers, scholars and various industries in the adjoining area. Many projects running in the Institute are laboratory oriented and quite often need high quality analytical data. At present CFL has got facilities and capabilities to determine about 45 elements including 14 rare earths in different types of matrices like rocks, minerals, soils, plants, and water samples with very good accuracy and precision. During this year a total number of four thousand four hundred and thirty seven samples were analyzed by CFL thus increasing the output by about 54% in comparison to last year. Out of these two thousand four hundred sixty six samples were from the Institute scientists and scholars and rest from outside organizations/industries.



USERS OF ANALYTICAL SERVICES 2005-06



Laboratory	WIHG Users	Outside Usrs	Total
RF	732	706	1438
XRD	514	298	812
SEM	902	357	1259
ICP-MS/AAS	318	610	928
TOTAL SAMPLES ANALYSED		4437	

Among the various instruments available in CFL, XRF found the maximum use (33%) followed by SEM (28%), ICPMS/AAS (21%) and XRD (18%).

Photography Section

During the reporting year around 50 rolls of colour negative, 6 rolls of colour transparency, 10 rolls of normal speed black and white negative and 30 rolls of slow speed black and white negative films were used by the Institute scientists and research scholars. Processing of 50 rolls of colour negative and 6 rolls of colour transparency films were arranged from the market. Besides this about 30 CD's and 500 digital prints were also got made from the market. The WIHG laboratory exposed around 25 film rolls (black and white and colour), processed around 40 rolls of black and white film (mostly slow speed with photomicrographs) and made around 1000 prints of assorted size. The laboratory also arranged for the photographic coverage of most of the functions organized in the Institute during the year.

Drawing Section

The Drawing Section catered to the cartographic needs of the Institute scientists as well as the sponsored projects. During the year the Drawing Section provided 63 geological/structural/geomorphological maps, 12 lithologs and 19 cross-sections to the scientists of the Institute. The Section also prepared 32, posters/charts, 18, geochemical diagrams, 20, fossil diagrams and various other jobs pertaining to line diagrams, labels/captions (both b/w and colored), writing work on photo plates and ammonia prints of different sizes.

Sample Processing Laboratory

The Sample Processing Laboratory provided thin/polished sections to the requirements of the Institute scientists. During the year laboratory provided 2133 thin and polished sections to various users for carrying out microscopic, fluid inclusion and EPMA studies.

MUSEUM

S.P. Nautiyal Museum

The Institute Museum is the major axis of education and continues to create a center of attention to the students and general public not only from the far-flung corners of India but also from overseas. Museum as usual remained the main centre of attraction for the national and international visitors. Students in large groups from different schools, universities, colleges and other Institutions visited the Museum; guided tours were provided to them. Also during the year, visitors from Canada, South Africa, Austria, Holland, USA, UAE, U.K, Germany, Australia, England, Japan, Nepal, France, Sri Lanka, Nepal, Poland, Moscow, Ireland, Italy, Israel and Austria visited the Museum.

The Museum observed open days on National Technology Day (11 May, 2005), Foundation Day (29 June, 2005), Founders Day (23 October, 2005) and National Science Day (28 February, 2006). Like the previous years enormous number of students and general public visited the museum on these occasions. The print media gave a wide coverage of the various functions organized during these open days. Science quiz and essay competition were organized during the Science Week celebrations. Students from various schools of Doon valley participated in the quiz competition. Prizes were distributed to the outstanding students who stood first, second and third in the merit both in quiz and essay competition.Two consolation prizes, each were also given for Hindi essay and for science quiz competition.

School children visiting Museum on National Science Day.

LIBRARY

The library of the Wadia Institute of Himalayan Geology is one of the best libraries in the field of earth sciences in the northern part of the country. It is a medium size specialized library consisting of books, monographs, journals and seminar/conference proceedings on earth sciences with special reference to Himalayan geology. A large number of national and international scientific core journals in the field of earth sciences are subscribed in the library which is not available in any other Library in the region.

The library subscribes to 132 journals, out of which 52 are Indian and 80 are foreign. The library received 12 titles of journals as gratis. During the period of this report the library acquired a total number of 263 books, while 28 books were received as gratis. In addition, 134 books in Hindi were purchased. The library has a good collection of Hindi books to promote Hindi language in the staff of the Institute.

The catalog of CD-ROMs available in the library has been compiled. The reprint collection of the library was reorganized. A new database named 'Rprint' consists of 1287 bibliographic records of reprints available in the reprint collection of the library. The Himalayan Geology Database (HIMGEO) has been updated and the web interface software named GenIsis is installed to provide web based access on intranet (LAN) to this database.

The library incorporates a reprographic cell which serves as a central facility for photocopying and cyclostyling. A large number of photocopies of articles from journals/ monographs were provided to the scientists of the Institute. The photocopying and cyclostyling facility was also provided to the administrative and technical sections of the Institute.

PUBLICATION & DOCUMENTATION

The Publication & Documentation section is involved in bringing out the regular journal on "Himalayan Geology" and publishing Hindi magazine, annual report yearly, etc. During the year the Section has published the Himalayan Geology vols. 26(2) 2005 and Vol. 27(1) 2006, Hindi magazine Ashmika vol. 11 and Annual Report of the Institute for the year 2004-05 both in Hindi and English. Books entitled "Earthquakes Laboratory Practice", "National Programme on Seismicity: Highlights and Achievements" and an Abstract Volume for the seminar on "Sedimentary Basins of Himalaya: Challenges for the Future (IAS 2005)" organized by Wadia Institute of Himalayan Geology were also brought out during the year. Apart from this various jobs such as printing of the J.B. Auden Lecture, Prof. Naha Memorial Lecture and D.N. Wadia Honour Lecture, Circular for the seminar on Sedimentary Basins of Himalaya: Challenges for the Future (IAS 2005)", invitation cards for the seminars/workshops, certificates for celebration of Foundation Day and National Science Day were also brought out by the Section during the year. Additionally, services for scanning and colour printing of maps, diagrams, figures as requisitioned by the Institute scientists were provided by the Publication & Documentation Section.

DISTINGUISHED VISITORS TO THE INSTITUTE

- Dr. H.K. Gupta, Secretary, Department of Ocean Development, Mahasagar Bhavan, Block-12,C.G.O. Complex, Lodhi Road, New Delhi-110 003.
- Dr. R.S. Tolia, Chief Secretary, Government of Uttaranchal.
- Sh. M. Ramachandran, Chief Secretary, Government of Uttaranchal.
- Prof. C. Leelanandam, Emeritus Professor, Osmania University.
- Dr. Madhav Karki, DDG, ICIMOD, Nepal.
- Dr. M.K. Virk, DIG, BSF, Jammu.
- Sh. M.K. Rajadan, DIG, BSF.
- Sh. Balbir Singh, DIG, BSF.
- Sh. B.K. Dey, IPS, Director, BSF Academy.
- Sh. J.P. Mohla, DIG, BSF.
- Maj. Gen. D. Mukherjee, NDC.
- Dr. Ragnar Stefansson and Ms. Steinann Jakobsdotir, Iceland Meterological Department, Iceland.
- Prof. Nibir Mandal, Department of Geological Sciences, Jadavpur University, Kolkata.
- Dr. Valeri Gitis, Institute for Information Transmission Problems RAS, Moscow.
- Dr. Alexey Lyubushin, Institute of the Physics of the Earth, Moscow.
- Dr. Vineet Kumar Gupta, Consultant Psychiatrists, Dehra Dun.
- Prof. Somnath Dasgupta, Department of Sciences, Jadavpur University, Kolkata.
- Dr. Joy Routh, Stockholm University.
- Dr. Jagdish Bahadur, Ex. Director, DST. New Delhi

Dr. Harsh Gupta, Secretary, Department of Ocean Development, Government of India, delivered the J.B. Auden Memorial Lecture at the Institute on April 8, 2005.

STATUS OF IMPLEMENTATION OF HINDI

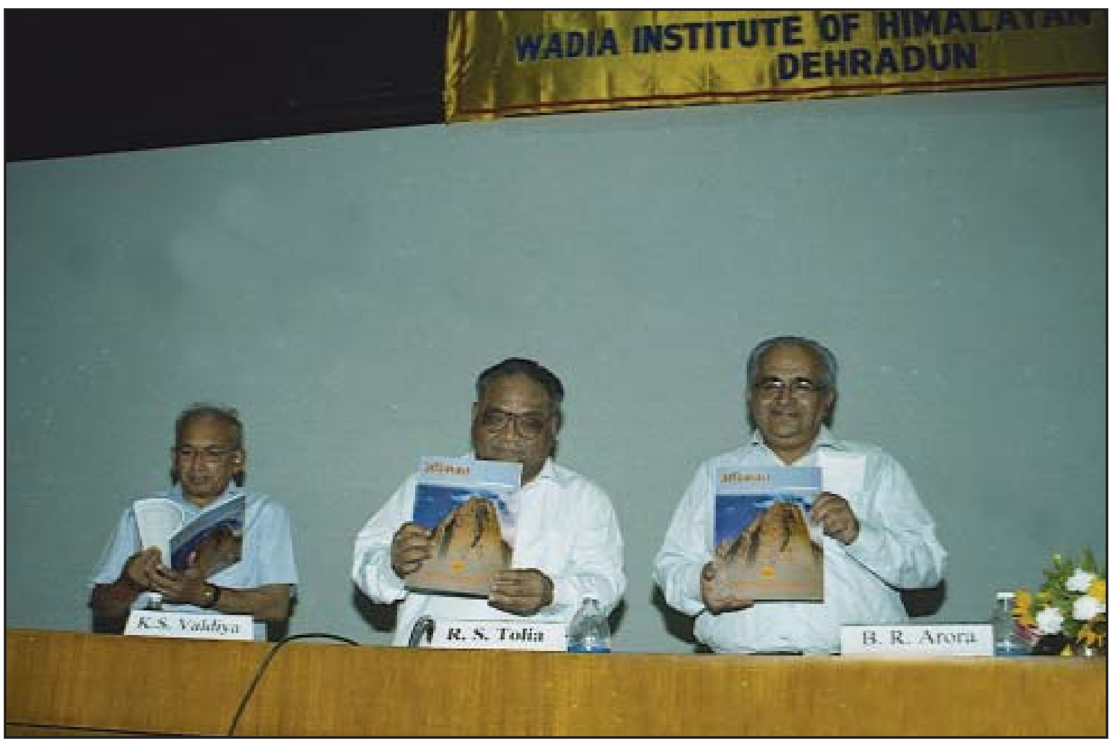
During the year under report, efforts for progressive use of Hindi were continued. The scientists and staff of the Institute were time and again apprised with the various orders and constitutional provisions of official Language Act to increase awareness for progressive use of Hindi in day-to-day work.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

On the occasion of the Foundation Day of the Institute on 29 June 2005, the Hindi Magazine 'Ashmika" Volume 11 was released. A scientist of the Intitute , Dr. P.S. Negi was conferred a prize for his article in Hindi entitled, "Jalwayu pariwartan evam uske viswavyapi prabhaw-ek vegyanic vishleshan" under a scheme for promoting scientific writing in Hindi.

Hindi fortnight was celebrated from 14 September 2005 to 29 September 2005, during which various competitions like poetry, essay and debate were organized. Professor V.K.S. Dave from I.I.T., Roorkee delivered a lecture entitled, "Rashtra Vigyan Evam Bhasha" on 15.9.2006 to inspire the staff for progressive use of Hindi in their work.

The Annual Report of the Institute for the year 2004-2005 was translated in Hindi and published in bilingual form.

On the occasion of the National Science Day week, a Hindi Essay competition was organized for the students of various schools of Dehra dun. The title of the Hindi Essay was "Himalayee Paryavaran-Samasyayein Evam Samadhan".



Dr. R.S. Tolia, Chief Secretary, Uttaranchal Government releasing the WIHG Hindi Magazine 'Ashmika'.

MISCELLANEOUS ITEMS

1. Reservations / Concessions for SC/ST employees

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

2. Monitoring of Personnel matters

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

3. Mechanism for redressal of employee's grievances

There is a Grievance Committee consisting of four Senior Scientist/Officers for redressal of employee's grievances. To look into the grievances of women employees in the Institute a separate Committee has also been constituted. The Committee consists of six members. Chairman and two other members of the Committee are female Officers, which include one officer from Geological Survey of India.

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 Institute is providing recreational facilities to its employees.

5. Sanctioned Staff-strength (category-wise)

[A] NON-PLAN :

Group/ Category	Scien-tific	Techni-cal	Adminis-trative	Ancillary	Total
A	61	-	2	-	63
B	-	2	5	-	7
C	-	35	30	13	78
D	-	28	-	25	53
Total	61	65	73	-	201

[B] PLAN :

Group/ Category	Scien-tific	Techni-cal	Adminis-trative	Ancillary	Total
A	2	-	-	-	2
B	-	-	1	-	1
C	-	2	-	1	3
D	-	-	-	1	1
Total	2	2	1	2	7

6. Approved budget grant for the year 2005-2006

Plan : Rs. 1000.00 Lakhs (Grant-in-aid) + 300.00 Lakhs as one time grant for purchase of an "Electron Probe Micro Analyzer (EPMA)

Non-Plan : Rs. 120.00 Lakhs

Total : Rs. 1120.00 + 300.00 = 1420.00 Lakhs

7. Xth Plan approved outlay

Plan : Rs. 3000.00 Lakhs

Released : Rs. 4055.00 Lakhs

Sl. No.	F. Year	Amount Released (Rupees in Lakhs)
1.	2002-2003	575.00
2.	2003-2004	630.00
3.	2004-2005	750.00
4.	2005-2006	1000.00
5.	2006-2007	1100.00
		4055.00 Lakhs

EPMA LABORATORY

As a part of the on-going upgradation of analytical facilities, CAMECA SX100 Electron Probe Micro Analyzer instrument for imaging and analyzing materials was installed at the Institute.

Prof. V.S. Ramamurthy, Ex-Secretary, DST inaugurating the EPMA facility at WIHG.

MAGNETOTELLURIC STUDIES

Magnetotelluric studies in Himalayan region initiated in the Institute from this year.

MT unit deployment near Dugadda, Uttaranchal.

On his superannuation on 31.7.2005 Dr. A.C. Nanda, Scientist 'G' and Doon Ratna, being fecilitated by Dr. B.R. Arora, Director

STAFF OF THE INSTITUTE AS ON 31.3.2006

(A) Scientific Staff

1.	Prof. B.R. Arora	Director
2.	Dr. A.C. Nanda	Scientist 'G' (retired on 31.7.05)
3.	Dr. A.K. Dubey	Scientist 'F'
4.	Dr. Trilochan Singh	Scientist 'F'
5.	Dr. R.K.Mazari	Scientist 'F'
6.	Dr. R.J.Azmi	Scientist 'F'
7.	Dr. J.T.Gergan	Scientist 'F'
8.	Dr. N.S.Gururajan	Scientist 'F'
9.	Dr. Devendra Pal	Scientist 'E'
10.	Dr. R.S.Rawat	Scientist 'E'
11	Dr.V.C.Tiwari	Scientist 'E'
12.	Dr. M.S.Rathi	Scientist 'E'
13.	Dr. K.S.Bist	Scientist 'E'
14.	Dr. D.K.Misra	Scientist 'E'
15.	Dr. B.K.Choudhary	Scientist 'E'
16.	Dr. R.K.Choujar	Scientist 'E'
17.	Dr. V.M.Choubey	Scientist 'E'
18.	Dr. N.R.Phadtare	Scientist 'E'
19.	Dr. P.P.Khanna	Scientist 'E'
20.	Dr. Rohtash Kumar	Scientist 'E'
21.	Dr. Keser Singh	Scientist 'E'
22.	Dr.(Mrs.)Meera Tiwari	Scientist 'E'
23.	Dr. S.K.Ghosh	Scientist 'E'
24.	Dr. M.P.Sah	Scientist 'E'
25.	Dr. N.K.Saini	Scientist 'E'
26.	Dr. S.K.Paul	Scientist 'E'
27.	Dr. T.N.Jowhar	Scientist 'E'
28.	Dr. K.K.Purohit	Scientist 'E'
29.	Dr. Kishor Kumar	Scientist 'E'
30.	Dr. N.Siva Siddaiah	Scientist 'E'
31.	Dr. Rajesh Sharma	Scientist 'E'
32.	Dr. G.Philip	Scientist 'E'
33.	Dr. Rafikul Islam	Scientist 'E'
34.	Dr. D.Rameshwar Rao	Scientist 'E'
35.	Dr. B.N.Tiwari	Scientist 'E'
36.	Dr. S.K.Bartarya	Scientist 'E'
37.	Dr. P.K.Mukharjee	Scientist 'D'
38.	Dr. S.J.Sangode	Scientist 'D'
39	Dr. Sushil Kumar	Scientist 'D'
40.	Dr. P. Banerjee	Scientist 'D'
41.	Dr. S.K.Parcha	Scientist 'D'
42.	Dr.H.K.Sachan	Scientist 'D'
43.	Shri B.S. Rawat	Scientist 'C'
44.	Dr. A.K.Mahajan	Scientist 'C'
45.	Dr. D.P. Dobhal	Scientist 'C'
46.	Dr. Vikram Gupta	Scientist 'C'
47.	Dr. S.S. Bhakuni	Scientist 'C'
48.	Dr. Suresh N.	Scientist 'C'
49.	Dr. Jayant Kumar Tripathi	Scientist 'C'
50.	Dr. Pradeep Srivastava	Scientist 'C'
51.	Dr. Ajay Paul	Scientist 'C'
52.	Dr. A.K.Mundepi	Scientist 'B'
53.	Shri. V.Sriram	Scientist 'B'
54.	Dr.B.P.Sharma	Scientist 'B'
55.	Dr. P.S. Negi	Scientist 'B'
56.	Dr.A.K.L Asthana	Scientist 'B'
57.	Dr. Kapesa Lokho	Scientist 'B'
58.	Dr. A.K.Singh	Scientist 'B'
59.	Dr.R.Jayangondaperumal	Scientist 'B'
60.	Dr. Khaying Shing Luirei	Scientist 'B'
61.	Dr. Renoj J. Thayyen	Scientist 'B'
62.	Shri Rajesh S.	Scientist 'B'
63.	Shri Gautam Rawat	Scientist 'B'

(B) Technical Staff

1.	Shri V.P. Singh	Sr.Pub. & Doc. Officer Gr.III (5)
2.	Shri Saeed Ahmad	Sr.Librarian Gr.III (5)
3.	Shri J.J. Sharma	Sr.Technical Officer Gr.III (5)
4.	Shri M.M.S. Rawat	Tech.Officer Gr.III (4)
5.	Shri B.B. Sharma	Tech.Officer Gr.III (4)
6.	Shri A.K.Pandit	Artist cum Modellor Gr.III (3)
7.	Shri Sanjeev Dabral	Junior Tech.Officer Gr.III (3)
8.	Dr. R.K.Sehgal	Junior Tech.Officer Gr.III (3)
9.	Shri Chandra Shekhar	Junior Tech.Officer Gr.III (3)
10.	Shri V.P. Gupta	Junior Tech.Officer Gr.III (3)
11.	Sh. Samay Singh	Jr.Tech.Officer Gr.III (3)
12.	Shri Vishnu Shreshtha	Sr.Lab.Asstt. Gr.II (5)
13.	Sh. S.C. Kothiyal	Lab.Asstt.Gr.II (5)
14.	Shri Rakesh Kumar	Sr.Tech.Asstt.Gr.III(2)
15.	Shri N.K. Juyal	Sr. Tech, Asstt.Gr.III (2)
16.	Shri T.K. Ahuja	Sr. Technical Assistant Grade III (2)
17.	Shri C.B. Sharma	Junior Engineer
18.	Shri S.S. Bhandari	Technical Assistant
19.	Sh. Rambir Kaushik	Technical Assistant
20.	Dr. Jitendra Bhatt	Technical Assistant (EDP)
21.	Shri Bharat Singh Rana	Technical Assistant
22.	Shri V.K.Kala	Draftsman Gr.II (5)
23.	Shri G.S. Khattri	Draftsman Gr.II (5)
24.	Shri Navneet Kumar	Draftsman Gr.II (5)
25.	Shri B.B.Saran	Draftsman Gr.II (1)
26.	Shri Chandra Pal	Section Cutter Gr.II (5)
27.	Shri Shekhranandan	Section Cutter Gr.II(5)
28.	Pushkar Singh	Section Cutter Gr.II (4)
29.	Shri Satya Prakash	Section Cutter Gr.II (2)
30.	Shri Santu Das	Section Cutter Gr.II (1)
31.	Shri Nand Ram	Elect.cum-Pump.Optr.Gr. II(3)
32.	Shri H.C. Pandey	Sr. Tech.Asstt
33.	Shri Ravindra Singh	Sr.Tech.Assistant
34.	Dr. S.K. Chabak	S.L.T.
35.	Shri Lokeshwar Vashistha	S.L.T.
36.	Shri R.M. Sharma	S.L.T.
37.	Shri C.P. Dabral	S.L.T.
38.	Shri Satish Pd.Bahuguna	F.C.L.A. Gr. I(4)
39.	Shri S.K. Thapliyal	F.C.L.A.Gr. I(4)
40.	Shri Shiv Pd. Bahuguna	F.C.L.A.Gr. I(4)
41.	Shri Sashidhar Pd.Balodi	F.C.L.A. Gr. I(4)
42.	Shri Rajendra Prakash	F.C.L.A.Gr. I(4)
43.	Shri A.K. Gupta	F.C.L.A.Gr. I(4)
44.	Shri Tirath Raj	F.C.L.A.Gr. I(4)
45.	Shri Balram Singh	F.C.L.A.Gr. I(4)
46.	Shri Anoop Singh	F.C.L.A.Gr. I(3)
47.	Shri Pratap Singh	F.C.L.A.Gr. I(3)
48.	Shri Ram Kishor	F.C.L.A.Gr. I(3)
49.	Shri Ansuya Prasad	F.C.L.A.Gr. I(2)
50.	Shri Puran Singh	F.C.L.A.GR.I(2)
51.	Shri Ram Khilawan	F.C.L.A.Gr. I(2)
52.	Shri Madhu Sudan	F.C.L.A.Gr. I(2)
53.	Shri Hari Singh	F.C.L.A.Gr. I(2)
54.	Shri Ravi Lal	F.C.L.A.Gr. I(2)
55.	Shri Preetam Singh	F.C.L.A.Gr. I(2)

56.	Shri Subodh Kumar Barthwal	Lab.Assistant
57.	Shri Nain Das	Lab.Assistant
58.	Mrs.Rama Pant	F.C.L.A.
59.	Shri R.S.Negi	F.C.L.A.
60.	Shri Ramesh Chandra	F.C.L.A.
61.	Shri Khusi Ram	F.C.L.A.
62.	Shri Tikam Singh	F.C.L.A.
63.	Shri Bharosa Nand	F.C.L.A.
64.	Shri B.B.Panthri	F.C.L.A.
65.	Shri M.S.Rawat	F.C.L.A.

(C) Administrative Staff

1.	Shri Dinesh Chandra	Registrar
2.	Shri Harish Chandra	Fin. & Accounts Officer
3.	Shri R.K. Matah	Administrative Officer
4.	Shri G.S. Negi	Asstt. Fin. & Accounts Officer
5.	Shri Manas Kumar Biswas	Store and Purchase Officer
6.	Shri Tapan Banerjee	Sr. Personal Assistant
7.	Shri U.S. Tikkha	Accountant
8.	Mrs. Manju Pant	Office Superintendent
9.	Mrs. Shamlata Kaushik	Assistant (Hindi)
10.	Mrs. Nirmal Rattan	Assistant
11.	Shri O.P.Anand	Assistant
12.	Shri N.B.Tewari	Assistant
13.	Shri B.K.Juyal	Assistant
14.	Shri D.P.Chaudary	Stenographer Grade - II
15.	Shri P.P.Dhasmana	Stenographer Grade - II
16.	Smt. Rajvinder Kaur Nagpal	Stenographer Grade – III
17.	Shri Hukam Singh	U.D.C (Assistant Adhoc)
18.	Shri D.S.Rawat	U.D.C
19.	Shri S.S.Bisht	U.D.C.
20.	Mrs. Sarojini Rai	U.D.C.
21.	Mrs. Sharda Sehgal	U.D.C.
22.	Shri M.M.Barthwal	U.D.C.
23.	Shri M.C.Sharma	U.D.C.
24.	Shri A.S.Negi	U.D.C.
25.	Shri S.K.Chettri	U.D.C.
26.	Shri Vinod Singh Rawat	U.D.C.
27.	Shri S.K.Srivastava	L.D.C. (UDC Adhoc)
28.	Shri R.C.Arya	L.D.C.
29.	Mrs. Prabha Kharbanda	L.D.C.
30.	Mrs. Kalpana Chandel	L.D.C.
31.	Mrs. Anita Chaudhary	L.D.C.
32.	Shri Shiv Singh Negi	L.D.C.
33.	Mrs. Neelam Chabak	L.D.C.
34.	Mrs. Seema Juyal	L.D.C.
35.	Mrs. Suman Nanda	L.D.C.
36.	Shri Kulwant Singh Manral	L.D.C.
37.	Shri Rahul Sharma	L.D.C.
38.	Shri Bhagat Singh	Bearer
39.	Mrs. Kamla Devi	Bearer
40.	Mrs. Deveshawari Rawat	Bearer
41.	Shri Shyam Lal	Bearer
42.	Shri S.K. Gupta	Bearer
43.	Shri Chait Ram	Bearer
44.	Mrs. Omwati	Bearer
45.	Shri Jeevan Lal	Bearer
46.	Shri Surendra Singh	Bearer
47.	Shri Vijai Ram Bhatt	Bearer

(D) Ancillary Staff

1.	Puran Singh	Driver
2.	Shri Khem Singh	Driver
3.	Shri Dewan Singh	Driver
4.	Shri Sohan Singh	Driver
5.	Shri Ganga Ram	Driver
6.	Shri Chander Pal	Driver
7.	Shri Naresh Kumar	Driver
8.	Shri Shyam Singh	Driver
9.	Shri M.K. Tamang	Driver
10.	Shri R.S. Yadav	Driver
11.	Shri Surjan Singh	Driver
12.	Shri Girish Chander Singh	Guest House Attendant cum Cook
13.	Sh. Dinesh Parsad Saklani	Guest House Attendant cum Cook
14.	Sh. Lal Bahadur	Chowkidar
15.	Shri Har Prasad	Chowkidar
16.	Shri Mahendra Singh	Chowkidar
17.	Shri Mine Ram	Chowkidar
18.	Shri Rohlu Ram	Chowkidar
19.	Shri H.S. Manral	Chowkidar
20.	Shri G.D. Sharma	Chowkidar
21.	Shri Swaroop Singh	Mali
22.	Shri Ashok Kumar	Mali
23.	Shri Satya Narayan	Mali
24.	Mrs. Dukhni Devi	Mali
26.	Shri Ramesh	Safaiwala
27.	Shri Hari Kishan	Safaiwala

(D) Security Staff (on Contract)

1.	Sh. Om Prakash Thapa	Security Guard
2.	Sh. Mohan Singh Rawat	Security Guard
3.	Sh Rattan Singh Panwar	Security Guard
4.	Sh . Manohar Lal Uniyal	Security Guard
5.	Sh Kirti Dutt	Security Guard

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

Governing Body
(w.e.f. 1.11. 2003)

Sl. No.	Name	Address	Status
1.	Prof. K.S. Valdiya	302, Sterling Apartments 10, Papanna Street Off. St. Marhs Road BANGALORE - 560 001	Chairman
2.	Prof. S.K. Tandon	Pro-Vice-Chancellor Delhi University DELHI - 110 007	Member
3.	Shri K. Krishanan Unni	(Ex. D.G., G.S.I.) 400, Saroj, Narikodi Extn. Chandranagar PALAKKAD - 678 007 (KERALA)	Member
4.	Prof. Alok Gupta	Director National Centre for Experimental Mineralogy and Petrology 14, Chattam Lines ALLAHABAD - 211 002	Member
5.	Prof. D.C. Goswami	Deptt. of Environmental Science Gauhati University GUWAHATI - 781 014	Member
6.	Dr. R.N. Singh	Emeritus Scientist National Geophysical Research Institute Uppal Road HYDERABAD – 500 007	Member
7.	Prof. S.K. Shah	69-70 Lake View Residency Sainik Puri SECUNDERABAD - 500 094	Member
8.	Prof. A.K. Jain	Department of Earth Sciences Indian Institute of Technology ROORKEE - 247 667	Member
9.	Shri K.P. Pandian	Joint Secretary (F&A) Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member
10.	Shri P.M. Tejala	Director General Geological Survey of India 27, Jawaharlal Nehru Road KOLKATA - 760 016	Member
11.	Dr. D.K. Pande	Director (Exploration) Jeevan Bharti Building Tower -II, 9th Floor, O.N.G.C. 124, Indira Chowk NEW DELHI - 110 001	Member
12.	Maj. Gen. M. Gopalrao	Surveyor General of India Surveyor General's Office Hathibarkala DEHRA DUN - 248 001	Member

13.	(a) Dr. G.D. Gupta (Nominee of Secretary, DST)	Adviser & Head Seismology Division Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member
	(b) Dr. B. Hari Gopal (Nominee of Secretary, DST)	Scientist 'F' & Adviser (AI) Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member (1.2.2006 onwards)
14.	Dr. R.N. Sarwade (Nominee of the Scientific Advisor to the Defence Minister)	Director Snow & Avalanche Study Establishment Research & Development Centre Ham Parisar, Sector, 37 A CHANDIGARH – 160 036	Member
15.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN – 248 001	Member Secretary
16.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN – 248 001	Non-Member Asstt. Secretary

Research Advisory Committee (w.e.f. 1.11. 2003)

Sl. No.	Name	Address	Status
1.	Prof. S.K. Tandon	Pro-Vice-Chancellor Delhi University DELHI - 110 007	Chairman
2.	Dr. D.K. Paul	BF/217, Sector – I Salt Lake KOLKATA - 700 064	Member
3.	Prof. D.C. Srivastava	Dept. of Earth Sciences Indian Institute of Technology ROORKEE - 247 667	Member
4.	Prof. P.K. Saraswati	Dept. of Earth Sciences Indian Institute of Technology Powai MUMBAI - 400 076	Member
5.	Dr. S.K. Biswas	201, C-Wing, ISM House 818-A, Thakur Village Kandivilli (E) MUMBAI - 400 101	Member
6.	Prof. R.S. Sharma	Dept. of Geology Rajasthan University JAIPUR - 302 004	Member
7.	Dr. R. Dhanaraju	6-3, 124 Hastinapuri Sanikpuri P.O. SICUNDERABAD – 500 094	Member
8.	Prof. Kanchan Pande	Dept. of Earth Sciences Indian Institute of Technology Powai MUMBAI - 400 076	Member

9.	Dr. S.K. Gupta	Physical Research Laboratory Navrangpura AHMEDABAD - 380 009	Member
10.	Dr. V.P. Dimri	Director National Geophysical Research Institute Uppal Road HYDERABAD - 500 007	Member
11.	Dr. Ramesh Chander	290, Sector – 4 Mansa Devi Complex PANCHKULA – 134 109	Member
12.	Dr. Shailesh Nayak	Group Director MWRG/SAC Space Applications Centre, Ambawadi Vistar P.O. AHMEDABAD - 380 015	Member
13.	Brig. Dr. B. Nagarajan	Director Geodetic & Research Branch Survey of India DEHRA DUN - 248 001	Member
14.	Dr. K.R. Gupta	H-44 B,Saket NEW DELHI – 110 017	Member
15.	Shri N.K. Lal	310/9, Mohit Nagar General Mahadeo Singh Road DEHRA DUN - 248 001	Member
16.	Dr. C.P. Rajendran	Scientist Centre of Earth Sciences Studies Akkulam THIRUVANTHAPURAM – 695 031	Member
17.	Dr. V.K. Raina	(Ex. Dy. Director General, GSI) House No.258 Sector – 17 PANCHKULA - 134 109	Member
18.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member & Convenor

Finance Committee
(w.e.f. 1.11.2003)

Sl. No.	Name	Address	Status
1.	Prof. A.K. Jain	Dept. of Earth Sciences Indian Institute of Technology ROORKEE - 247 667	Chairman
2.	Dr. D.K. Paul	BF/217, Sector – I Salt Lake KOLKATA - 700 064	Member
3.	Shri S.K. Ahuja	Under Secretary (F) to the Govt. of India Department of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI – 110 016	Member
4.	Shri K.P. Pandian	Joint Secretary (F&A) Department of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI - 110 016	Member

5.	Shri M.K. Jain	Deputy Financial Adviser Indian Institute of Petroleum DEHRA DUN - 248 001	Member
6.	Mrs. Alka Sharma	OSD to FADS (Finance) Ministry of Defence Room No. 23 - B South Block, NEW DELHI-110016	Member
7.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member
8.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member
9.	Shri Harish Chandra	Finance & Account Officer Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary

Building Committee (w.e.f. 1.11.2003)

Sl. No.	Name	Address	Status
1.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Chairman
2.	Shri S.K. Tyagi	Suptt. Engineer, Dehra Dun Central Circle, C.P.W.D., Nirman Bhawan, 20, Subhash Road, DEHRA DUN - 248 001	Member
3.	Shri Rajesh Agrawal	Chief Engineer (Civil) Deptt. of Civil Engineer Shed No. 32 Oil & Natural Gas Corporation DEHRA DUN - 248 001	Member
4.	Shri K.S. Nepolean	Director, Department of Science & Technology, Technology Bhawan, New Mehrauli Road, NEW DELHI - 110 016	Member
5.		Head Civil Engineering Department Indian Institute of Technology, ROORKEE - 247 667	Member
6.	Shri C.R. Srivastava	Executive Engineer, Indian Institute of Petroleum, Mohkampur, DEHRA DUN –248 001	Member
7.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary

STATEMENT OF ACCOUNTS

A.K. KASHYAP & CO.
Chartered Accountants

37, Rajpur Road,
Dehra Dun - 248 001
Phones: Off. 2652346, 2655634, 2713962
Fax : 0135-2655634
E-mail : akkashyap1@hotmail.com

AUDITOR'S REPORT

We have examined the attached Balance Sheet of **Wadia Institute of Himalayan Geology, Dehradun,** as at 31st March 2006 and the annexed Income & Expenditure Account and Receipt and Payment Account for the year ended on that date. These Financial statements are the responsibility of the Institute's management. Our responsibility is to express an opinion on these financial statements based on our audit.

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

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

1) In the case of the Balance Sheet of the state of affairs as at 31st March 2006.
2) In the case of Income & Expenditure Account of the surplus for the year ended on 31st March 2006.
3) In the case of Receipt & Payment Account of the receipts and payments for the year ended on 31st March 2006.

For A.K. Kashyap & Co.
Chartered Accontants

Sd/-

(ASHOK KASHYAP)
F.C.A. Partner

Date : 31 August 2006
Place : Dehra Dun

A.K. KASHYAP & CO.
Chartered Accountants

37, Rajpur Road,
Dehra Dun - 248 001
Phones: Off. 2652346, 2655634, 2713962
Fax : 0135-2655634
E-mail : akkashyap1@hotmail.com

SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS FOR THE YEAR ENDING 31.03.2006

SIGNIFICANT ACCOUNTING POLICIES

A. ACCOUNTING CONVENTION

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

i) Interest accrued on FDR of GPF/CPF and Pension Fund
ii) Interest accrued on Employees/Employer's contribution of GPF/CPF
iii) Expenses Payable

B. FIXED ASSETS

i) Fixed Assets are stated at cost of acquisition or cost of construction plus the related expenditure. As per the decision of management from the current year depreciation has been charged on the Fixed Assets at the rates specified in the Income Tax Act. Full depreciation has been charged on the additions to all Fixed Assets made during the year.
ii) Vehicle purchases prior to 01.04.98 have been debited to Equipment account.

C. CLASSIFICATION

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

A.K. KASHYAP & CO.
Chartered Accountants

37, Rajpur Road,
Dehra Dun - 248 001
Phones: Off. 2652346, 2655634, 2713962
Fax : 0135-2655634
E-mail : akkashyap1@hotmail.com

NOTES TO ACCOUNTS

A. MAIN ACCOUNT OF WIHG:

i) Schedule '1' to '15' forms part of the Balance Sheet, '16' to '38' forms part of the Income & Expenditure and Receipt & Payments Account as on 31.03.06.
ii) Balance of Debtors and Creditors as on 31.03.06 subject to confirmation.

B. GENERAL PROVIDENT FUND/CONTRIBUTORY PROVIDENT FUND

The management contribution towards provident fund has been provided at the year end.

C. PROJECTS

The Miscellaneous Contingency Account head includes expen0ses pertaining to Repairs and Maintenance, Registration Expenses, Printing and Stationery and other expenses related to Projects.

For A.K. Kashyap & Co.
Chartered Accountants

Sd/-

(Ashok Kashyap)
F.C.A.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
BALANCE SHEET AS ON 31ST MARCH 2006

Amount in Rupees

Particulars		Current Year	Previous Year
LIABILITIES			
Corpus/ Capital Fund	*1*	*515,701,033*	*404,389,287*
Reserves and Surplus	*2*	-	-
Earmaked/ Endowment Fund	*3*	*1,967,401*	*2,754,647*
Secured Loans & Borrowings	*4*	-	-
Unsecured Loans & Borrowings	*5*	-	-
Deferred Credit Liabilities	*6*	-	-
Current Liabilities & Provisions	*7*	*4,649,666*	*3,700,604*
Pension Fund	*8*	*41,782,016*	*32,594,111*
CPF/GPF Fund	*9*	*34,292,388*	*32,520,662*
Total		*598,392,504*	*475,959,311*
ASSETS			
Fixed Assets	*10*	*319,084,686*	*276,677,235*
Investment from Earmaked/ Endowment Fund	*11*	*19,255*	*19,255*
Investment-others	*12*	-	-
Current Assets Loans & Advances	*13*	*203,214,159*	*134,148,048*
Pension Fund	*14*	*41,782,016*	*32,594,111*
CPF/GPF Fund	*15*	*34,292,388*	*32,520,662*
Total		*598,392,504*	*475,959,311*

AUDITOR'S REPORT

"As per our separate report of even date"

Significant Accounting Policies and
Notes on Accounts as per Annexure

For A.K. KASHYAP & CO.
Chartered Accountants

Sd/-
Ashok Kashyap
(F.C.A.)

Date : 31.08.06
Place : Dehradun

Sd/-
(Harish Chandra)
Finance & Accounts Officer

Sd/-
(Dinesh Chandra)
Registrar

Sd/-
(B.R. Arora)
Director

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
Income & Expenditure A/c for the period ended 31st March 2006

Amount in Rupees

S.No.	Particulars		Current Year	Previous Year
A	**INCOME**			
	Income from sales/ services	16	-	-
	Grants/ Subsidies	17	82,000,000	74,950,000
	Fees/Subscription	18	16,000	19,370
	Income from Investments (Income on Invest from Earmarked/ Endowment - Fund)	19	217,896	121,544
	Income from Royalty, Publication etc.	20	81,266	58,391
	Interest earned	21	3,452,272	1,159,488
	Other Income	22	2,677,942	2,843,280
	Increase/ Decrease in stock of Finished goods & WIP	23	-	-
	TOTAL (A)		**88,445,376**	**79,152,073**
B	**EXPENDITURE**			
	Establishment Expenses	24	58,587,288	45,651,833
	Other Research & Administrative Expenses	25	15,205,379	12,210,716
	Expenditure on Grant/ Subsidies etc.	26	-	-
	Interest/ Bank Charges	27	9,794	8,190
	TOTAL (B)		**73,802,461**	**57,870,739**
	Surplus/ (Deficit) being excess of Income over Expenditure (A - B)		14,642,915	21,281,334
	Transfer to Special Reserve (Specify each)		-	-
	Transfer to / from General Reserve		-	-
	GRAND TOTAL		**88,445,376**	**79,152,073**

AUDITOR'S REPORT

"As per our separate report of even date"

Significant Accounting Policies and Notes on Accounts as per Annexure

For A.K. KASHYAP & CO.
Chartered Accountants

Sd/-
Ashok Kashyap
(F.C.A.)

Date : 31.8.2006
Place : Dehradun

Sd/-
(Harish Chandra)
Finance & Accounts Officer

Sd/-
(Dinesh Chandra)
Registrar

Sd/-
(B.R. Arora)
Director

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
Receipts & Payments Account for the year ended 31st March 2006

Amount in Rupees

Particulars		Current Year	Previous Year
RECEIPTS			
Opening Balance	30	22,246,227	7,786,329
Grants - in - Aids	35	142,000,000	88,500,000
Grants - in - Aids (Ear Marked)	36	5,449,400	5,500,175
Loan & Advances	28	16,724,578	20,519,828
Fees/Subscription	18	16,000	19,370
Income from Investments	19	217,897	121,544
Income from Royalty, Publication etc.	20	81,266	58,391
Interest earned on Loan to Staff	21	3,452,272	1,159,488
Other Income	22	2,677,942	2,843,280
Investment	32	9,500,000	15,783,000
Decrease in stock (publications)		-	-
		202,365,582	142,291,405
PAYMENTS			
Establishment Expenses	24	58,467,788	45,651,833
Other Administrative Expenses	25	15,205,379	12,210,716
Interest/ Bank Charges	27	9,794	8,190
Loans & Advances	29	12,883,309	20,257,280
Investments	33	38,100,000	9,500,000
Fixed Assets	34	59,400,414	29,194,398
Ear Marked Fund Expenses	37	5,500,948	3,194,758
Grant - in - Aid (Ear Marked) Refunded	38	735,698	-
Closing Balance	31	12,062,252	22,246,227
Increase in value of closing Stock (Publications)		-	28,002
		202,365,582	142,291,405

AUDITOR'S REPORT

"As per our separate report of even date"

Significant Accounting Policies and Notes on Accounts as per Annexure

For A.K. KASHYAP & CO.
Chartered Accountants

Sd/-
Ashok Kashyap
(F.C.A.)

Date : 31.08.06
Place : Dehradun

Sd/-
(Harish Chandra)
Finance & Accounts Officer

Sd/-
(Dinesh Chandra)
Registrar

Sd/-
(B.R. Arora)
Director

WADIA INSTITUTE OF HIMALAYAN GEOLOGY
Publication & Documentation Section

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