WADIA INSTITUTE OF HIMALAYAN GEOLOGY

ANNUAL REPORT

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WADIA INSTITUTE OF HIMALAYAN GEOLOGY

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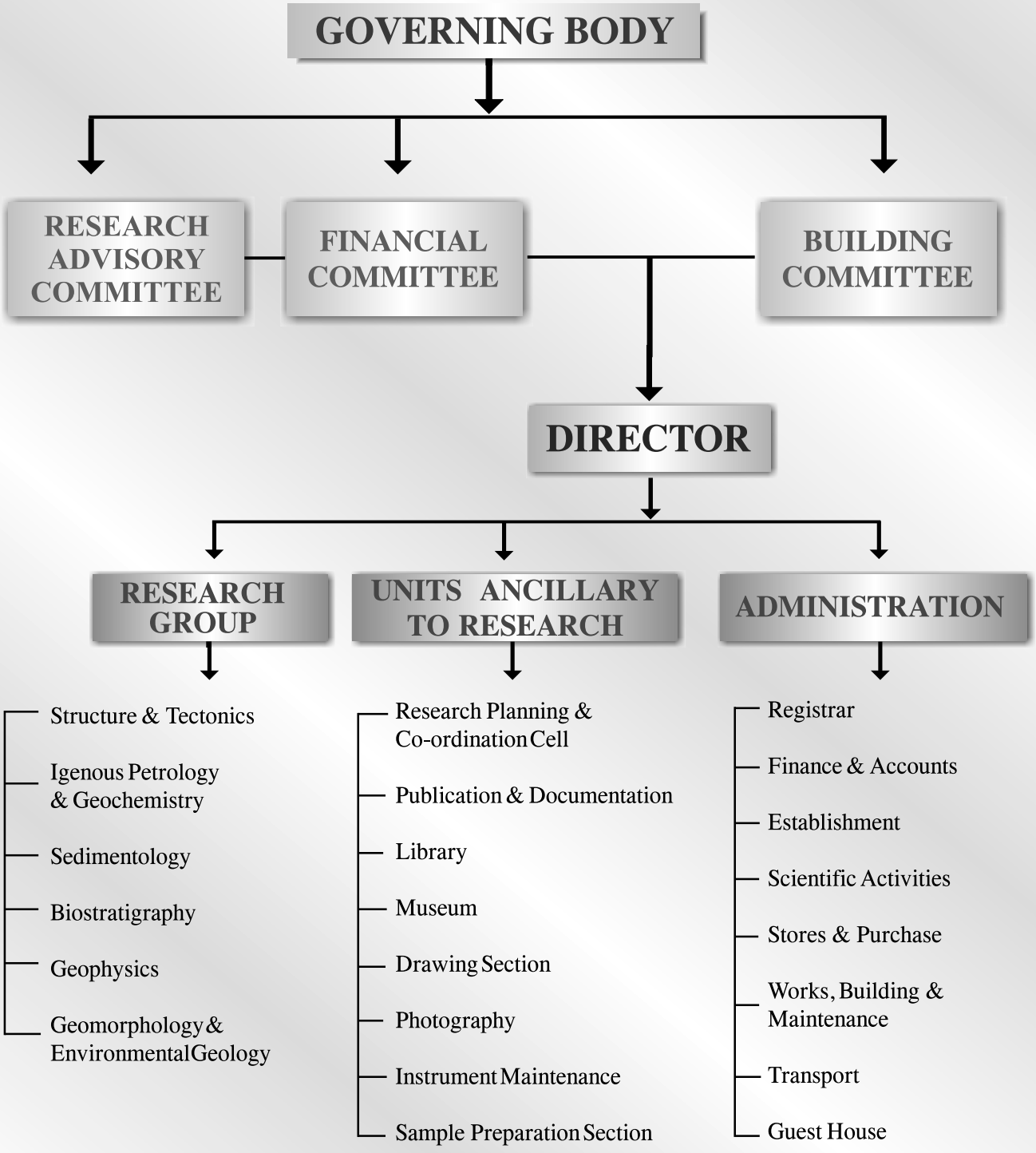


OVERVIEW

Baldev Raj Arora, Director

Wadia Institute of Himalayan Geology is an autonomous Institute of the Department of Science and Technology, Government of India, devoted to basic and applied research on geology, natural resources, environment and natural disasters in the Himalaya. The scientists of the Institute continued to work on the basic and applied aspects of the Earth Science studies in the Himalaya. Number of new programs are initiated and on-going projects as a part of 10th Five Year Plans have progressed well.

Given the geodetic evidences the central arc of the Himalaya is critically stressed that may generate a great earthquake. Hence a number of new initiative are taken by the Institute for intense seismic monitoring and variety of earthquake precursors. The Department of Science and Technology has approved installation of 10 stations telemetry array of broad-band seismometers in the Garhwal Himalaya. This, with already operational network operated by the Institute, Kumaun University, CSIO, Chandigarh and IIT, Roorkee, will bring the earthquake detection level to magnitude ≥ 3. Under the Mission Mode Project on Seismicity, launched by the DST, the Institute is establishing a Multi-parametric Geophysical Observatory in Uttaranchal for monitoring earthquake precursors. This will be a unique and first of its kind observatory where more than 9 parameters will be monitored simultaneously. The observatory will be equipped with broad-band seismometer, accelerometer, GPS receiver, radon eminometer, electro-magnetic emission sensors, water level monitoring system as well as geomagnetic and electric sensors. The most significant addition in this observatory will be establishment of a super conductivity gravimeter that can register gravity changes as low as 2 μ Gal. Another major initiative being implemented by the Institute is a Himalayan School Earthquake Learning Programme (HIMSELP). As a part of this initiative a network of seismic stations is being installed in various schools of Uttaranchal and Himachal Pradesh to inculcate the culture of seismological data acquisition and introduce teaching of basic principles of physics and earthquake sciences. The goal of the HIMSELP is to create fruitful links between research institutions, colleges/secondary schools and public at large.

Recognizing the need of trained man-power to take-up research in emerging areas of research, the Institute has introduced a fresh graduate programme. Under this scheme 6 JRF, 2 SRF and 5 Research Associates have joined the academic cadre of the Institute. A special re-orientation course is being planned. This is in addition to the 3 Scientists, who have joined the ranks of the Institute. In order to broaden the research in the inter-disciplinary areas, the Institute has also signed a Memorandum of Understanding with the National Geophysical Research Institute (NGRI), Birbal Sahni Institute of Paleobotany (BSIP), and with the International Institute for Geoinformation Sciences and Earth Observation (ITC), Netherlands. To prompt academic and scientific interaction, a number of Distinguished Scientists were invited to deliver special D.N. Wadia, and W.D. West Lectures, besides the regular in-house seminars.

With an objective to provide necessary infrastructural facilities to produce internationally competitive data base research at the Institute, a phased – manner programme for the upgradation of analytical laboratory facilities has been initiated. A major achievement in this direction during the year has been the procurement of Electrone-Probe Micro Analyzer. This, coupled with the new ICP-MS and XRD facilities established last year, has made the geochemical laboratory at the Institute at par with the most modern labs. All these facilities are available to national institutions and universities. In addition, 4 units of broad-band seismic instruments with digital data acquisition system are procured. To step up the petrological and biostratigraphic studies, two modern microscopes with on line digital imagery analyzer are also made operational.

The on-going studies were performed at varius platforms. For example, preparation of geological maps, collection of data on microseismicity, and GPS studies were performed in field. Microscopic and geochemical studies, and data interpretation was done in laboratories. The field and lab data was integrated in order to understand the evolution of the Himalaya and active tectonics of the region. The endeavours of the scientists are described under the following thrust heads:

- Geodynamics and Crustal Evolution
- Basin Evolution
- Natural Hazards
- Glaciology and Natural Resources
- Paleoclimate and Environment
- Studies in NE Himalaya

The projected objectives are achieved through long-term and short-term projects of the Institute, supplemented by sponsored projects. The year witnessed all round progress in all the research projects. Important achievements in each thrust area are highlighted below.

Geodynamics and Crustal Evolution

Studies supported by geological mapping, experimental modeling, petrochemical analyses and mineralogical inputs were carried out to throw light on the geodynamic evolution of the northwestern Himalaya. This included parts of the Indus Suture Zone, Pangong Tso and Tso Morari Crystalline Complex in Ladakh; Kishtwar window in Kashmir; and Champawat Crystalline Complex in Uttaranchal.

The studies show that the southeastern extension of the Shergul Ophiolitic Melange terminates at north of Tso Kar while the younger Zildat Ophiolitic Melange obducts along the Zildat Fault in eastern Ladakh. The former could not advance eastward due to obstruction created by then highland of the Tso Morari Crytallines. The early collision boundary of NW-SE trending Shergul Ophiolitic Melange was caused by anticlockwise rotation of the northward advancing Indian plate.

In regard to characterization of the MCT in Kishtwar window of the Kashmir Himalaya, a prograde metamorphic sequence towards the core of the Thatri dome is observed for the first time along the Chenab valley. The base of this sequence has a tectonic contact with the underlying Lesser Himalayan rocks and is, thus, interpreted as the MCT. The new tectonic interpretation is not in line with the existing views, which demarcates the MCT around the Kishtwar Window.

The geometric and kinematic models reveal that rotation of layers during thrusting or development of drag folds produced by movement along listric faults results in the formation of dilation space at the junction of the thrust ramp with the basal decollement. This is accompanied by upwarping of the basement to occupy the available space thereby producing an antiformal structure, which restricts the thrust displacement. The structure is termed a decollement upwarp and examples are cited from the foothill belt of the Himalaya.

Detailed magnetic fabric study along either side of the Dehra Dun re-entrant shows that the original EW direction of magnetic lineation (Kmax) as well as magnetic foliation has progressively changed to NS direction by interaction with the underlying structural high/lateral ramp.

The chemical profiling of garnet present in kyanite-sillimanite bearing rocks of Pangong Tso-Metamorphic Complex suggests progressive nature of metamorphism. The fluid inclusion study shows the presence of carbonic-aqueous fluids. Petrochemical studies on the eclogites and garnet-amphibolites that occur as lenses and bands within meta-sediments of the Tso-Morari Crystalline suggest that the protolith melts for the rocks are derived from the upper mantle MORB source with an enriched component either in the form of incompatible-element rich veins or OIB-composition 'plums" or derived from continental material in a subduction zone or alternatively in an intra-continental rifting stage followed by crustal contamination.

Geochemical and fluid inclusion studies on the Champawat Granitoids show that granitoids are adamellite, with their molecular A/CNK ratio averaging around 1.1, and show metaluminous to peraluminous nature. Polymetallic sulphide mineralization in Quartzo-feldspathic schists and gneisses of Precambrian Askot Crystallines in Kumaun Lesser Himalaya consist of complex sulphide assemblage. Both replacement and exsolution features are observed in sulphides. Amongst the four types of fluid inclusions observed in mineralized quartz, primary saline aqueous type I and type II inclusions entrap part of the magmatic fluid that was exsolved from the crystallizing granitic rocks. Syn- to post-granite carbonic fluids evidence variation in X_{CO_2}.

Basin Evolution

Biostratigraphical, sedimentological, and palaeomagnetic studies have provided additional insights into the evolution of basins in the various sectors in the northwestern Himalaya.

A diverse assemblage of ichnofossils has been recorded from the Early and Middle Cambrian strata of the Zanskar region of the Tethys Himalayan. The temporal and environmental implications have been interpreted on the basis of behavioral characteristics, taxonomic diversity and density of the ichnofauna. The varied fossil assemblage reveals deep water, shallow intertidal to shallow water conditions of sediment deposition.

A major hiatus of about 1 billion years has been inferred between the metasediments (Jaunsar/Damtha Group) and the Mussoorie/Deoban Group sedimentaries, suggesting that almost the entire Meso-Neoproterozoic sediments are not preserved in the Lesser Himalayan region. This is based on the delineation of Precambrian-Cambrian boundary datum protoconodonts (544 Ma), glaciation events in the younger sedimentaries (600 Ma Vendian) and volcanics (1500-1800 Ma) in the older metasediments.

The Dharmsala Group (intervening Subathu and Siwalik Groups) in Kangra valley has yielded an isolated ctenodactyloid rodent molar. This is a significant find indicating early Miocene age of the sediments.

Exceptionally well-preserved isolated hexactinellid and monaxons are described from Gangolihat Dolomite of Kumaun Lesser Himalaya. The sponge spicules of such small size are not reported in the Neoproterozoic rocks till date. Their small size indicates that we are dealing with fossils of small ancestral sponges.

Sedimentary facies, stromatolites and carbon ratios indicate shallow marine sedimentation for the Meso-Neoproterozoic carbonates of the Uttaranchal Himalaya. A passive margin is inferred for the post-glacial Krol carbonates on the basis of Ediacaran fauna.

Detailed bulk rock chemistry of Proterozoic sediments of the Lesser Himalaya suggests intense weathering in warm and moist climatic conditions that prevaled during their deposition. Also, presence of monocrystalline quartz, characteristic major, trace elements, enriched LREE and negative Eu anomaly all point to granite or granite gneisses as the source area.

Magnetic polarity stratigraphy along Subathu-Dagshai section of Kaushalya nala (H.P.) records the onset of continental input in the Himalayan foreland at <40.75 Ma with its time transgressive nature by about 750 Ka. A changeover from the shallow marine anoxic depositional environment to marly-pedogenic estuarine continental conditions within a geological time span of 1.5 Ma appears to have played a key role in altering the atmospheric chemistry due to organic carbon exhumation immediately after the passage bed. This demands a closer look on the role of the Subathu-Zanskar sea as a carbon sink and the effect of exhumation of the organic matters on the contemporary regional climate change within a warm to warm humid scenario.

The studies show that spatio-temporal occurrence of paleosols and the intensity of their development in the Siwalik basin is controlled by the interplay of the degree of Himalayan uplift, sedimentation rate, basin subsidence and climate.

Natural Hazards

Under natural hazards programme newer understanding emerged with respect to landslides, earthquakes and seismicity including December 26, 2004 Tsunami.

Quaternary geological and geomorphological maps on 1:50,000 scale of the Kullu valley corridor (Aut-Rohtang section) were prepared to provide basic data base for analysis of mass movement and environmental management of the area. The Quaternary sediment-landform association shows revealing evidences of active tectonic movements and climate change which have implications in the geoenvironmental aspects of the region. The lichen based study on Pawari landslide suggests that the boulders containing more percentage of lichen cover (about 70 %) are stable in the present climatic scenario or have moved least as compared to the one showing less percentage (about 40 %) of lichens.

Structural, lithological and geotechnical studies of the Khanera slide an active zone in Yamuna valley, shows multiple and complex slide having combination of rotational planer and wedge failure. The progressive stepping failure along two local high angle faults trending NNE-SSW parallel to valley with in the slide zone are major factors for the present topographic scenario of the area.

Morpho-structural analysis using remotely sensed data along with selected field investigations helped to delineate new traces of parallel to sub-parallel active faults in the Pinjor Dun of the northwest Frontal Himalaya. Many conspicuous tectono-geomorphic features such as warping and back tilting of fluvial and alluvial fan surfaces and fault scarplets in the Quaternary deposits observed along the active fault traces show basically a thrust movement with north side up. The development of fault scarps with heights varying from 5 to 25m are indicative of long-term uplift/ deformation along these faults in the current tectonic regime

and cumulative slip along the faults. These fault systems are considered to be the manifestation of Quaternary tectonics to the south of Main Boundary Thrust and around the Himalayan Frontal Thrust.

For monitoring and analysis of seismicity in northwestern Himalaya 11 digital, short period and broad band 3-components seismic stations were installed in Himachal Pradesh. As many as 69 local events were recorded in our seismic array since the time of installation in March 2004. As regards site response studies in major population centres like Shimla and Chandigarh preliminary results indicate that amplification in bedrock motion was almost nil as compared to Chandigarh where it was very little, which simply explains that Dehra Dun was subject to high damage during 1905 Kangra Earthquake. Historic and recent records suggest that motion from nearby and from distant earthquakes have been felt widely in Dehra Dun city over the past one hundred years or so. GPS measurements on the motion of Indian plate, Sunda plate and Andaman blocks were taken to study the inter-seismic strain accumulation rate in the Andaman arc where devastating December 26, 2004 earthquake occurred.

Helium measurements in cold and hot water springs along Yamuna, Bhagirathi and Mandakini valleys in Garhwal Himalaya indicate high presence of helium in hot springs whereas it was low in the case of the hand pumps implying deep circulation in regard to the former. There was no correlation between helium and radon concentrations in any situation. Radon studies were also conducted in the soils of the Kumaun region where its concentration was found to bear some relationship with the rock type.

Glaciology and Natural Resources

Based on the chemical characteristics, the waters of the eastern Kumaun have been catetegorized into four major groups, i.e. calcium bicarbonate, magnesium bicarbonate, calcium-magnesium sulphate and sodium bicarbonate, of which calcium and magnesium bicarbonate facies are dominant in the Pithoragarh area and sodium bicarbonate in Champawat area. Strong influence of rocks on ground water characteristics has been observed in the entire region.

Glaciological studies continued on two glaciers i.e. Dokriani Bamak and Chorabari both in the Garhwal Himalaya. Studies on Dokriani Bamak show that discharge from the glacier during 2004 summer ablation months (May-October) was 41×10^6 m^3, which is lowest ever recorded since the initiation of studies on Dokriani glacier and close to the 1999 (43×10^6 m^3) summer discharge. Both these years experienced very low winter snow precipitation. Detailed analysis of glacier discharge, temperature and glacier mass balance suggests that winter snow precipitation characteristics influence the glacier runoff rather than the temperature variations.Dokriani glacier snout receded by 20 m during October 2003- October 2004 period. Recession during last year (2002-2003) was 7m.

In the case of Chorabari glacier annual mass balance calculated for the year 2003-2004 was found to be negative. The snout of glacier receded by 10 m between October 2003 and October 2004. The glacier has receded about 206 m from 1962 to 2004 with an average rate of 4.9 m/yr. Four stages of advance and retreat of the glacier were demarcated on the basis of morphological evidences. First stage of retreat started about 270 years ago (based on lichnometric studies), whereas last stage of recede was probably 160 years ago.

Potential hill slope movement is discernible through ecological signal provided by the plant communities. It has been found that *Alnus nepalensis* manifest as a habitat precursor for slope instability in the central Himalaya. Thus area of potential landslides can be delineated by its floral dynamics. Laboratory investigation and microclimatic field studies suggest that nitrogen fixing capabilities, obtrapezoid-winged nuts morphology, and radiative balance at different aspects of micro-watersheds and interwoven air-wind dynamics create holistic system for viable mechanism of seed dissemination and establishment to new habitats of potential landslide.

Geochemical characteristics of radioactive elements (U, Th, K), in active stream sediments from Bhagirathi-Alaknanda valley have been investigated. Together with the previous reports of radioactive mineralization and Radon anomaly studies, the present study further provides sufficient evidence that part of the area under study has anomalously high radioactive element abundance exceeding the limits said to be safe for human or animal exposure. Distribution pattern of these elemental abundances show intrinsic relation with the lithology and tectonics of the area.

Palaeoclimate and Environment

The 3500 year century-scale vegetation and climate history inferred from the multi-proxy data on the tree-line fluctuation and glacier history of the Pinder valley in Kumaun Higher Himalaya was reconstructed. Several phases of climatic shifts have been recorded. The climate was drier between 3500 and 3300 cal yr B.P., cool and dry between 3300 and 1600 yr B.P. with improved climate during 2300-2100 cal yr B.P., but significantly warm and moist conditions prevailed during 1600 – 740 cal yr BP (Medieval Warm Period). Between 740 cal yr B.P. to the present several minor phases of climatic oscillations have been recorded which include the Little Ice Age during 1540-1730 A.D. Climatic reconstruction of the past 6000 years has also been done for part of the Bhagirathi valley.

A new initiative called as Geodata Base for Rudraprayag District was launched to compile the data base pertaining to socio-economic development in the State of Uttaranchal. In the first stage, data for natural resources was plotted in the form of thematic maps on 1:50,000 scale to facilitate its retrieval in GIS mode for the purpose of developmental planning at micro-level. Secondary data included population structure, migration, sex-ratio, literacy, etc. to be finally viewed in respect of the natural resource data base of the district.

Northeast Himalaya

Structural studies were undertaken to generate data pertaining to hanging walls of Himalayan Frontal Thrust (HFT) and Main Boundary Thrust (MBTa) in the Siang valley section in Arunachal Pradesh. Some observations on neotectonics were also made. In addition, data related to the structural control of Abor volcanics was also collected. The studies show that hanging walls of both the HFT and the MBT are characterized by a set of normal faults which are basically of gravity collapse nature. As regards Abor Volcanics, these occur as sills and dykes along the Siang window.

Other studies include fixing of age of the Buxa Formation, discovery of Neoproterozoic glacial event and significance of deep marine benthic foraminifera of the Disang Group in Nagaland. Vendian sponges have been discovered from the Buxa Dolomite, Arunachal Lesser Himalaya. Sponges are the most primitive of multicellular animals with a low grade of organization and they first appeared in terminal Neoproterozoic. The other microfossils found associated with sponges are coiled cyanobacterial and spinated forms confirming Vendian age for the Buxa Dolomite in Arunachal Himalaya. For the first time, terminal Neoproterozoic (Vendian) glaciogenic diamictite deposits have been recorded from the base of the Buxa Dolomite in the Subansiri valley in Arunachal Lesser Himalaya. All these evidence strongly suggest Vendian age for the Buxa Dolomite. The carbon isotope ratios are significantly positive for the Buxa Dolomite and correspond to the global terminal Neoproterozoic carbon isotopic evolution.

A large number of Uvigernid benthic foraminifera of upper bathyal environment in the Upper Disang (Middle to Late Eocene) of Nagaland suggests a possible source rock for hydrocarbon generation.

Academic Pursuits

Under the on-going research programmes pursued during the year, the Institute has published 65 research papers both in national and international journals and about 90 research papers are in press/communicated. In addition to this 74 papers were presented in national and international seminar/ symposia/workshop by the Institute scientists, many of these include invited/keynote review talks. Further six Ph.D. thesis have been awarded and one submitted for the award of Ph.D. degree. WIHG has signed a MoU with BSIP, NGRI, ITC, the Netherlands and Govt. of Uttaranchal to take collaborative programmes in the areas of rock magnetic, palaeoclimate and palaeoecological changes, tectonics and sedimentation history in the Precambrian and Upper Palaeozoic-Quaternary succession in the Himalaya (with BSIP), collision dynamics to understand the uniqueness and lateral variability in the mountain building processes as well as addressing problems of seismogenesis of Himalaya (with NGRI) surface studies using geophysical techniques (with ITC) and microzonation of landslides and involvement of WIHG in disaster management and public awareness programme of the Govt. of Uttaranchal.

Institute brings out regular Himalayan Geology publications. During the year volumes 25(2) and 26(1) were brought out along with volume 10 of the in house Hindi magazine Ashmika. Apart from this a book (Hazard Survival Guide), pertaining to Understanding Earthquakes and Landslides by Prof. K.S.Valdiya and abstract volume for the workshop on Indian Geotransect was also brought.

To promote geoscience research in the Himalaya, the Institute organizes the seminar, symposia and workshops on various special themes. The Institute organized a two day workshop on Indian Geotransects (WinGeo –2004) under the aegis of Deep Continental Programme of Department of Science and Technology from 25-26 November, 2004.

The Institute coordinated a workshop on Disaster Management at WIHG Dehra Dun from 6-12 December, 2004. This workshop was jointly organized by the of Department of Science and Technology New Delhi and Asian Disaster Preparedness Center (ADPC), Thailand. Also Institute coordinated Brain Storming Session on the Great Tsunami of 26 December, 2004. The workshop was organized by Department of Science and Technology in association with Department of Ocean Development and Indian National Science Academy at Indian National Science Academy, New Delhi from 21-22 January, 2005.

Other Highlights

In keeping with the annual programme for the implementation of the official language policy of the Union of India, various steps were taken to promote use of Hindi in routine work as well as in scientific research. Hindi magazine Ashmika was published by the Institute. Hindi noting-drafting and Hindi typing were implemented, also day today work, general circular, notices etc. were issued both in Hindi and English. Hindi fortnight was celebrated from 14 September to 30 September, 2004, during which various competitions like poetry, essay and debate 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 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 in eastern Ladakh.

The flysch and molasse of the Ladakh Group of the fore arc basin form a central anticlinal core of the Eocene Miru Formation (Flysch) deposited in pelagic marine environment. The southeastern extension of Miru Formation is complexly folded possibly controlled by earlier extensional structures and superposed by contractional structures related to the Himalayan Orogeny. The northern and southern boundaries of these anticlines are overlain by the Red Bed Formation (flysch) and Hemis Formation of post Eocene molasses.

The southeastern extention of Shergul Ophiolitic Melange terminates near Nalbukar to the north of Tso-Kar in eastern Ladakh as it could not advance further eastward due to obstacle provided by the then highland of Tso Morari Crystalline. The continued northward advancing Indian plate with anticlockwise rotation, forced the early collisional boundary of NW-SE trending Shergul Ophiolitic Mélange to terminate at Tso-Kar and then it shifted further northward of the Tso-Morari Crystalline, which acted as a buttress giving rise to N-S trending Tso-Kar Transfer Fault (T-KTF). The T-KTF cut across southeastern closure of the Hemis Formation exhibiting sinistral sense of movement and joins northwards with the WNW-ESE trending Zildat Fault. The ultramafic rocks of the Zildat Ophiolite Melange were obducted along the Zildat Fault and also along the N-S trending T-KTF. It indicates that T-KTF and the rocks of the Zildat Ophiolitic Melange are definitely younger than the Eocene-Oligocene Hemis Formation. The ultramafics and ophiolitic mélange at the southern margin of T-KTF are highly fractured and brecciated. The rock to the western side of the T-KTF is displaced sinistrally northward for at least half kilometer.

Sillimanite and kyanite bearing metamorphic rocks collected from Tso-morari and Pangong Tso areas were investigated for detail mineralogical and fluid inclusion studies. Garnet is present in the Pangong Tso metamorphic complex in kyanite-silliimanite bearing gneisses along with biotite, plagioclase and chlorite. The biotite is present on the margin of garnet grains as well as aligned parallel to foliation plane, whereas garnet occurs as euhedral to subhedral porphyroblast. Majority of the garnet grains are synkinematically grown and contain lots of mineral inclusion such as chlorite, muscovite quartz and epidote. The chemical profiling of garnet shows that they are chemically zoned. The Mg and Mn distribution is vise-versa. The Mg increases towards the rim whereas the Mn increases towards the core part of the garnet and show perfectly bell-shaped profile. These chemical features are indicative of growth zoning.

Monophase and two-phase fluid inclusions are observed in quartz associated with kyanite-sillimanite bearing metamorphic rocks. These inclusions are having both the vapour bubble and the liquid. The biphase aqueous inclusions are also observed in the form of cluster, which suggests primary origin of such inclusions. Besides these early inclusions, some secondary trail bound inclusions also occur. These inclusions are mostly biphase in nature. Many single gas rich inclusions are also observed in the quartz. The single gas rich inclusions are carbonic in nature.

The carbonic inclusions are monophase at room temperature. Carbonic inclusions are also noticed in form of primary and secondary inclusion. Most of the inclusions show initial melting temperature(Tm) close to pure CO_2 triple point (-56.6°C). Homogenization of Primary carbonic inclusion occur in the range of -12.4 to -7.1°C while secondary carbonic inclusions show homogenization between -4 to -1.2^{0}C. The primary biphase aqueous inclusions show their final melting temperature range from –7 to –1.2°C with their homogenization temperature 175-212^{0}C. Whereas re-equilibrated inclusion homogenized between 216-228^{0}C while their final melting temperature lies in the range of -3.4 to -8^{0}C. The secondary inclusion are also of biphase aqueous in nature homogenized in the range of 182 to 230^{0}C but their final melting temperature recorded with in the range of -4.6 to -7.2^{0}C.

Petrochemical studies on the eclogites and garnet-amphibolites that occur as lenses and bands within meta-sediments of the Tso-Morari Crystalline Complex of Ladakh were also studied. The study provides clues for better understanding of the geological history of the region and to unravel the evolution of the terrain. Major and trace element data of garnet amphibolites including analyses of eclogite samples indicate subalkaline tholeiitic composition. Further, in most of the variation diagrams, eclogites clearly plot along with the garnet amphibolites. They are characterized by higher content of TiO_2 in the range from 1.14 to 2.87 wt. %, and lower Al_2O_3 contents ranging between 10 to 14 wt. %, and their Mg number (mg#) range from 20 to 45 indicating negligible crystal fractionation. The LREE are strongly enriched (La_N/Yb_N = 3.38) with Eu sometime displaying a small negative anomaly. The LREE abundance varies from 20 to 60 x chondrite and HREE from 8 to 15 x chondrite. Samples plotted on a spider-diagram normalized to primitive mantle; show enrichment of mobile elements, such as LIL elements relative to less mobile elements such as the High Field Strength Elements. The samples show negative Nb- and Sr-anomalies compared to their neighbouring elements and show geochemical characteristics ranging from E-MORB to OIB. The petrochemical studies carried out suggest that the protoliths melts for the rocks understudy are derived from the upper mantle MORB source with an enriched component either in the form of incompatible-element rich veins or OIB-composition 'plums" or derived from continental material in a subduction zone or alternatively in an intra-continental rifting stage, followed by crustal contamination. Further detail studies are in progress.

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)

52 experiments at 1050$\pm$2°C to determine the melt temperatures of the Himalayan granitoids in space and time were carried out. In addition, characterization of 25 samples for metals was also carried out. EPMA studies on polymetallic syn-sedimentary sulphides suggest two types of base metal mineralization, i.e., primary syn-sedimentary which had remobilized during the Himalayan tectonic episodes.

Geochemical and fluid inclusion studies on the Champawat Granitoids show that granitoids have SiO_2 in the range of 65-69% and have relatively high CaO and MgO concentrations, averaging around 1.9 and 2.5% respectively. Their K_2O vs Na_2O compositions suggest that they are adamellite, with their molecular A/CNK ratio averaging around 1.1, and plot marginally along the metaluminous to peraluminous fields. They have well fractionated REE patterns with SREE of these rocks averaging around 195. Their $(La/Lu)_N$ values are around 13 and the rocks show significant negative Eu anomalies. The fluid inclusion studies have shown that during the crystallization of Champawat Granite sodium rich high saline aqueous fluid phase was present along with the melt phase. The homogenization of high saline inclusions occurred either by dissolution of salt daughter crystal or by disappearance of vapour bubble. Salinity of this fluid varied from 40 to 60 wt% NaCl and their homogenization occurred at as high as 572 ^{O}C. A $C0_2$ phase participated in metamorphism and deformation of these rocks.

Polymetallic sulphide mineralization known from quartzo-feldspathic schists and gneisses of Precambrian Askot Crystallines in Kumaun Lesser Himalaya have also been studied. Complex sulphide assemblage including chalcopyrite, galena, sphalerite, arsenopyrite, pyrite, pyrrhotite, cubanite etc. shows both replacement and exsolution features. Askot arsenopyrite is pure Fe species: As wt% in it suggests a temperature of formation as 450$\pm$20 ^{O}C. Amongst the four types of fluid inclusions observed in mineralized quartz, primary saline aqueous type I and type II inclusions entrap part of the magmatic fluid that was exsolved from the crystallizing granitic rocks. Aqueous hydrothermal fluid of 350 to 460 ^{O}C temperatures and with boiling signature was evolved after assimilation. Syn- to post-granite carbonic fluids evidence variation in $XC0_2$. During granite emplacement to retrogression their densities varied from 0.93 to 0.71 gm/cm^3. Flux of hydrothermal fluid and fluid unmixing had favoured the deposition of these sulphides.

$\delta^{34}S$ analysis of barite is significant to the understanding of source of sulfur consumed in barite formation. Tons valley barite with $\delta^{34}S$ in the range of +26 to +29% rules out the possibility of participation of any magmatic sulfur. This data suggests the involvement of Proterozioc seawater for the deposition of barite. Fluid inclusion microthermometric studies have been carried out on talc deposit of Bageshwar area. Various fluid phases and their phase data have been recorded.

Samples collected from Bhatwari-Gangotri region are being studied with reference to mineral chemistry,

petrogenesis and P-T estimates of Higher Himalayan crystallines. The HHC is comprised of an association of garnet biotite schist, amphibolite, granite gneiss and a undeformed metadolerite of the Bhatwari group in the lowermost parts. This sequence is overridden by the Harsil Group metamorphics along the Vaikrita Thrust with the intervening phyllonite and intensely sheared actinolite schist. These metamorphics contain garnet-biotite schist, staurolite-kyanite and sillimanite bearing schist and gneiss, calc-silicate, amphibolite and migmatites. The Gangotri leucogranite (Bhagirathi leucogranite) is situated structurally above the kyanite and sillimanite gneisses of the Vaikrita Group which in turn overlie the north-dipping Main Central Thrust Zone of inverted metamorphic isograds. A pegmatite-aplite leucogranite sill and dyke swarm is present around the margins of the leucogranite. Compared to other High Himalayan leucogranites it is particularly rich in tourmaline. These tourmaline leucogranites cut the foliation of the surrounding older biotite granite and two mica porphyritic granite (Bhaironghati granite).

1.3 SUB PROJECT

Study of frontal and oblique ramps in the Western Himalaya

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

In the thin-skinned or allochthonous model of thrust tectonics, the thrust ramp structures flatten at depth and join a prominent plane of decollement below which the basement (i.e. rocks below the decollement) remains largely undeformed. The individual thrusts propagate upwards with staircase geometry by forming a series of flats along incompetent layers and ramps across competent layers. A lubricating horizon (e.g. salt, gypsum, graphite, shale) as flat can facilitate a translation of several tens of kilometers. The staircase geometry involves a complicated tectonic history of straining and unstraining as the hanging wall rock mass moves over a ramp and flat structure.

The study of the foreland foothill belt of the Himalaya is important in this context to understand the thrust tectonics in the region. The geological cross-sections based on the Oil & Natural Gas Corporation (ONGC) data demonstrate a plane of decollement at the preTertiary-Tertiary boundary (Fig.1). The rocks below the decollement consist of preTertiary sedimentary and metasedimentary rocks (mainly shale, slate, quartzite, and limestone with minor phyllite) whereas the cover rocks consist of Tertiary sedimentary rocks (mainly shale, sandstone, and lime stone with minor conglomerate). Hence the rocks above and below the plane of decollement have comparable rheological properties. The subsurface data do not easily fit in the ideal thin skinned model because; (i) the plane of decollement at the Tertiary-preTertiary boundary is not very prominent as the pre Tertiary rocks are also involved in thrusting, and (ii) the decollement surface is slightly undulatory because it is marked by upwarps at the contact of thrust ramps with the pre Tertiary rocks (Fig. 1). The basement upwarps have remained unnoticed despite their common occurrence throughout the Sub-Himalayan Foothill Belt. It is possible that the structure was probably ignored because the effect of its presence on displacement along a basal decollement during thrusting was not fully appreciated.

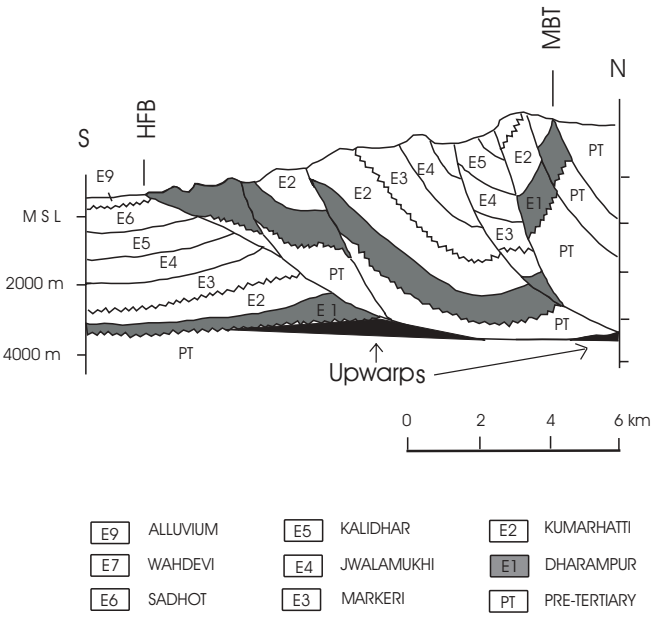


Fig.1. A geological cross-section across the subHimalaya, west of Tanakpur, Kumaun Himalaya showing a decollement upwarp (marked in black) (after Raiverman *et al.* 1995).

Development of structures at a lower flat along the basement-cover contact to a ramp in the cover was studied with the help of the following simplified geometrical model.

Faults with listric geometry are characterized by gradual variation of dip with depth (Fig. 2a). The geometry may result in variation of fault displacement and formation of a number of dilation spaces in the profile plane. The hanging wall layers above the basement-cover interface rotate during thrusting thereby producing extensional strains along the layering and reverse drag in the vicinity

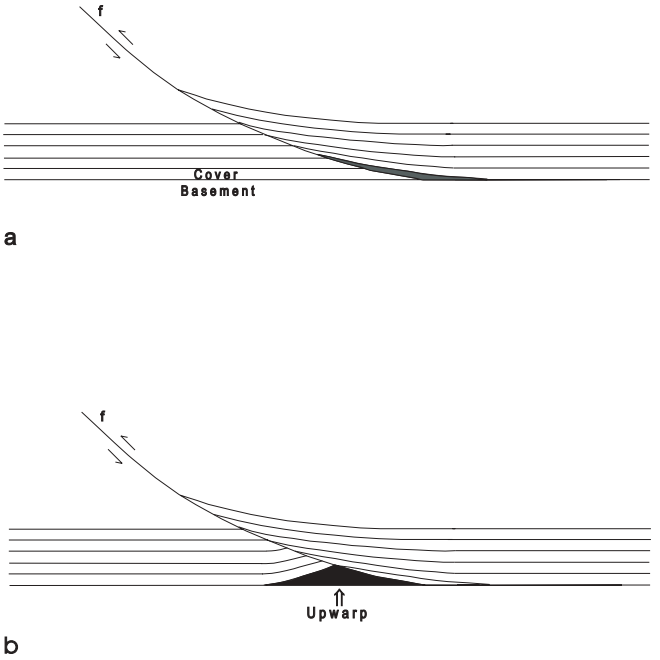


Fig. 2. Formation of a decollement upwarp at the basement cover interface. (a) Displacement along the listric fault 'f' accompanied by rotation of the hanging wall layers and formation of a dilation space (shaded in grey) above the basement. (b) Curvature of the lower footwall layers to occupy the dilation space and formation of decollement upwarp (marked in black)

of the thrust surface accompanied by a dilation space at the interface (Fig. 2a). The available relief leads to curvature of the footwall layers in the normal drag sense and formation of a basement upwarp (Fig. 2b). The size of the upwarp mainly depends upon the dip of the thrust fault or geometry of the listric fault, initial dip of the hanging wall layers, friction on the thrust, nature of the basement-cover interface, and amount of shortening.

Figure 3 illustrates a number of decollement upwarps in a series of listric faults. The individual upwarps may not affect the displacement along the adjacent listric fault but the thrust sheet will propagate along the basal decollement with bumpy movements. Alternatively, the basal decollement thrust may penetrate and crosscut the basement upwarps. This is a difficult proposition because of absence of a weak plane across the upwarps. Hence the thrust propagation is likely to form a zone of decollement rather than a plane of decollement and the hanging wall thrust sheet may incorporate a part of the basement.

In view of the above, it is suggested that a decollement upwarp is an antiformal structure formed at the junction of basement flat and cover thrust ramp structures as a result of displacement of the hanging wall block or rotation of hanging wall layers in the vicinity of the thrust ramp accompanied by upward warping of the basement to occupy the available space. Presence of the decollement upwarp suggests that the basal decollement cannot be a planar structure. Moreover, a series of imbricate thrusts may form a number of decollement upwarps thereby producing a greater inhibition in the motion of the thrust sheet and a zone of decollement incorporating basement slices. An understanding of these upwarps may greatly help in understanding thrust propagation especially in a foreland foothill belt where the deformation is in the brittle or brittle-ductile regime.

In addition, work was also carried out to understand the kinematics and origin of prominent curvature of MBT near Dehra Dun. The Dehra Dun re-entrant of the Himalayan fold- thrust belt in Garhwal Lesser Himalaya has a prominent re-entrant shape in map view with thrust traces strongly concave towards the foreland. Detailed magnetic fabric study on both sides of the re-entrant shows that the original EW direction of magnetic lineation (Kmax) and magnetic foliation has progressively changed into NS direction by interaction with the structural high/lateral ramp present in the area. This suggests that a model of "modification at structural high in the basement into lateral ramp boundaries" best explains the structure and kinematics at the edges of the Dehra Dun re-entrant. Further, this model has also

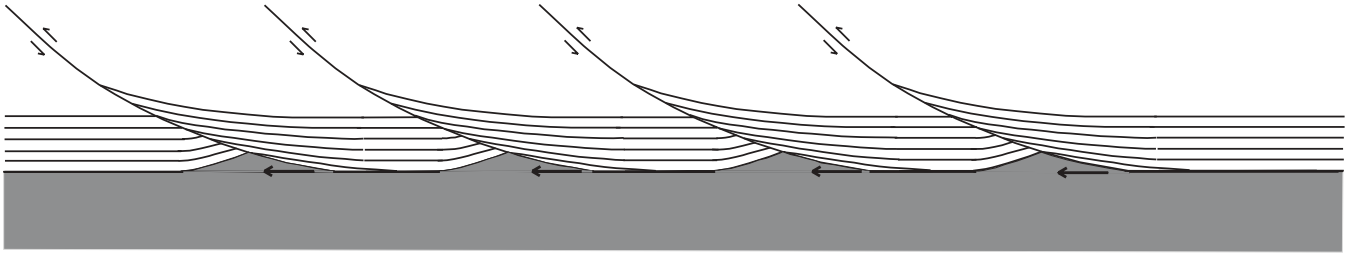
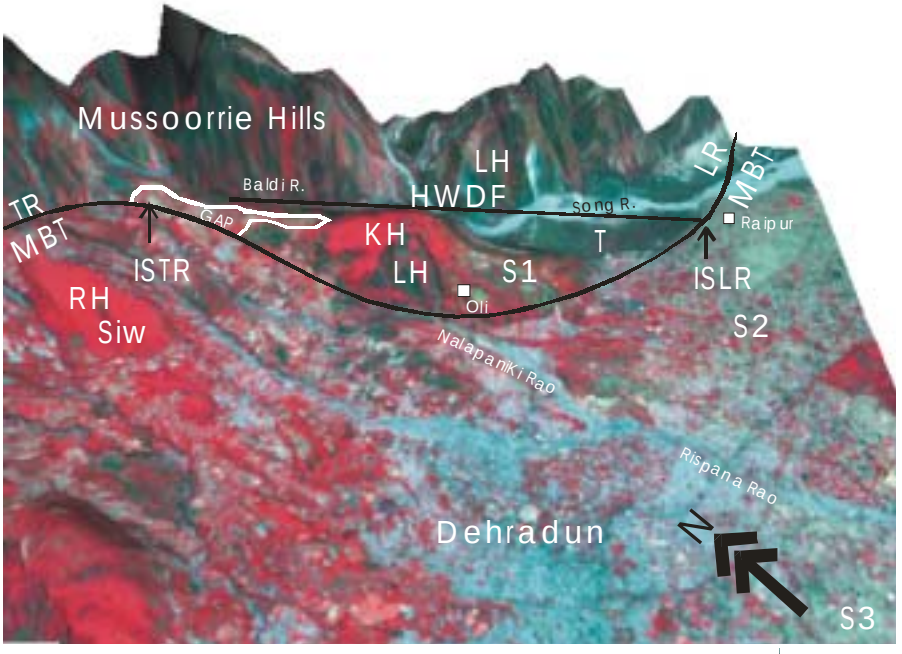


Fig. 3. Decollement upwarps along a series of listric faults inhibiting motion of the thrust sheet. In order to be a planar structure, the thrust should propagate across the upwarps in the direction indicated by the arrow.

documented and provided the kinematics of the hanging wall drop fault and lateral ramp fold (Fig. 4) in the Main Boundary thrust of NW Himalaya in Dehra Dun re-entrant.



RH = Rajpur Hill
KH = Kalanga Hil
LH = Lesser Himalayan Rocks
MBT = Main boundary Thrust
Siw = Siwalik Rock
TR = Trailing Ramp
LR = Leading Ramp
ISTR = Intersection of Trailing with Lateral Ramp
ISLR = Intersection of Leading with Lateral Ramp
HWDF = Hanging wall Drop Fault
S1,2,&3 = Higher, Middle and Lower Dun Surfaces
T = Terrace

Fig.4. Digital Elevation Model of the Dehradun Pre-entrant along with Hanging wall Drop fault.

Besides, paleoseismological studies of the late Quaternary expression of the HFT at seven sites based on field work, interpretation of air photos, and excavated trench suggest the following,

- That the HFT is not blind but rather, an emergent fault system.
- Evidence of the late Holocene surface rupturing earthquakes at Chandigarh, KalaAmb, Rampur Ganda, Dehra Dun, Laldhang and Ramnagar covering a distance of ~350 km along strike of the HFT of India.
- The overlapping ages, single event scarps, and incomplete historical data allow the interpretation that all sites ruptured simultaneously between A.D. 1404 and 1422.
- On the basis of size and possible synchroneity of the most recent displacement recorded between 1404 and 1422 A.D. (or, 1413 + 9 A.D.) that the earthquake recorded in the trenches is larger than historical earthquakes and indicate a potential for sections of the HFT to rupture simultaneously along lengths of the HFT greater than the ~350 km.

The concept and interpretation that the Kashmir nappe has moved southward over the Lesser Himalaya along the Panjal Thrust as proposed by Wadia is modified in terms of a new tectonic contact i.e. Chamba Thrust. The studied area forms the SE closure of the Kashmir nappe. It exposes nearly complete Tethyan sequence along the Marbal Pass section. The basal unit of this section consist of dominantly carbonaceous slate interbedded with argillaceous slate and limestone (Ordovician-Silurian age) exposed around Chattru. It tectonically overlies the garnetiferous-biotite schist of Higher Himalayan Crystallines (HHC) along the Chattru Thrust. This tectonic contact is traced northeastward along Warwan valley, where again a nearly complete Ordovician - Triassic succession is exposed in a NW-SE trending overturned syncline. This sequence is obliquely cut on the eastern limb by NNE-SSW trending unnamed tectonic contact. The tectonic contact is interpreted as the northern extension of the Chattru Thrust.

The Chattru Thrust does not merge southward into Panjal Thrust as proposed by Wadia, 1931; but was placed higher and separates the crystallines as well as the Chail/Panjal Thrust Sheet (equivalent of Salkhala and Ramsu Formations) from the entire overlying Tethyan rocks of the Kashmir nappe. Structural disposition indicate that Chattru Thrust is equivalent of Chamba Thrust. The continuity of this thrust in the frontal zone is yet to be established. Evidence that the Kashmir succession has moved over the HHC is based on the presence of isolated blocks of Panjal Trap and limestone within the HHC. These blocks are interpreted as klippen of the Tethyan rocks.

The recognition of a major tectonic break, commonly described as Trans Himadri Fault/Tethyan Thrust/ Zanskar Shear Zone, along the southern side of the Tethys Himalaya with the HHC is established. It supports the present contention of a tectonic break between the Chamba and Kashmir nappes from the underlying Chail Thrust Sheet and the Higher Himalayan Crystallines.

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)

Temporal and environmental implications of ichnofossils

The diverse assemblage of ichnofossils have been recorded from the Early and Middle Cambrian strata of the Zanskar region of Tethys Himalaya. The temporal and environmental implications are interpreted on the basis of behavorial characteristic, taxonomic diversity and density of the ichnofauna. The recorded ichnofaunal assemblages include the ichnogenera *Planolites, Tapherhelminthopsis, Teichichnus, Didymaulichnus, Lockeia (Pelecypodichnus), Bifungites, Chondrites, Skolithos, Dimorphichnus, Monomorphichnus, Trepitichnus, Isopodichnus, Palaeophycus, Cruziana, Diplichnites, Rusophycus* and Trilobite scratch marks and other traces of unknown origin. The rare occurrences of *Chondrites,* deep water ichnofaunal elements can be attributed to mixing of sediments due to the progressive transgression of sea. The ichnofaunal element of shallow water intertidal *Skolithos* ichnofacies (*Skolithos* and burrows) is abundant in the lower part of the sections, while in the upper part of sections the ichnofaunal elements of *Cruziana* ichnofacies (*Cruziana* and *Rusophycus*) with traces of arthropod origin (*Dimorphichnus*, *Monomorphichnus*, *Diplichnites*, and trilobite scratch marks) predominantly dominates. These traces occur much below the Middle Cambrian trilobite bearing horizons, while only few ichnofossils like *Skolithos* and *Planolite* are found above the trilobite bearing beds. The shallow intertidal to shallow water shelf condition is interpreted for the deposition of upper part of the Phe Formation on the basis of ichnofaunal studies. The diversity of traces and tracks of variable sizes reveal that the animal's inhabitating the sea floor were variable in size and morphology. The present assemblage of ichnofossils is significant because so far no body fossils of Early Cambrian age have been reported from the Zanskar basin of Ladakh Himalaya.

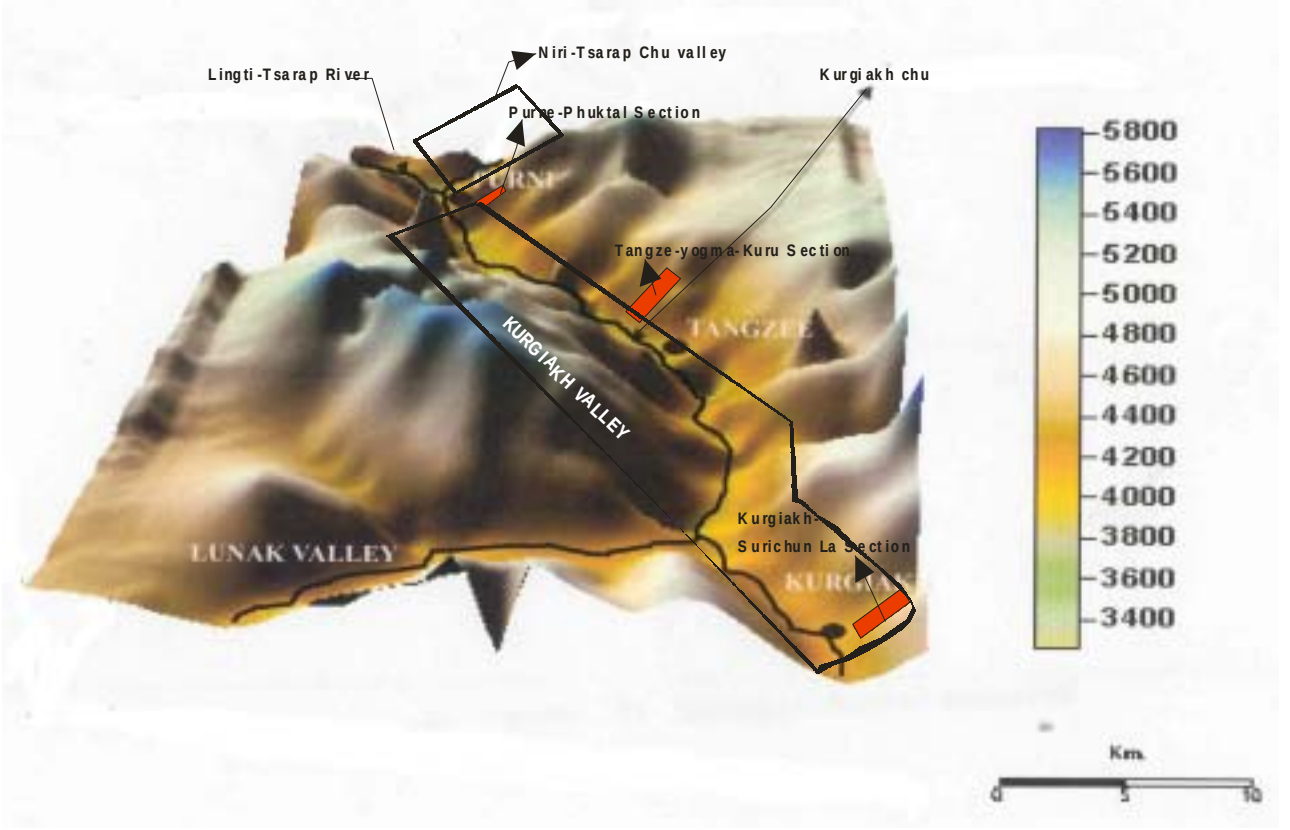


Fig.5. Digital elevation model for the Kurgiah and Niri-Tsarap Chu Valleys.

Distribution of Cambrian rocks in SE Zanskar: An approach from field data and digital elevation model (DEM)

The studied sections in the Zanskar region of Ladakh Himalaya are shown in digital elevation model (DEM) for the Kurgiakh and Niri-Tsarap Chu valleys (Fig.5). The model illustrates the topographic features of the Kurgiakh valley. The DEM shows the variation in height from 3400m to 5800m with corresponding colors indicated in right column of the figure. The superimposition of field measurements shows that the Cambrian formational units are restricted in between the height from 3800m to 4290m.

Morphometric analysis of Trilobites

The morphological variables often have non-normal distribution. The statistical analysis of such variables by imposing normal assumption invariably yields unreliable results. Classification and Regression Trees (CART) and Random Forests (RF) are non-parametric techniques that are alternative to conventional classification methods, such as cluster analysis and linear discriminant analysis used in morphometric research works.

Biometric analysis

In this method non-parametric techniques to the variables of the cranidial features of the trilobite genera *Hundwarella* and *Iranoleesia* were applied and it was found that misclassification rates in CART and cluster analyses are comparable, while it is reduced substantially by the use of 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)

Recovery of biomineralized cyanobacterial tubes of typical Precambrian-Cambrian boundary age (~544 Ma), besides the protoconodonts and other Lower Cambrian small shelly fossils from the wide-spread localities of *Inner Carbonate Belt* in Garhwal-Kumaun region clearly suggests that the commonly accepted Mesoproterozoic age (~1400 Ma) for the Deoban and Gangolihat Formations based on "Riphean stromatolites' is erroneous. These formations can now be confidently correlated with the Blaini-Krol-Tal Formations (Mussoorie Group) of the Outer Carbonate Belt (*Krol Belt*); both now of Vendian-Early Cambrian age (600-510Ma). These micropaleontological results further encourage investigating the Shali and Jammu limestones of Himachal and Jammu region, which were also commonly assigned as Mesoproterozoic and equated with the Deoban Limestone and the Gangolihat Dolomite (Formations) based on the 'Riphean' stromatolites.

The biostratigraphic results so far obtained from the Lesser Himalayan carbonate successions (Deoban/ Gangolihat Formations and Krol-Tal successions) suggest that there appears to be a very big hiatus (of the order of ~1 billion years) between the Vendian – Early Cambrian carbonates and the underlying lowgrade metamorphics (Jaunsar and Damtha Groups siliciclastics, 1500-1800 Ma) (Fig.6). Similarly, a major hiatus of this order has also now been found in the Vindhyan and Ganga Basin

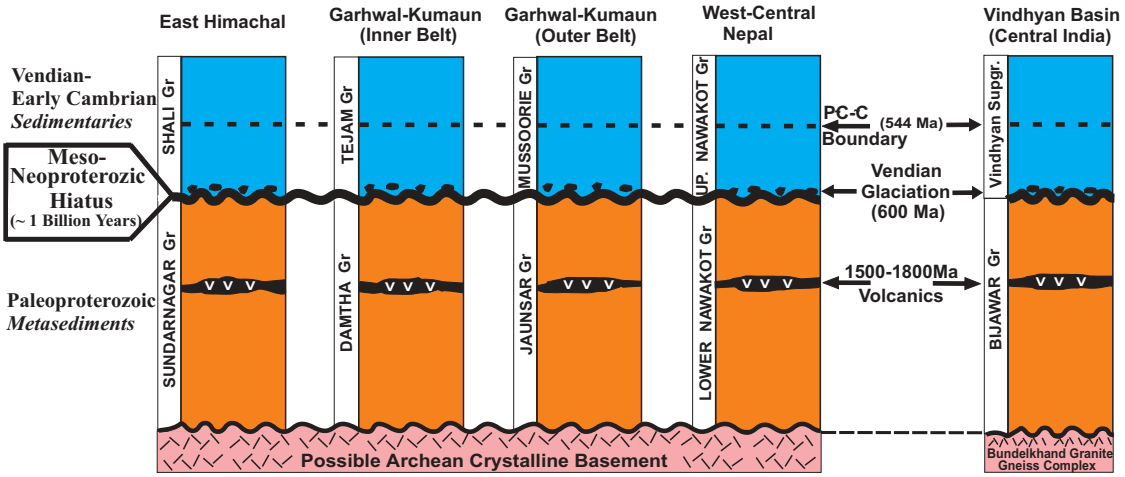


Fig. 6. About 1 billion year hiatus in the Proterozoic successions of the Lesser Himalaya and the Vindhyan Basin (based on Azmi and Paul, 2004; Azmi, 2004; Azmi et al., 2005 in press).

successions (Azmi, APG Conf. 2004; Azmi et al., 2005 in press). The biochronological results thus call for re-mapping and tectono-stratigraphic re-interpretation of the Lesser Himalayan sedimentary successions. Particularly so because presently it is commonly believed that the Deoban / Shali / Gangolihat / Jammu carbonates are stratigraphically much older than the Jaunsar Group low grade metasediments, and therefore, obviously these coeval inner carbonates are also supposed to be stratigraphically much older (based on evidence of Riphean stromatolites) than the Mussoorie Group (Blaini-Krol-Tal) succession of Vendian-Lower Cambrian, which is actually not so as our micropaleontological results from the inner carbonates (Deoban and Gangolihat) have indicated. In the revised chronostratigraphic scenario, however, both Lesser Himalayan and Vindhyan carbonates are equivalent and are of Vendian to Early Cambrian age, which is represented as part of a single extensive platform on the northern part of the Indian shield. Thus the concept of the 'Great Vindhyan Basin' of pioneering workers (e.g. Holland, 1908) is strongly corroborated by the present biochronological studies that have been carried out in the Lesser Himalaya and the Vindhyan Basin of central India.

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)

Petrography and carbon and oxygen isotopic ratios of the Meso–Neoproterozoic Uttarkashi Limestone in Bhagirathi Valley and Lameri Limestone (equivalents of Deoban Formation) in Garhwal were investigated. Microbially formed biogenic structures, microstromatolites (Fig.7) and microbiota were studied with special reference to environmental changes and basin evolution. The carbon isotopic ratios suggest shallow marine depositional environment for the limestones. Petrography of the limestones, stromatolitic structures and cherts were studied to know the carbonate micro facies and diagenetic changes. Morphological changes occurred due to environmental factors in the stromatolitic laminae (conical, columnar, stratified and domal etc.) have been established. X-ray diffraction, geochemical and carbon and oxygen

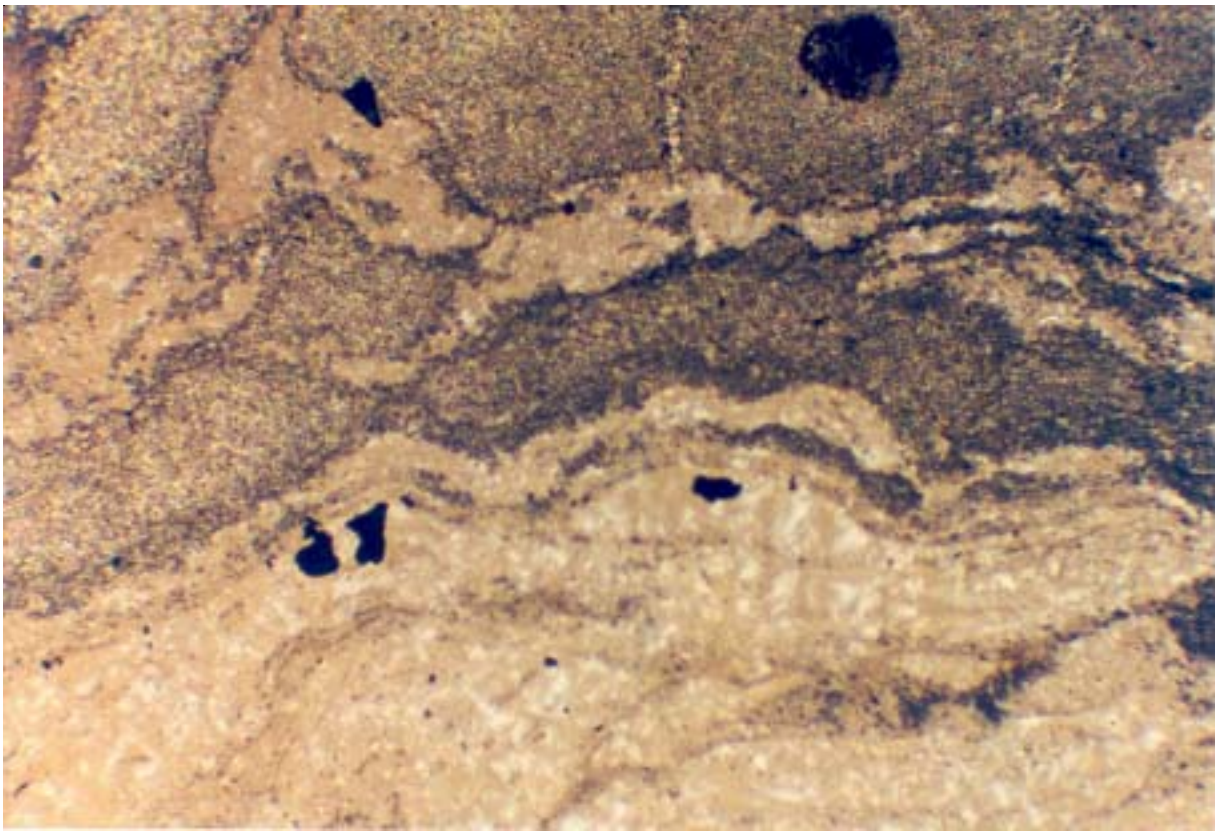


Fig. 7. Microbially formed biogenic structures (microstromatolites).

isotopic analysis of some representative limestones samples were carried out. The sedimentary facies, stromatolites and carbon isotope ratios indicate a shallow marine sedimentation (carbonate platform) for Meso-Neoproterozoic carbonates.

A super-continent Rodinia may have existed at the end of the Mesoproterozoic (1000 Ma) upto 750 Ma including the entire continental crust. The Rodinia supercontinent was broken around 750 Ma and the East Gondwana (India, Australia and Antartica) separated from West Laurentia. The Baltica, Africa and South America occupied the other side of the Rodinia. The Neoproterozoic rifting, breakup of Rodinia and fragmentation of the Gondwanaland, low-latitude glaciation and global warming events have been recorded from the Lesser Himalaya of India. The Deoban-Jaunsar Group in the Lesser Himalaya represents pre-Ediacaran carbonate-siliclastic sedimentation and the Mesoproterozoic age is strongly supported by the Lower to Upper Riphean stromatolite assemblages and the associated microbiota. The diversification of these stromatolites and microbiota has been declined in the end of the Mesoproterozoic. The Jaunsar clastic facies does not show any preservation of trace fossils or soft bodied metazoans. The unconformably overlying Blaini Formation is a glacial deposit corresponding to the snowball earth palaeolatitude and the pink cap microbial carbonate of the Blaini Formation represents the base of the Terminal Proterozoic. The carbon and oxygen isotopic variation and chemostratigraphy of the Blaini-Krol-Tal succession strongly supports the Precambrian-Cambrian transition in the Lower Tal Formation ($\delta^{13}C = -4\%_{PDB}$). The Krol belt in the Lesser Himalaya is characterized by positive $\delta^{13}C$ value ($+1$ to $6\%_{PDB}$). The emergence of multicellular Ediacaran life in the Upper Krol (Ediacaran Period) is consistent with an increase in atmospheric oxygen, which played a major role in metazoan evolution and Cambrian explosion of life on Earth. The base of the Terminal Proterozioc System in the Lesser Himalaya is established in the Blaini Formation. The pink cap carbonate of the Blaini Formation shows negative $\delta^{13}C$ value ($-3\%_{PDB}$) and this Blainian glaciation is correlated with Marinoan glacial event (Cryogenian Period). A comparison of the available carbon and oxygen isotope curves from the other regions of the Eastern Gondwanaland and South China, parts of Siberia and North Africa suggest that the Neoproterozoic-Early Cambrian chemostratigraphy is consistent in the isotopic variation. There is carbon isotopic similarity between Neoproterozoic Bambui Group in Central Brazil, South America and the Krol Formation of the Lesser Himalaya, India.

2.4 SUB PROJECT

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

(Meera Tiwari)

The Neoproterozoic-Cambrian time was a time of fundamental change in the biosphere. Between the late Neoproterozoic to the late early Cambrian marine organisms underwent considerable evolutionary changes due to change of ecological setting. The fossil record of biological evolution across the Neoproterozoic-Cambrian transition is directly related to the ecological diversification of marine organisms, and to the development of taphonomic and sedimentary conditions suitable for the preservation of mineralizing and non-mineralizing organisms. Vast majority of marine animals, plants and macroscopic bacteria lacked hard parts are found to be preserved exceptionally in Neoproterozoic sediments. In order for non-mineralized organisms to become fossilized, one of the most important factors i.e. biodegradation must be reduced sufficiently under certain circumstances to permit these microbiotic remains to fossilize. In addition to an important body fossil record across the Neoproterozoic-Cambrian transition, the record of organism-sediment interactions was demonstrated by trace fossils, which underwent dramatic changes. Escalation in predator-prey system through the late Neoproterozoic and early Paleozoic evidently resulted in changing morphologies among predators and prey, and some changes in burrowing behavior may have accompanied these changes.

Trace fossils present in the Neoproterozoic-Cambrian boundary sections in the worldwide localities are generally well-preserved and well- diversified. The Neoproterozoic-Cambrian 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 fossils bearing sections in the arenaceous sandstone beds of the Upper Tal Quartzite Member. The best-preserved section is along the Mussoorie- Dhanaulti road section. The traces are mostly in the form of burrows, tracks along with some scratch marks. Most common trace fossils consist of simple, horizontal burrows assigned here as *Planolites,* sets of laterally repeated ridges are referable to *Monomorphichnus* sp. and vertical burrows identified as *Skolithos* and are rare in this section. The trails occur

as grooves, ridges with positive epirelief. In the absence of micro fauna at this level this trace fossil assemblage can be used in identifying the Early Cambrian succession in this region. Earlier, detailed work in Krol- Tal belt of the Lesser Himalaya various workers have recorded several trace fossils from the Tal Formation, besides significant findings of mineralized fossils and organic walled microfossils of the Neoproterozoic –Cambrian boundary interval (e.g. small shelly fossils, trilobites and trace fossils) which are reported from the Mussoorie, Garhwal, Korgai, Nigalidhar and Nainital synclines. The present find of trace fossils is from the Mussoorie syncline of Uttaranchal Himalaya.

In the Inner Lesser Himalaya, from the Gangolihat Dolomite (Deoban Formation) exceptionally well-preserved fossil finds of Hexactinellid and monaxons sponge spicules extends the record of sponges down to the Ediacaran period. Isolated hexactinellid and monaxons are reported in the Gangolihat Dolomite of Kumaun Lesser Himalaya. The sponge spicules described contribute significantly as no such small hexactinellids are reported in the Neoproterozoic rocks till date. Their small size indicates existence of small ancestral sponges during Neoproterozoic time. The report of entire sponge fossil from strata of the Neoproterozoic is still lacking.

2.5 SUB PROJECT

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

(S.K. Ghosh and R. Islam)

Investigations were mainly concentrated on acquiring and processing of sedimentologic, petrographic and geochemical data of the Lesser Himalayan sedimentary packages. Seven lithofacies were indentified in the Pre-Blaini Formations 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), Shale facies (SH). Distribution of lithofacies amongst the different Pre-Blaini formations are as follows- Chakrata Fm (mainly FGS > SH > IMFS), Rautgara Fm (MGS > FGS > SH), Berinag Fm (CGS > GS > MGS), Mandhali Fm (FGS > SH > IMFS), Chandpur Fm (IMFS > FGS > MGS) and Nagthat Fm (MGS > IMFS > FGS). Detailed facies analysis aspects is awaited, needs more additional data from other sections. From the present field studies it has been observed that especially the distribution of GS and CGS facies (Pre-Blaini Formations) are concentrated in the southern extremes of Outer- and Inner- Lesser Himalaya. This possibly hints towards the presence of Intrabasinal highs (Horst and Graben - ?). Petrographical study suggest that there is a gradual upward increase in compositional maturity of the siliciclastics (from Rautgara to Nagthat Formation-Pre Blaini Formations).

In order to create a geochemical data base for the Lesser Himalayan sedimentary packages, the samples from Mandhali, Chandpur and Nagthat (Pre-Blaini formations) of the Lesser Himalaya are analysed for their major trace and rare earth elements. The bulk major oxides of all the formations exhibit a negative trend with SiO_2 and a positive trend with Al_2O_3. The SiO_2 – Al_2O_3 plot exhibit a very high correlation coefficient (> 0.9). A positive correlation between Al_2O_3 – K_2O, indicating clay mineral control on the major oxide composition i.e. diluted with increasing quartz content. The clay control is also evident by the relationship between $Fe_2O_3^T$, K_2O and Al_2O_3 content and mainly matches with chlorite – muscovite – illite end members. Positive correlation of LOI particularly with Al, Mg, Fe and K as well as presence of illite and chlorite as a major mineral species, support their clay mineral control. Most of the silty rich (arenite) variety, especially from Mandhali, Chandpur and Nagthat contain a reasonably good amount of plagioclase, K- feldspar and clay minerals. This characteristic feature reflects the mineral decomposition of feldspar but higher decomposition of ferromagnesiam minerals thus supports the poor content of Ni, Co, Cr and Nb. Higher concentration of Cr in some samples support presence of fuchsite bearing mica at their source area. In general the "REE content of all the formations are high. They are enriched in LREE and depleted in HREE. Among these, Mandhali Fm exhibits depletion in HREE as compared to Chandpur Fm. The REE pattern of Chandpur Fm typically matches with PAAS. All samples exhibit a pronounced negative Eu anomaly. In the Lesser Himalayan terrane despite the large range of REE, patterns are coherent in shape across the grain size grades, suggesting that the REE are diluted by quartz and thus preferentially stored in the argillaceous composition than the arenitic varieties. This observation leads to the conclusions that the phase controlling the REE occur in about the same proportion regardless of the effectiveness of the sorting. Presence of monocrystalline quartz, characteristic major, trace elements enriched LREE pattern with pronounced negative Eu anomaly infer granitic to granitic- gneiss source area of these rocks.

2.6 SUB PROJECT

Evolution of the Himalayan Foreland Basin.

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

The study was mainly focused on the upper part of Subathu Formation in four localities, namely, Kaushalya Nala section in Kalka area, Kumarhatti area, Saharan area and Bagthan area. Field data suggest that transition from marine to fluvial succession is gradual and does not support the hiatus between this transitions. In all four localities passage beds are observed. However, lithofacies shows spatial and temporal variation. Kaushalya Nala section have *Nummulites* bearing dark grey shale and lensoid bodies of fine dark grey fine sandstone and limestone in the lower part and gradually limestone percentage increases in upper part. This succession passes upward into red mudstone referred as "passage bed". Overlying succession have narrow deep incise valley fill bound by red pedogenic siltstone with trace fossils and concretions in mature soil profile. Although passage bed observed in all the section, the *Nummulites* bearing dark grey shale is absent except in Bagthan section where *Nummulites* bearing limestone are observed in place of red mudstone. In the Kumarhatti section, conglomerate bed and tuffaceous layer (?) is observed below passage bed. Sarahan section exposes red mudstone and ribbon grey sandstone below passage bed. This architectural variation in the transitional horizon indicates variable shore line of Subathu sea. In Kaushalya and Bagthan area, the depth of the sea is higher as compared to other area.

The 270 m thick Subathu-Dagshai passage in the Kaushalya Nala, has been analysed to trace the changes in magnetic mineralogy, depositional fabrics and rates of sedimentation by erecting magnetic polarity stratigraphy. The magnetic polarity inferred an age from 41.5 Ma to 38 Ma. The estimates for cumulative sediment accumulation rate are ~5 cm/ka for the Subathu, ~ 6 cm/ka for the passage bed and ~ 9 cm/ka for Dagshai zone. An abrupt change in the magnetic mineralogy from ferrimagnetic to canted antiferromagnetic minerals is noted 30 m at (~40.75 Ma) below the 'Subathu-Dagshai: Passage Bed (40-40.5 Ma)'. Magnetic fabrics record tidal effect till ~ 41.25 Ma and the paleoflow became streamlined only after ~39.5 Ma in the Dagshai continental facies. Significantly higher flow regimes are noted at 39.8 Ma with paleoflow reversal, and at 39.15 Ma without much change in paleoflow, possibly due to orogenic folding during the former and climatic and/or tectonic impulse during the latter.

The shallow marine anoxic conditions of the Subathu sea at ~41.5 Ma observed to record the continental input at ~40.75 Ma. This indicates that the continentality was started at <40.75 Ma within the Subathu basin and suggest its time transgressive nature by at least 750 Ka. A changeover from the shallow marine anoxic depositional environment to marly-pedogenic estuarine continental conditions within a geological time span of 1.5 Ma appears to have played a key role in altering the atmospheric chemistry due to organic carbon exhumation immediately after the passage bed. This demands a closer look on the role of the Subathu-Zanskar sea as a carbon sink and the effect of exhumation of the organic matters on the contemporary regional climate change within a warm to warm humid scenario. Our study indicates that although the landform rose above the sea level by ~40 Ma, the sedimentation opted to continue under divergent manner with incision in some part and deposition

Petrographic studies of Kaushalya Nala section reveal the presence of calcareous shale, limestone, calc-arenite, tuffaceous (?) shale and fine-grained sandstone. The limestone is bio-mecritic in nature in which forams are filled by micro-spars and opaque minerals. Opaque are mostly restricted in the inner chamber of forams.The shales are mostly calc-argillaceous in nature.The sandstones are commonly fine grained and quartzose (Q_{85} F_5 R_{15}) in nature. Feldspars include mainly plagioclase and are weathered. Rock fragments are represented by argillites and chert. An interesting lithology noticed in the transitional zone where it shows highly altered ferruginous shale having specks of opaque, chlorite and glassy material. This is being identified as altered tuffaceous shale (?).Detailed analytical study on the sample is undergoing.

Geochemical analysis of 30 mudstone samples of Kaushalya Nala section were carried out for major and trace elements. The Al_2O_3 and TiO_2 exhibits a positive correlation (r = 0.8), suggesting the presence of Ti in clay minerals. Some TiO_2 may also be retained in the detrital rutile. In general Al_2O_3 also exhibit a very good correlation with Fe_2O_3, MgO and K_2O. The dolomite bearing samples shows enhanced Ca, Mg, and LOI. The lower concentration of MnO in the samples suggests MnO depleted sea water. The samples of the section show lower Mn/Al ratio (0.002) which is significantly lower than the average shale (0.01; Wedepohl, 1970). This lower Mn/Al ratio may be due to anoxic condition. Further the lower

concentration of Ba and Rb is due to the incoming of fresh water in the basin after passage bed which has flushed out the sea water. Alternatively we suggest that since the sediments have passed through weathering, erosion and redeposition cycles, each cycle might have added or removed certain elements.

Field observations combined with laboratory studies on Siwalik paleosols from the Mohand Rao and Haripur areas, and their comparison to global tectono-climatic events indicate that: the frequency of occurrence as well as the intensity of development of paleosols in the Siwalik Foreland Basin is controlled by the interplay of the degree of uplift of the Himalayan-Tibetan plateau system, rate of sedimentation and basin subsidence.

Existence of three phases of this interconnection as: *Phase-I:* Rapid uplift, triggering higher precipitation with increased sediment flux, and thus, poor development of soils during ~10 to <7 Ma; *Phase-II*: Low rate of sedimentation relative to phase-I, higher rate of basin subsidence and hence more pedogenesis during/around 5 Ma; and *Phase-III*: Major uplift of the Himalaya-Tibetan plateau, more physical weathering, higher rate of sedimentation, but low basin subsidence compared to Phase-II, hence moderate development of soils, frequently interrupted by coarse grained conglomerate facies after about 3 Ma. This is supported by development of clay, Rb/Sr ratios and variation in magnetic susceptibility that indicate an apparent increasing trend in pedogenesis from Middle Siwalik (11-5 Ma) to Upper Siwalik (5 Ma). Thus, the spatio-temporal occurrence and degree of development of paleosols are controlled by the interplay of Himalayan uplif, sedimentation rate, basin subsidence and climate.

Work with an international team of scientists has resulted in tracing the evolution of hearing in whales from Kakara and Subathu formations. For toothed whales, ear is the most important sense organ and directional hearing absolutely critical because they locate food by echolocation. Fossils of four groups of early whales from India, Pakistan, Egypt, USA etc. document how cetacean hearing has changed from ear of whales' land ancestors that lived in Lower-Middle Eocene to the ear of near-modern whales. Shift from living on land to living in water required changes in ears as land mammals cannot tell the direction of sound under water. It took less than 15 million years for whale bodies to evolve for a fully aquatic life. Pakicetids, the earliest cetaceans, (~50 Ma), used the same sound transmission system as land mammals and had poor underwater hearing. Protocetids and remingtonocetids (43-46 Ma) retained land-mammal system, but also developed a new system similar to that of modern whales. They could hear better in water than pakicetids and they could also hear in air. Basilosauroids (~ 40 Ma) lost the old land-mammal ear and had a near modern sound transmission system.

New sampled localities include coaly horizons of the Kakara (Ghanagug-Kog area near Darla) and Subathu formations (Kaushaliya nala near Parwanoo). These are likely to yield pre-Middle Eocene mammal remains like coeval beds of Pakistan, Rajasthan and Gujarat. Bulk samples are being processed. New fossils studied include crocodilians, whales, rodents and hyracodontids from sub-Himalaya and lower vertebrates from western India.

Sayimys and related forms from Bharil Local Fauna: Ctenodactylid rodents are an integral component of micro-mammalian assemblage from the Siwalik Group of Indian subcontinent. Siwalik ctenodactylids comprise many species (~6) of *Sayimys* and are known from Lower and Middle Siwalik excepting one report from Upper Siwalik. From Indian Siwalik, ctenodactylids are so far known from Middle and Upper Siwalik horizons in Haritalyangar section. With record of modest sample size of isolated molars from relatively older horizons in Bharil, towards west of Haritalyangar, we are reporting second Indian Siwalik ctenodactylid locality. This faunal locality is a washing site and its assemblage is still being enlarged for getting a representative collection of the Bharil local fauna. So far known associated faunal elements from Bharil are cranial and post cranial elements of bovids, rhinocerotids, carnivores, fishes, snakes, crocodiles, and turtles along with gastropods, charophytes, fossil seeds, and coprolites.

Modern ctenodactylid rodents inhabit dry and arid region and are confined to north Africa. However, study of their ancestral forms reveals that they inhabited variety of environments and, therefore, are apparent exception to the proposition that modern mammalian analogues are useful in inferring habitat variables of Miocene rodent fauna.

*Discovery of Rodentia from Dharmsala G*roup: Enigmatic and putative late Eocene-early Miocene horizons, namely, Murree, Dagshai / Kasauli and Dharmsala of the Lesser Himalayan region of India intervene marine Eocene Subathu and freshwater Neogene Siwalik stratigraphic entities below and above respectively. Trickling reports of age-diagnostic fauna from these horizons are paving way for resolving ambiguity

pertaining to their age-range and palaeobiogeographic and palaeogeographic aspects. Here we report discovery of an isolated rodent molar from Traffic Check Post (TCP) locality in the Upper Dharmsala Formation and it is significant as rodents are best age-diagnostic component of the freshwater micro-mammalian fauna; TCP locality is on Dharmsala-McLeod Ganj Road and is known for published account on its micro-fish remains, ostracods, charophyte gyragonites, crocodilian teeth and bone fragments besides for palynological studies. The molar is 2.5 mm in length, 1.25 mm in width and has a robust root intact. Occlusal surface of the molar is though not well preserved, but still has sufficient features to compare it with lower first molar of early Miocene forms. With this empirical evidence we infer that lower horizons of Upper Dharmsala Formation were laid down in early Miocene. Amongst host of additional microfossils interesting elements comprise dasyatids (rays) and fossil seeds: the seeds are comparable to published fossil seeds of freshwater aquatic floating plant *Stratiotes* (Family Hydrocharitaceae). These faunal evidences reveal that during the deposition of yielding horizon at the beginning of Upper Dharmsala sedimentation water bodies were supporting most of the known biota.

Prodeinotherium from the Upper Dharmsala horizons: Record of a well preserved isolated left upper third premolar of *Prodeinotherium* from the Upper Dharmsala horizons, exposed at traffic check post locality on Dharamsala-McLeodganj Road in Dharamsala, Himachal Pradesh is important towards understanding pre-Siwalik larger mammals of the region. Together with earlier record of an isolated rodent molar we have now two ages constraining mammalian elements from this locality.

Predominating laterally persistent medium-grained light-coloured sandstone units of the Dharmsala Group are exposed between Dharmsala and McLeodganj. However, fossiliferous dark grey mudstone facies, uncommon in Dharmsala Group, is exposed in the high gradient nala right below the Traffic Check Post across the road; the TCP section and the locality in the nala is around 4 km by road towards McLeodganj from Dharamsala. In an adjacent nala too, towards the GPS location of the TCP locality is $32^0$13.74N:$76^0$18.46E : in up dip direction at a relatively higher altitude, the dark grey mudstone facies is exposed.

The isolated molar of the *Prodeinotherium* from the TCP locality bears the Repository no WIF/A 1064 and will be in personal care of B C V till he finally hands it over to the Institute for posterity and till such time cast of the molar will occupy the number allotted to the original specimen.

Class : Mammalia
Order : Proboscidea
Family: Deinotheridae
Genus: *Prodeinotherium*
Genus and species : *Prodeinotherium orlovii* Sahni & Tripathi, 1957

Locality and Horizon: TCP Locality, 4 km towards McLeodganj from Dharmsala via Cantonment. From topmost level of the dark grey lithofacies of Upper Dharmsala Formation exposed in the Locality

Material : An isolated left upper third premolar (LP^3; WIF/A 1064)

Description : The well preserved isolated premolar is almost square in occlusal outline measuring length 52 mm and width 57 mm. Roots are not preserved and the crown height is 30 mm (maximum at 40 mm at postero-labial corner i.e. metacone). The molar is in very early stage of wear and therefore must be of a not very old individual. Three lophes, namely protoloph, ectaloph and metaloph with cingulam on anterior and posterior sides characterize the premolar in our collection from TCP Locality of Upper Dharmsala Subgroup. Centrally located enamel valley being bordered by protoloph, ectaloph and metaloph on anterior, labial and posterior side opens towards lingual side with slight obstruction from enamel beads of lingual cingulam.

Though morphology of WIF/A 1064 is diagnostic to lead its identification as left upper third premolar of *Prodeinotherium* but broadly compares well with tapir molars. However absence of parastyle in the TCP cheektooth being a characteristic feature of molars of *Tapirus* precludes it to be a tapir tooth. Above all it compares well with GSI Type No A596 which is a LP^3 and was described by Sahni and Tripathi, 1957 as a part of type material for newly established *D. orlovii*.

2.7 SUB PROJECT

Standard reference sections for the Siwalik Group and migration of the faunas with reference to the other Cenozoic horizons such as Dharamsala and Ladakh molasses groups.

(A.C. Nanda)

The work was mainly confined to the Pinjor Fauna and its relation to the post-Siwalik faunas of Peninsular India and

Indo-Gangetic Plain. The various island faunas of Southeast Asia were also studied and attempts were made to establish the relations among different faunas. In addition to this faunal lists of various Siwalik formations were revised and attempts were made to sort out faunal discrepancies.

Pinjor and post-Siwalik faunas and migratory routes

Pinjor Fauna is the youngest fauna of the Siwalik Group. The process of its extinction and migration started at 1.77 Ma and after 0.6 Ma. Only twenty one Pinjor genera survived in the younger Peninsular and Indo-Gangetic horizons. Out of these twenty one, fifteen genera survived with different species, which indicates the presence of the Pinjor elements in the post-Siwalik faunas. Only six Pinjor species were present in Post-Siwalik faunas of Peninsular India and Indo-Gangetic Plain.

Pinjor Fauna ranges from 2.58 Ma to 0.6 Ma and its equivalent faunas in Java are : Satir Fauna (ca. 1.5 – 2.0 Ma), Ci Saat Fauna (ca. 1.0-1.2 Ma), Trinil H.K. Fauna (ca. 0.9 Ma), Kedung Brubus Fauna (ca. 0.7 – 0.8 Ma) and Ngandong Fauna (Late Pleistocene). Linkages of the Pinjor Fauna with these faunas are poor. Only two Siwalik taxa, ?*Homo erectus* and *Hexaprotodon sivalensis* are present in Javaenese horizons and Pinjor beds. However six genera, represented by *Panthera*, *Stegodon*, *Elephas*, *Rhinoceros*, *Sus* and *Bubalus*, are common in both regions. At least 15 genera including six species of the Post-Siwalik deposits or Pinjor beds survived in Southeast Asia or South China. This indicates that at the time of deposition of Pinjor beds eastern route lying at the foothills of the Himalaya became open and was more prominent at the time of deposition of the Post-Siwalik faunas.

Faunal Discrepancies

The various Siwalik faunal contacts are not sharp rather these are transitional. A faunal transitional zone (10- 90m thick) was demarcated near Chandigarh, in which both Tatrot and Pinjor genera/species lived together. These genera or species include *Crocuta colvini, C. felina, Sivatherium giganteum*, *Cervus* spp., *Leptobos falconeri*, *Sivacobus palaeindicus* (all belonging to the Pinjor Formation), *Hipparion antilopinum*,*Cormohipparion theobaldi*., *Proamphibos kashmiricus* and *Merycopotamus dissimilis* (belonging to Tatrot Formation). The grey mudstones characteristics of pre-Pinjor beds (equivalent to the Tatrot Formation) are also found time transgressive.

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 main emphasis was laid on preparing basic geomorphic and Quaternary geological maps of the Kullu valley corridor which comprises the present area of investigations. The details of each of these basic components would be refined with subsequent field visits to the project area for final analysis and interpretation. As regards the Quaternary geological map the Kullu valley is entirely covered with interlocking massive alluvial fans whose source of sedimentation lies higher in the side valley catchments. These fans were essentially evolved during the Pleistocene period when the area experienced alternative cycles of cold and warm climate as a sequel to the global change. Impact of spasmodic tectonic activity is also evident in these fans as expressed by the development of series of terrace levels in various sections of the Kullu valley. Shifts in Beas river course close to the terrace levels indicate recent tectonic movements in the region. Also, differential development of terrace levels along the side valleys suggests differential tectonic movements on either side of the corresponding river channels.

The distribution of landforms in the Kullu valley corridor clearly indicates a shift in the climatic zonation of the region during the Quaternary period. What was previously an area experiencing periglacial climate is now under the influence of sub-humid climate. This obviously suggests an environmental change in the region with implications on demographic sustenance owing to changes in moisture levels particularly surface and ground water for agricultural activity and living.

Analysis of discharge and sediment delivery of the Beas river and its major tributaries (Fig.8) was also attempted. While there is direct relationship between the two parameters exhibited by the Beas river there are but some deviations which need further field investigations and additional inputs of the monitored data from the various agencies engaged in this pursuit.

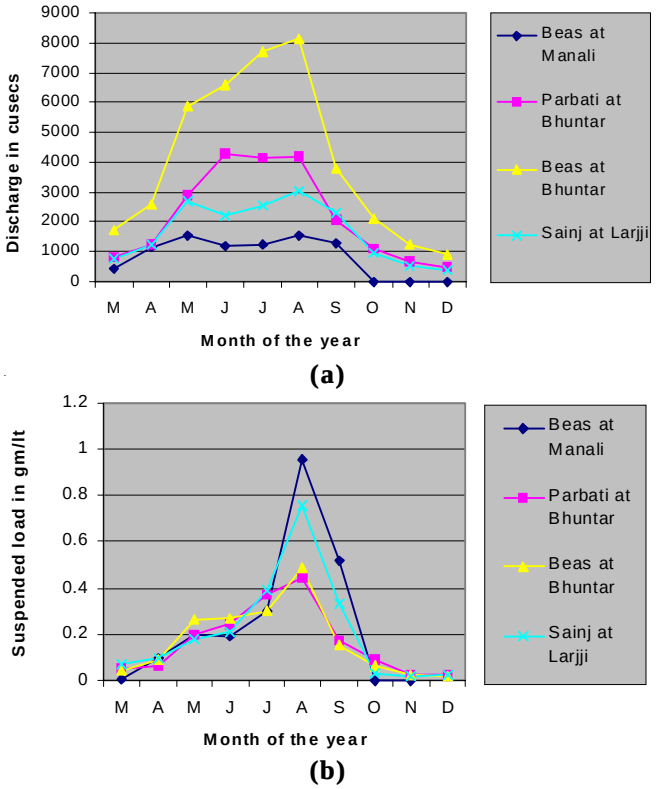


Fig. 8. Discharge and suspended sediment load of the Beas river and its major tributaries for the year 2002.

3.2 SUB PROJECT

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

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

During the year, fieldwork was carried out mainly in the Yamuna valley between Gangani and Yamunotri in Uttarkashi district. In the Yamuna valley detailed mapping on 1:1000 scale was carried out for Khanera active landslide zone in the vicinity of MCT, which has blocked the main Yamunotri High way in 1980. The base map for this mapping was acquired through the local office of PWD. The Khanera landslide is a multiple and complex slide having combination of rotational, planer and wedge failure. The lithology at the site is mainly quartzite intercalated with metabasics of Lesser Himalayan sequence (Garhwal group) i.e. footwall of the MCT Zone. NNE–SWS trending rocks are highly deformed into mesoscopic open type NWN – SES trending asymmetric folds plunging due west and shows variation in dip direction from ESE to WNW at an angle ranging from 32^0 to 48^0. The rocks within the slide zone are highly jointed and fractured and traversed by two N-S trending high angle faults. Along the fault planes the rocks are highly crushed and pulverized. Also fault breccia and silicansides are observed along the fault planes. There are four sets of joint planes indicating probable failure mechanism of a slope. For rock quality designation (RQD) the values have been estimated roughly from the surface observations. Movement along two existing faults trending NNE-SSW parallel to the valley at this place has resulted a progressive stepping failure of the slope facing towards west. The role of water seepage observed in the zone is accelerating the mass movement. At crown area, orientation of the slope and discontinuities in the rocks are responsible for the rock fall, where as in the accumulation zone rotational and planner movement is observed.

Besides above, to the north of Khanera a fresh slope failure was observed at Kuthanaur, which occurred in the current year i.e.2004. The failure is due to high precipitation and saturation of the thick colluvium on steep slope, where the bedrock was highly jointed and fractured. Four sets of joint planes were observed and the failure is planer as well as wedge type which has exposed the bedrock on the slope. It has damaged the agricultural fields downwards situated at the left bank of the Yamuna River.

3.3 SUB PROJECT

Mapping of active faults using remote sensing techniques.

(G.Philip)

Active faults of the Himalaya are significant in the study of active tectonics because displacements along them are considered as the direct reflection of continued tectonic movements. The present study displays morpho-structural analysis using remotely sensed data along with selected field investigations in delineating new traces of parallel to sub-parallel active faults that have been recognized in the Pinjor Dun of the northwest Frontal Himalaya. Active tectonics in the Pinjor Dun valley is reflected in the form of dislocation of landforms by major and minor faults in Quaternary and pre-Quaternary sediments. Most of the fault traces and lineaments show a NW-SE trend, which is almost parallel to the regional trend of the MBT, Barsar and the Nalagarh Thrusts. Some stream courses are fault guided and also controlled by the lineaments. The activity is demarcated by the nature of uplifted and tilted Quaternary landforms and sediments 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 observed

along the active fault traces show basically a thrust movement with northside up. The traces of active faults running parallel to each other, traverse through late Pleistocene to Holocene alluvial-fan sediments. The development of fault scarps with heights varying from 5 to 25m are indicative of long-term uplift/deformation along these faults in the current tectonic regime (CTR) and cumulative slip along the faults. 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 the common features observed. These fault systems are considered to be the manifestation of Quaternary tectonics to the south of Main Boundary Thrust (MBT) and around the Himalayan Frontal thrust (HFT). The study of the tectonic landforms and active fault systems will strengthen our understanding that the Frontal Himalayan region in the Pinjor Dun and the surroundings has been subjected to intense neotectonic activity which resulted into a number of major earthquakes in the recent past and also sculptured the present day geomorphic configuration.

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 3-components seismic stations have been installed in the Himachal Himalaya. The installations include design of seismic array, selection of site, and preparation of the seismic pit for sensor. The data collection started from March 15, 2004. During this period total 69 local events were recorded at our seismic array. The epicenters of most of the events lie around or north of Chatrari (HP) station. Focal depth of all the events distributed rang between 8 to 20 km (Fig.9). The detailed analysis of data is under process to obtain the 1D, 3D and P & S wave velocity structure.

The moderate earthquake which triggered on November 11, 2004, in Chamba region of Himachal

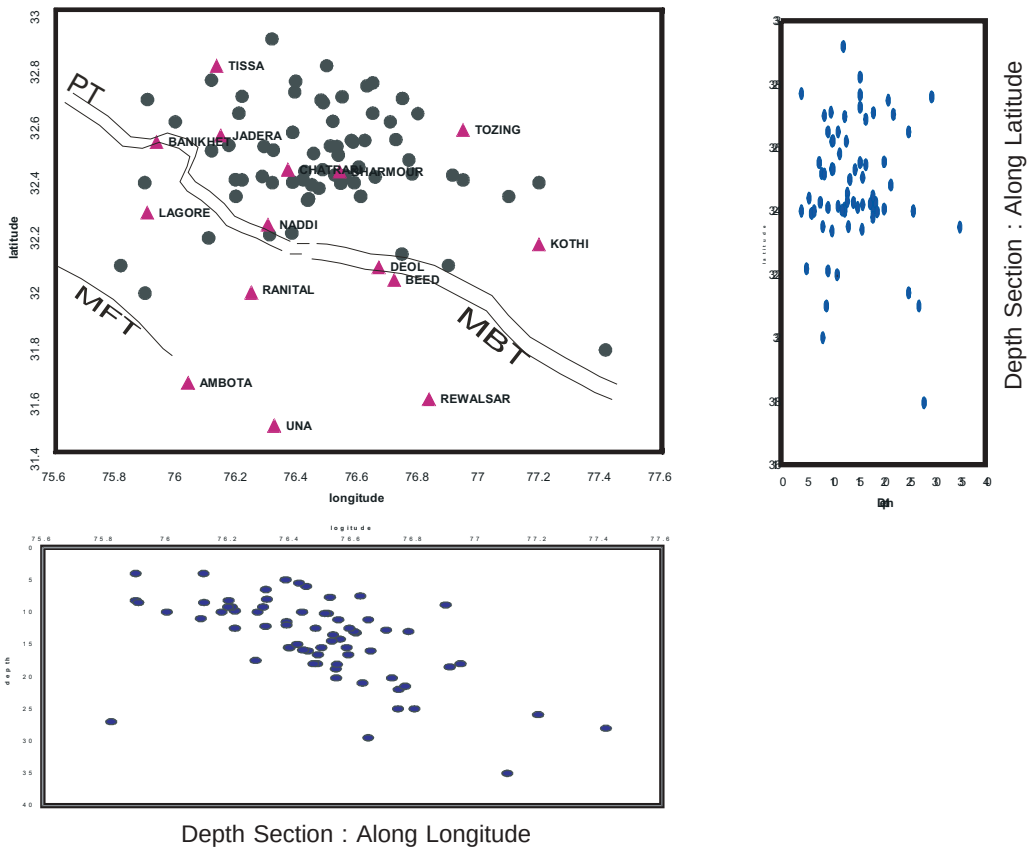


Fig. 9. Hypocentres of the 69 local earthquakes recordedin the NW Himachal Himalaya during March 15 - Dec 26, 2004. Depth sections shown are along the Latitute and Longitude

Table 1. The hypocentral parameters.

S. No.	Station Name	Latitude		Longitude	
		Degree	Minute	Degree	Minute
1.	Banikhet (SPS)	32	32.839	75	56.364
2.	Bharmour (SPS)	32	26.369	76	32.586
3.	Chatrari (SPS)	32	26.783	76	22.36
4.	Lagore (SPS)	32	17.526	75	54.476
5.	Deol (SPS)	32	5.621	76	40.337
6.	Naddi (BB)	32	14.85	76	18.409
7.	Rajiyana (SPS)	32	0.087	76	15.117
8.	Ambota (SPS)	31	40.506	76	2.579
9.	Tissa (SPS + BB)	32	49.316	76	8.294
10.	Tozing (BB)	32	35.40	76	57.0
11.	Una (BB)	31	31.26	76	19.62

SPS: Short Period Seismograph **; BB:** Broad Band Seismograph

Himalaya was recorded in our seismic array. The coda magnitude of this earthquake estimated is 4.7 and occurred at depth of 16km near Chatrari. The hypocentral parameters are listed in the Table-1. The epicenter of the earthquake lies north of Panjal Thrust near Bharmour village (HP). Fault plane indicates the thrust faulting with 40° fault dip.

3.5 SUB PROJECT

Site response studies in major population centres in NW Himalaya.

(Kamal, A.K. Mundepi)

Several surface or borehole geophysical methods can be chosen for determination of the extent of the sedimentary column in an area. Most of them are either prohibitively expensive or logistically impractical in a densely populated area. In the last decade or so, the H/V technique has become very popular for a quick estimation of site's natural frequency, mainly because of its ease of operation and non destructive nature. This technique directly provides an estimate of the predominant frequency of the local site. The depth of the sedimentary column can usually be calculated if the suitable assumption about the average shear wave velocity can be made. In the absence of shear wave velocity information, direct estimate of the sedimentary column thickness was obtained by empirical relations only. A suitable empirical formula is used in this study to estimate the sedimentary column thickness in the city of Dehra Dun, India (Fig.10), situated in the foothills of NW Himalaya.

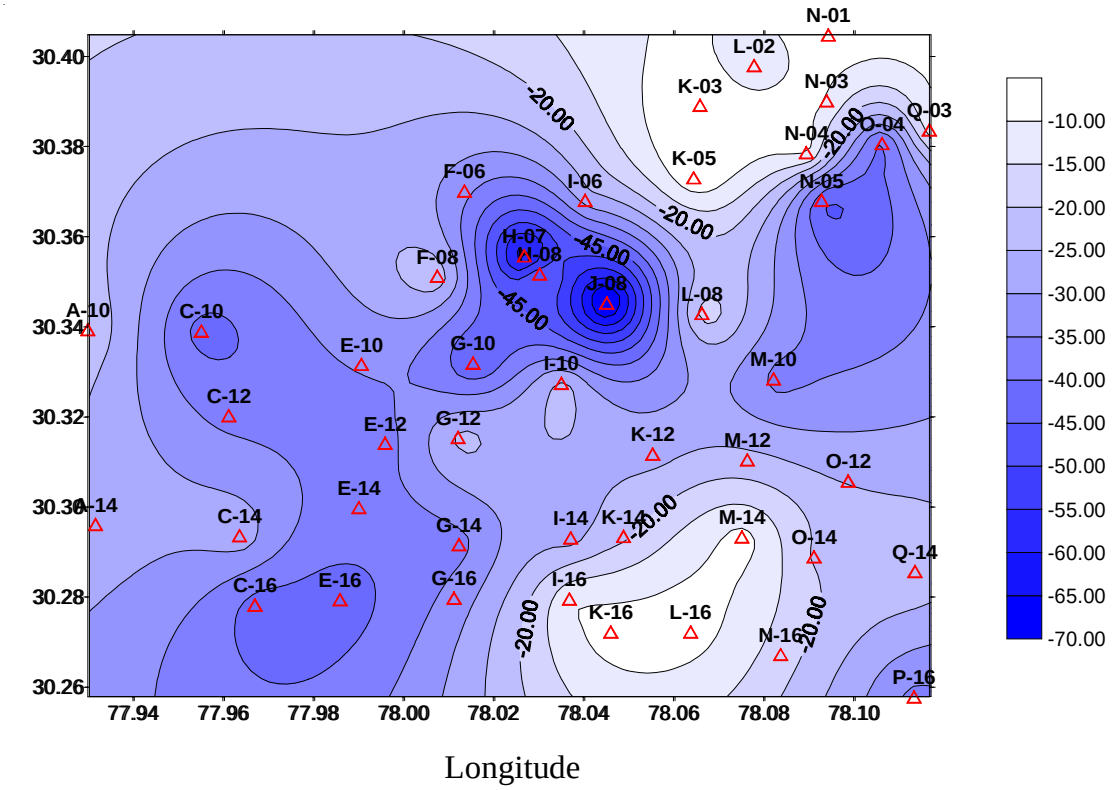


Fig 10. The thickness of soft sediment column under Dehra Dun city, India as estimated using empirical relation. The depth is in meters from the ground surface.

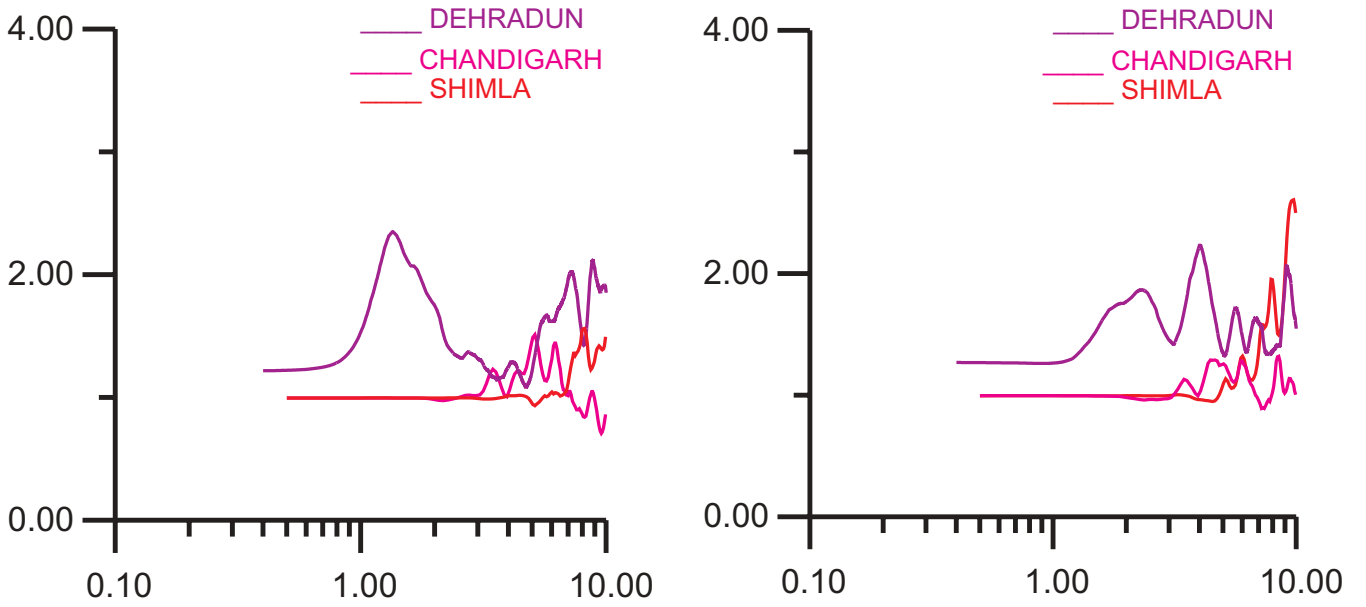


Fig. 11. H/V ratio comparison at different sites in Shimla, Chandigarh and Dehra Dun

The field work related to site response estimation in Shimla and Chandigarh was carried out during the month of December 2004 and January 2005. Preliminary results indicate almost no amplification in the bedrock motion in Shimla and very little amplification in Chandigarh as compared to Dehra Dun (Fig. 11). This may explain the fact that Dehra Dun was subjected to high damage during the 1905 Kangra Earthquake.

3.6 SUB PROJECT

Seismicity, seismotectonics and seismic hazard assessment of NW Himalaya.

(V.Sriram)

Eighty strong motion records recorded from 12 events (1986, Dharamsala earthquake, 1991, Uttarkashi earthquake, 1999, Chamoli earthquake and 9 of its after shocks) analyzed in the magnitude range 4.5 to 7.0 in the NW Himalaya to estimate the source parameters and to establish a scaling relation of the source spectrum for the region. The estimated moments for these events range from 1.4e16 Nm to 1.1e19 Nm. The static stress drops of these events lie between 40-60 bar. The regression relation between the seismic moment (M_0) and the corner frequency (f_c) shows that M_o is proportional to f_c^{-3}. These estimated parameters are useful in constraining various parameters needed for seismic hazard assessment of the region

3.7 SUB PROJECT

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

(Sushil Kumar)

To obtain a well-constrained Tomographic model of the region, huge local data is required. In the present study we have analyzed the travel time of seismic P waves from Hindu Kush earthquake recorded at temporary seismograph stations in the Himachal Himalaya, and have tried to obtain the crustal thickness and upper mantle P-wave velocity using earthquake cluster of 27 earthquakes triggered in the Hindu Kush. The epicenters of the Hindu Kush earthquakes whose data are analyzed were clustered in a 80 km by 60 km area. The focal depth of these earthquakes as estimated by the USGS ranged between 46 and 259 km approximately. We analysed 27 earthquakes lying in the focal depth range of 46 to 95 km, to estimate the upper mantle V_p The hypocentral location and origin times of the concerned earthquakes as reported by the US Geological survey to obtain the necessary travel times have been adopted.

A shooting strategy based on formulation of Sorrels et al (1971) was adopted to trace the desired ray iteratively in specified models of V_p. Using the reported epicentral coordinates of the earthquakes, 129(27 earthquakes 3-7 stations) epicentral distances were computed using the standard formula (Bullen and Bolt

1985). Corresponding travel times were obtained using the USGS determined origin times for these 27 earthquakes and the respective P wave arrival time. A ray tracing exercise revealed that the travel time of the rays through the crust would be a small fraction of the total travel time. Therefore we decided to include an average crust with a single layer of average P wave velocity in the models. Hirn et al (1984) average of value of V_p in the crustal layer in the Himalaya is of the order of 6.3 km/s. However, for the Himachal Himalaya, as observed from analysis of local data that the V_p in the second crustal layer has the value of 6.2 km/s, which is not very different from the Hirn et al (1984). Hence we adopt an average V_p of 6.2 km/s for the crustal layer in order to carry out the upper mantle value.

While using the travel time data for the 27 earthquakes cluster, it is seen that the minimum of $E(V_{pl})$ is at crustal thickness of 38 km and upper mantle V_p of 8.06 km/s do yield the least total squared error. Thus we conclude a crustal thickness 38 km in the Himachal Himalaya and upper mantle V_p of 8.06 km/s.

3.8 SUB PROJECT

Seismic microzonation study of Dehra Dun City.

(A.K. Mahajan and S.K. Chabak)

2D shear wave velocity investigation using the Multi-channel Analysis of Surface Waves helped to identify lateral and vertical variation of shear waves to a depth of 30 to 60 meters. This information is very much required for predicting the ground motion response to earthquakes in areas where significant soil cover exists over firm bedrock. Shear wave velocities of the near-surface soil were determined at 50 sites in the urban zone of Dehra Dun city. The average shear wave velocity for the surface layers (5-6 meters) has been estimated to be around 220 meters/sec for most of the sites. However, in some of the sites the SH velocity of the upper soil layer (5-6 m) is less than 150 meters/sec. The sites with low velocities are generally located in the southwestern part of the city. The northern part of the Dehra Dun city shows high velocities, ranging from 300 m/s to 1000 m/s at shallow depth. In general, the shear wave velocities range from 150 meters/sec in the top layer to 1000 meters/sec at a depth of 30-40 meters. Based on the average SH-velocities of the upper 30 m of the soils, sites located in the heart of the city are predominantly classified as D (180-360m/s) in accordance with the 1997 NEHRP provision. Sites located in the northern part of the city have average V_s values larger than 360 m/s thereby qualifying them as a class C site (360 -760 m/s) (street et al., 2001). The shear wave velocities for the soil column in different sites of the city may help to provide a first look at predicted ground motion response.

Site amplification is a concern in Dehra Dun city because it is in an area of moderate seismic activity, and it is important to study the site effects of the area because of the large amount of sediment and landfill (e.g. Doon

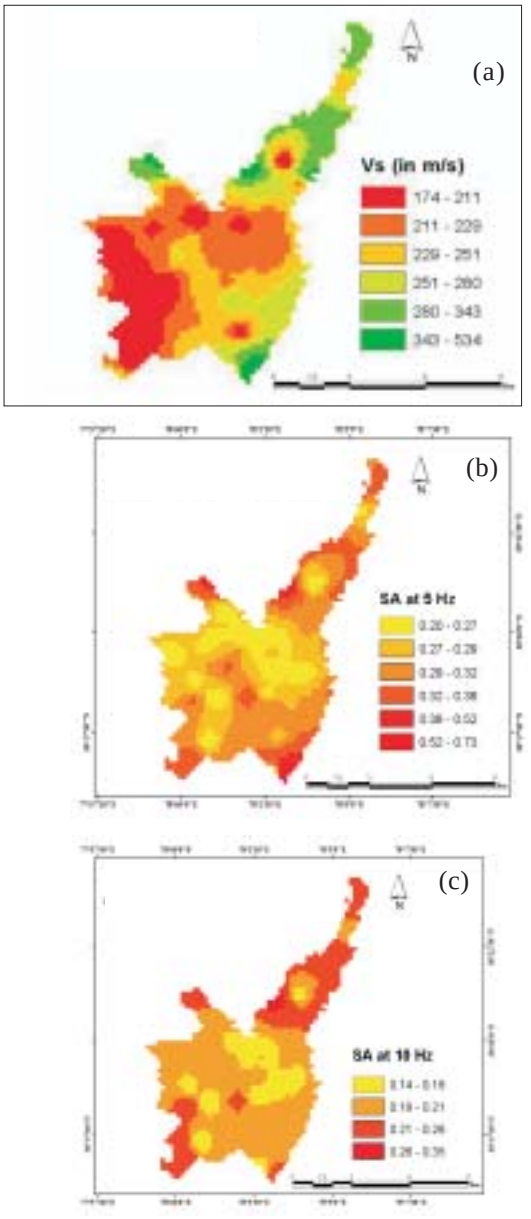


Fig.12. (a) Shear wave velocity map of Dehra Dun City.
(b) Spectral Acceleration Map of Dehra Dun City at 5 Hz Frequency.
(c) Spectal Acceleration Map of Dehra Dun City at 10 Hz Frequency.

gravels and fan deposits), which may greatly amplify seismic waves. Historic and recent records indicate that motion from nearby and from more distant earthquakes have been felt widely in the Dehra Dun city over the past one hundred years (e.g. 1905 Kangra, 1991 Uttarkashi and 1999 Chamoli earthquakes). Intensities up to RF VIII and MMI VI have been reported in Dehra Dun. The objective of this research is to produce seismic microzonation maps for the Dehra Dun city showing the spatial variability of expected spectral acceleration for a given input rock motion. The necessary inputs for the modeling of the site response in Dehra Dun are geotechnical parameters such as shear-wave velocity measured using MASW technique, plasticity index (PI), unit weight and groundwater levels. This information, along with bore hole log information from the large collection of tube well (from Irrigation Deptt.) is being assembled into a queriable Arc GIS Geographic Information Systems (GIS) database for use in the microzonation maps. The computer program SHAKE uses the geotechnical parameters and input ground motion from the soil columns to compute the response. The response is being determined at 50 sites in an area of 65 sq km. Microzonation maps for the spectral acceleration for the natural frequency of 5 Hz and 10 Hz equivalent to 2 story and single story buildings respectively have been determined (Fig.12). However the peak amplification has been noticed at 1.9 Hz to 3 Hz in whole of the city but majority of the city lies between 1.9 to 2.5Hz, which corresponds to 3 to 5 storyed building.

3.9 SUB PROJECT

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

(P.Banerjee)

GPS data from entire Himalayan region, Indian peninsula, and surrounding countries were processed. The India-Sunda South China plate convergence process was studied. Motions of Indian plate, Sunda plate and Andaman blocks were investigated to derive inter-seismic strain accumulation rate in the Andaman arc where devastating 2004 earthquake occurred. The results were communicated for publication in Current Science.

The Garhwal-Himachal-Ladakh campaign and permanent GPS station network data were processed. Westward extrusion of Himachal sites confirms right-lateral movements along the Karakorum fault. Segmentation of the Himalayan convergence is being studied from these networks.

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 and helium measurements were carried out in cold and hot water springs along Yamuna, Bhagirathi and Mandakini valley Garhwal Himalaya. Study indicates that Helium is mostly present in the hot water springs. The helium concentration varies from 5.81 to 3077 ppm. It is highest in spring in Matli (between Uttarkashi and Dharasu) and lowest observed in hand pump at Lavri (near Tilwara). The temperature, conductivity and TDS of these hot water springs vary from 28°C to 73°C, 662 to 2140 µs/cm and 334 to 1060 mg/l respectively. Where as, radon concentration in above sample varies from 3.2 to 86 Bq/l. No correlation was observed between helium, radon and other chemical parameters. Presence of helium in hot water springs is possibly related with deep circulation of water beneath the surface and high temperature resulting in high conductivity and TDS due to solubility of the minerals.

The radon data collected from soil and water from Kumaun region was also processed and analyzed during the year. The radon in soil, associated with rocks of Barinag formation (mostly quartzite and tuffaceous volcanic and slates), varies from 0.5 to 16.9 kBq/m^3 with an average of 5.5 kBq/m^3. Whereas, the radon in water present in the same formation show an average of 18.3 Bq/l. Radon in soil of the Mandhali formation (carbonaceous slate, limestone, pebbly quartzite and phyllites) varies from 1 to 17 kBq/m^3 with an average of 9.1 kBq/m^3, whereas average radon concentration in water is 3Bq/l.. Radon in soil of Deoban formation (limestone, slates and phyllites) varies from 0.6 to 2.7 kBq/m^3 with an average of 1.3 kBq/m^3. However, radon in water from the same formation varies from 1.7 to 22.7 Bq/l with an average of 9.2 Bq/l. The radon concentration in the soil of Saryu Formation (Almora group- chlorite sericite schist, micaceous quartzite, porphyritic granite and gneisses) varies from 1.3 to 35.2 kBq/m^3 with an average of 12.9 kBq/m^3 and in water it varies from 3.7 to 187 Bq/l with an average of 63.7 Bq/l. Relatively lower values of radon in both soil and water were observed in the sedimentary rocks of Berinag, Mandhali and Deoban formation in comparison to the metamorphic rocks of Saryu formation of Almora group. It has been also observed that the samples located in the vicinity of the different thrusts and faults show relatively higher concentration of radon in both the soil and water.

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 studies were focused on updating the existing landslide inventory as well as mapping of Pawari and Nathpa landslides in the Satluj valley. Landslide inventory for upper part of the valley has been updated and detailed mapping of the Pawari landslide has been carried out. Samples collected from the Pawari landslide zone and the adjoining areas have been analyzed for geotechnical characteristics. Preliminary results show that there is an increase in the frequency of landslide in the area; however, statistical analysis is still underway.

The lichen based study involving the measurement of percent cover of lichens on the slided materials in the Pawari landslide zone has also been done. This has been correlated with the indicators showing the movement of deposits and the activity of slide. It is well documented that the boulders containing the more percentage of lichen cover (about 70 %) are stable in the present climatic scenario or has moved least as compared to the one showing the less percentage (about 40 %) of lichens. The slopes covered with more or less fresh rock boulders and pebbles (no lichen coverage) in the slide zone indicate an active part within the slide mass. This has been used as an indirect method to assess the differential movement of slope (first order microzonation map) within the slide mass.

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)

Hydrochemistry of Pithoragarh- Champawat area

The diagnostic chemical composition of the groundwater (spring, and borewells) and stream of the Lesser Himalayan basin in eastern Kumaun can be described in terms of hydrochemical facies (Back, 1966). Based on their chemical characteristics, the waters of the eastern Kumaun have been catetegorized into four major groups - calcium bicarbonate, magnesium bicarbonate, calcium-magnesium sulphate and sodium bicarbonate - of which the calcium and magnesium bicarbonate facies are dominant in the Pithoragarh and Sodium bicarbonate are dominant in Champawat area. A piper trilinear diagram shows the strong influence of dolomitic limestone with gypsum and pyrite in the rocks of the recharge area of the Pithoragarh valley. Comparison of these hydrochemical facies with the maps depicting geology, groundwater flow and drainage pattern corroborates the deduction that these facies varies perceptibly from area to area.

Calcium bicarbonate water

This is the predominant facies, and has the widest distribution, except in the western part of the Champawat district. Waters entering the basin system via recharge areas acquire their initial chemical characteristics by contact with rocks of the Saryu formation of Almora group.

Magnesium bicarbonate

This facies occur in the Pithoragarh area, where dolomitic limestone of the Gangolihat Formation predominates.

Calcium – Magnesium Sulphate Water

The Calcium–Magnesium sulphate facies is produced by the solution of gypsum and pyrite occurring in the Gangolihat formation. The relationship of these waters with the water flow paths and geology shows that the recharge waters undergo a gradual change in chemistry (from calcium bicarbonate or magnesium bicarbonate to calcium magnesium sulphate) as a result of increasing residence time and consequent contact with minerals present in the flow paths. The TDS of these waters are significantly higher than those of calcium bicarbonate waters.

Sodium bicarbonate waters

Sodium rich water, in springs and hand pumps, occurs locally near Champawat and Didihat area where rocks of the Champawat granite and granodiorite comprising schists, and highly weathered granite are present. The enrichment of Sodium and potassium has also been observed in Pithoragarh area. While the leaching of Na and K from soda –potash rich feldspars present in granites is the main source of localized alkali enrichment in Champawat area, the anthropogenic enrichment of

sodium in the soils is possibly the source of sodium enrichment in Pithoragarh area. The TDS of these sodium rich waters are more than the TDS of $CaHCO_3$ and $CaMgSO_4$ water of the other parts of the study area. Ion exchange (which reduces the calcium in solution, and adsorption of Na ions), could explain the increased prevalence of sodium over calcium in groundwater discharging from these springs and bore wells (hand pumps), or the source rocks which contain high Na_2O content than CaO.

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)

Glaciological studies of the Dokriani glacier were continued by monitoring three hydrological and meteorological stations in the Din Gad catchment. Winter snow precipitation plays an important role in determining the mass balance as well as glacier and headwater stream runoff. The winter of the year 2003-2004 experienced another dry spell, amounting to only 190mm snowfall at the Base Camp (3763m a.s.l.) of Dokriani glacier. However, the last quarter of the ablation season experienced good snowfall, lasting for nearly 10 days starting from the second week of October and effectively increasing the snow deposit at the accumulation zone. Analysis of temperature data at three meteorological stations established at altitudes (2540, 3483 and 3763 m a.s.l.) in the Din Gad catchment revealed that the station pair within the alpine zone (3483 and 3763 m a.s.l.) of the catchment shows distinct variations in lapse rate as compared to the valley scale (2540 and 3763 m a.s.l.) lapse rate. Yearly variations in the lapse rate within the alpine zone of the catchment were higher than the variations of valley scale lapse rate, which show 40-50% reduction in the lapse rate in 1999 and 2000 as compared to 1998. It is also observed that in the valley scale, lapse rate values were lower during the monsoon months, compared to the rest of the ablation months. However this trend is absent between the station pair located within the alpine zone. The non-linearity of lapse rate of Din Gad valley as observed in our study, suggest that the lapse rate of the alpine zone is most representative of the glacier catchment, suitable for snow/glacier melt runoff and mass balance models. Also the lapse rate of alpine zone of the catchment have to be monitored for modeling hydrological processes of Himalayan glaciers, rather than adopting the lapse rates of mountain areas of other geographical locations or extrapolating lapse rate values of lower elevations of the Himalayas, as being practiced today. This study also suggest that the snow/glacier regime of Himalaya is possibly warming at more higher rate than the lower elevation owing to the energy flux variability induced by the variations in the snow cover over the years.

In continuation of the glacier monitoring programme for Himalayan glaciers, Mass balance, snout recession, geomorphological and Lichnometrical studies have been carried out in Chorabari glacier. Chorabari glacier is a medium sized compound valley type glacier located in the southern part of the main mountain range of Gangotri group of Glaciers (Central Himalaya). It is six km long with width varying from 100m to 900m and lies between elevation 6000m and 3860m (masl). Ablation area of the glacier is gently sloped and has thick debris cover. The accumulation area is formed by two small cirques and is bounded by steep mountain slopes. Melt water stream emerging from the glacier is the source of Mandakini river which later on merges with Alaknada river (a tributary of River Ganga) at Rudrapryag.

Annual mass balance of the Chorabari glacier has been determined for the year 2003-04 by applying the direct glaciological method (Stake network). The winter balance was surveyed in the month of June and again in October 2004. The snow depth was measured at different elevations in accumulation zone by digging pits and by manual probing. The mean snow density was determined about 0.58gm/cm^3. The total accumulation during the period 2003-04 was 0.60m w.eq. The summer balance was determined by establishing a network of 32 stakes through out the ablation area. For the net ablation and accumulation at each stakes an isoline was drawn on the map. The balance amounts (expressed in meter) were multiplied by density for water–equivalent and this value again multiplied by the corresponding area for each elevation band to obtain the net mass balance.

The net annual balance of the Chorabari glacier for the year 2003-04 was negative, amounting to -3.0×10^{-6} m^3. The Equilibrium line altitude (ELA) was estimated from the field observation as well as vertical mass balance gradient (Fig. 13) and found at an elevation of 4950m masl. The accumulation area ratio (AAR) estimated was 0.47. The detailed mass balance results are given in table 2.

The snout of the glacier was monitored by GPS survey and manually (chain-Tape method) to determine the recession during the year 2003 - 2004. The total recession of the snout at centre was 10m where as on the left and right flank it has receded about 8m and 6m

Table 2. Summary of mass balance results of Chorabari glacier.

Elevation extension	Abl.area sqkm	Accu. area Sqkm	Net abl. $x10^{-6}m^3$	Net acc. $x10^{-6}m^3$	NetBal. $x10^{-6}m^3$	Sp. Bal m	AAR	ELA m.
3860-6000	2.83	2.52	-4.50	1.50	-3.0	-0.54	0.47	4950

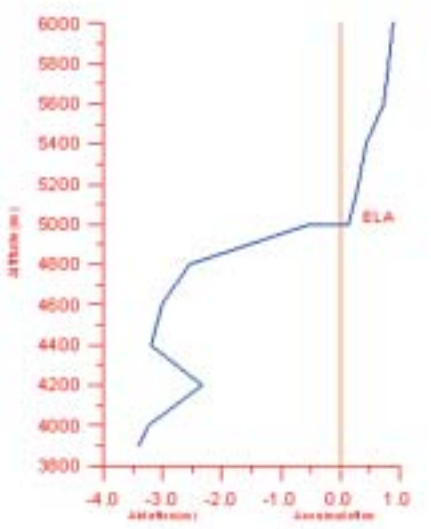
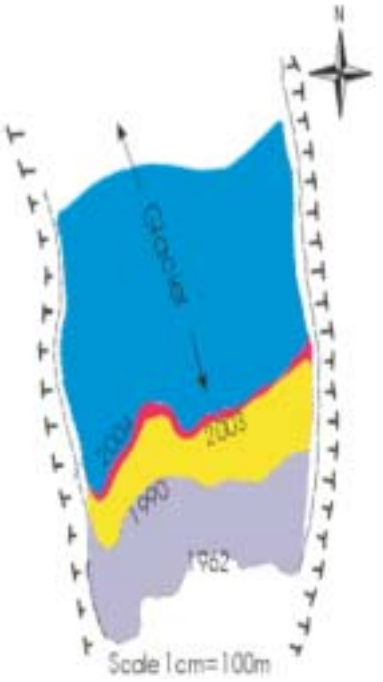


Fig.13. Vertical Mass balance gradient of Chorabari glacier for the period 2003-2004.

respectively. Based on field observation and SOI toposheet the total recession of snout between 1962 and 2004 has been calculated (Fig.14). The results show that the recession rate of the Chorabari glacier is less than other glaciers like Gangotri and Dokriani.

Under lichenometric study, more than 260 samples measurement from Himachal Pradesh and Garhwal area were investigated and analyzed in order to establish chronological affinity with glacier melting. Previous joint study reveals that due to microclimatic diversity, growth rate and colonization delay is different in various parts of study area. The colonization delay is ranging from 24 to 86 years while growth rate is showing variation of 0.54 mm to 0.73 mm per annum. Lichen data collected earlier from the loops of different cycles of advance and retreat of the Chorabari Glacier boulders has also been remeasured for its caliberation between melting of glacier and lichen growth.



Snout recession of Charabari glacier

Fig. 14. Snout dynamics and shape of Chorabari glacier in different observation periods.

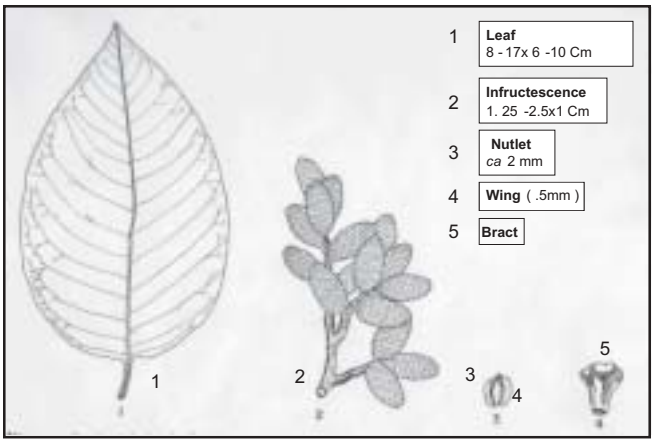


Fig.15. *Alnus nepalensis* -Habitat precursor for slope instability in Himalaya.

Under bioengineering ecological signal of area of potential hill slope movement has been deciphered. Study reveals that *Alnus nepalensis* (Fig. 15) manifest as a habitat precursor for slope instability and area of potential landslides can be delineated by its floral dynamics. Laboratory investigation and microclimatic field studies suggest that obtrapezoid-winged nuts (2mm) morphology, radiative balance at different aspects of micro-watersheds and interwoven air and wind dynamics create holistic system for viable mechanism of seed dissemination to new habitats of potential landslide.

Inherent nitrogen fixing, fast growth and multi-pedological adaptation characteristics of identified precursor taxa is found to be as main factors for invasion, establishment and sustaining in unfertile soil or rocky strata of unstable slopes or exposed slip surface. Widespread occurrence in ravines, stream banks and along newly constructed roads is also attributed to unstable slopes habitat of *Alnus nepalensis*.

The habitat ecology data was recorded from pre-slope failure phase by visual reconnaissance and ground studies along MCT zone of Garhwal Himalaya. Laboratory analysis has been carried out for seed morphology and its adaptation for seed dissemination to unstable hill slopes. Phytogeographical range in study area explored between 1000-2600 m.s.l. and which is coinciding with the Lesser Himalayan range (800-3000 m.s.l.).This range has turned very sensitive to landslide hazards due to active geological formations and intense anthropogenic pressure.

The proposed bioengineering technique is eco-friendly, cost effective, socially acceptable and involves local resource and traditional wisdom as a scientific tools and technical excellence. It will play significant role in landslides hazard mitigation for Hindu Kush-Himalayan range and similar geographical region of the world. Where landslides has become major devastating natural hazards and eventually acquired the tendency of natural calamity or annual catastrophe.

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)

Stream sediments collected from Kosi-Ramganga-Saryu-Gola catchment (along Mohan-Daba-Hatyura-Chaukutyia-Bageswar-Baijnath-Bhawali-Bhimtal sections) are being analysed for major, minor and trace elemental abundances. Apart from this work on previously collected samples from upper parts of Alaknanda-Mandakini-Bhilangana-Bhagirathi catchments was carried out. A set of 19 elements (Al, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Si, Th, Ti, U, Zn, Zr), has been used to study their spatial distribution in the environment. The geochemical datasets are statistically analysed (mean, mode, median, maximum, minimum, correlation coefficient) to understand the association of elements .A comparison of the elemental abundances made with the averages upper continental crust (AUCC) indicates that the most of the trace elemental abundances are enriched. Further, with exception of SiO_2, MgO and TiO_2 all other major elements are depleted against AUCC. The enrichment of SiO_2 may be due to quartz dilution effect as evident by the inverse correlation between most of the major oxides and trace elements (Ni, Co) with SiO_2 Relationship between various elements have been identified based on correlation coefficient. Positive correlation of Cu with Zn and Pb, is related to possible sulphide mineralisation. Whereas the enhanced concentration of Cr as compared to Ni and AUCC may be diagenetic or due to co-precipitation of Cr with Fe oxides.

Also geochemical characteristics of radioactive elements (U, Th, K), in active stream sediments over the whole area have been investigated. Together with the previous reports of radioactive mineralization and Radon anomaly studies, the present study further provides sufficient evidence that part of the area under study has anomalously high radioactive element abundance exceeding the limits said to be safe for human or animal

exposure Distribution pattern of these elemental abundances show intrinsic relation with the lithology and tectonics of the area. A comparison of the elemental abundances made with the averages upper continental crust (AUCA) indicates overall enrichment of these elements. . The higher concentration of U and Th across MCT indicates probable mineralization in this area, and the enrichment therefore may be linked to deformation induced radioactive element remobilization and concentration. Also anomalous areas are of some concern to environmental health hazard

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 century-scale record of tree line fluctuation based on vegetation and climate history inferred from the multi-proxy records (pollen, diatoms, phytoliths, total organic matter, and magnetic susceptibility) from a peat deposit (2650 m a.m.s.l.) reveal that the tree-line altitude in the Pinder valley fluctuated significantly during the past 3500 years (Fig.16).

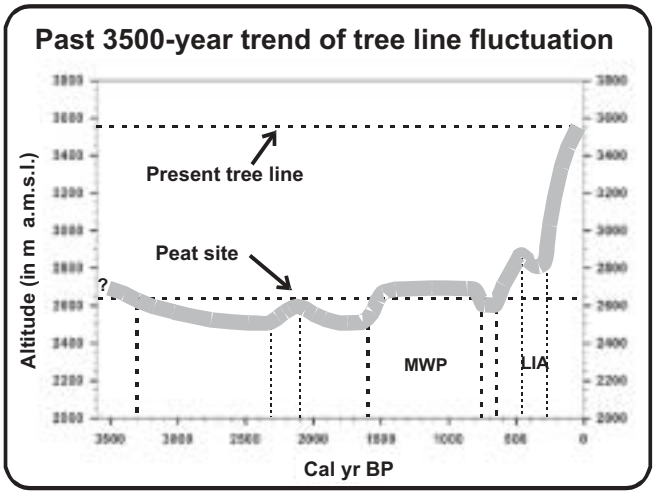


Fig. 16. The tree line fluctuation based on the pollen-inferred vegetation and climate history of the Pinder Valley. The Medieval Warm Period (MWP) corresponds to ca. 1600 – 740 cal yr BP (~400 – 1260 cal AD), while the Little Ice Age (LIA) is represented by 460 – 270 cal yr BP (~1540 – 1730 cal AD) event.

Around ca. 3500 yr BP, the upper tree line was located slightly above the 2650m altitude. The significant climate shift towards drier conditions around 3300 cal yr BP, resulted in its retreat towards lower altitude. Except for a short interval of improved climate during 2300 – 2100 cal yr BP, the progressively cool and dry conditions prevailed between 3300 and ca. 1600 cal yr BP reveal that the tree line was further retreated, and reached at the lowest altitude during its 3500-year history. An abrupt climatic shift towards significantly warm and moist conditions around 1600 cal yr BP (~400 cal AD) probably caused its ascendance above 2650m altitude. The continued warm/wet and relatively stable climate during 1600 – 740 cal yr BP (Medieval Warm Period) indicates that for this period the tree-line altitude remained nearly unchanged. During decreased temperature and precipitation of the following century (740 – 640 cal yr BP), the tree line once again retreated below 2650m altitudes. In response to improved climate between ca. 640 and 460 cal yr BP, the tree line yet again ascended to higher elevations, significantly above 2650-m altitude. With a discrete cool interval of ca. 460 - 270 cal yr BP (~1540 – 1730 cal AD, corresponding to Little Ice Age) that possibly caused a minor retreat, the consistently moist and warmer climate prevailed since 270 cal yr BP (1730 cal AD) indicates that with steady advance the tree line zone has attained its present altitude (i.e. ca. 3500 m a.m.s.l.). The multi-proxy paleoclimate record thus indicates that with an average ascendance rate of ~1.5 m altitude/year, the upper tree line has climbed about 900m altitude since 640 cal yr BP (~1360 cal AD).

The altitudinal distance between the glacier boundary and tree line ecotone zone, on a longer time scale, generally remains almost constant. The tree line history inferred from pollen record, therefore, suggests that the Pinder Glacier might have possibly retreated by about 900m altitude since 1360 cal AD.

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)

Rudraprayag District has been selected first for establishing district database at Wadia Institute of Himalayan Geology, Dehra Dun. All the thematic maps like drainage, slope, geology, geomorphology, relief regions, road network and location of cloud burst have been prepared and digitized

for GIS application and Natural Resources Data. Village wise socio- economic data has been collected during field work from the various Governmental offices as well as three developmental blocks like Ukhimath, Agastmuni and Jakholi blocks. These socio-economic data are on the theme of demography, occupational pattern, landholding and livestock, education, health, communication and transport, general amenities, drinking water and electricity, landuse, irrigation and cropping pattern, whereas under natural resource data the themes are, geomorphology, geology, soil, water, meteorology, forest and landuse. Under R&D some application projects such as landslides, cloud bursts / flashfloods, rain water harvesting, earthquakes and subsidence taking colossal loss of life and property are covered.

In the current year, work was started in Pithoragarh District, which has been divided into five tehsils viz Munsiari, Dharchula, Didihat, Gangolihat and Pithoragarh having its headquarters in Pithoragarh and the 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 1991 census, total population of the district is 4,16,647 out of which 2,09,177 are males and 2,07,470 females. Literacy rate of the district at present is 61.4%.

Uttaranchal State has a population of 84.49 lakhs. It has 13 districts of which Champawat district is least populated with a population of 2.24 lacs i.e. 2.64% while Rudraprayag district has a population of 227461 which is 2.68% of Uttaranchal. Highest population density is in Hardwar district i.e. 612 per/km.

The migration trend shows that Champawat district is having 16.6% persons in the last decade (1991-2001 census), whereas Rudraprayag district has migrating trend of 4% mainly due to search of job in plain areas, better living conditions and less productive agricultural practices in the hilly region. Literacy in women (36.9%) and the sex ratio (964 of female per 1000 males) of the state exhibits impressive figures and has increased considerably in last 10 years. Most of the districts of the state have recorded a literacy rate of more than 70%. Nainital is the highest literate district (79.61%) followed by Dehra Dun (78.96%), Hardwar (64.6%) and Rudraprayag (40.92%) repectively.

The sex ratio among children 0-6 years age group does not show an impressive picture (906, the state average) as compared to the average sex ratio (964 female/ 1000 males) from total population of the state. The sex ratio of the children reduces to 906 (in 2001) from 948 in (1991), indicates further decrease in forthcoming decade. A significant decline in the sex ratio among children might affect the male-female ratio of the State in the next few decades.

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 studies were carried out in Arunachal Pradesh, along Kameng, Subansiri and Siyom valleys. The study was mainly concentrated on the Bomdila Group of crystallines exposed over a major part of the Lesser Himalaya, predominantly made up of quartzofeldspathic gneisses. These crystalline rocks have been classified into three varieties. The first variety is the basal tabular sheet of highly deformed, lineated and mylonitised gneisses that are exposed in most places along the basal thrust, namely the Bomdila Thrust. These gneisses in eastern Himalaya extend from Sikkim to Arunachal and can be correlated with the Lingste gneisses of Sikkim. The second group is coarse grained, porphyritic, exposed in Subansiri valley and is known as the Ziro gneisses. The field relationship indicates that the pluton size elongated ziro gneisses is an intrusive body associated with basic precursors. The third variety probably the earliest phase, is a hornblende-bearing granodiorite that occur as satellite type of bodies. All the three varieties of gneisses have intrusive relationship with the low-grade country rocks made up of pelites and quartzites of the Bomdila crystallines.

Within the Bomdila crystallines (orthogenesis + metasediments) a major fault bound wedge of the Lesser Himalayan Sequence (LHS), dominantly consisting of quartzite, occur in the western limb of the Siang antiform (syntaxis). However, our investigations show that the LHS does not occur as a single continuous band, rather there are two bands separated by a minor fault. The southern band with conglomerate horizon exposed in the Bame-Sadadoke area belongs to LHS that pinches out towards north while the band exposed in the northern part of the Siyom valley, is part of the Bomdila crystallines, showing greenschist facies metamorphism and recrystallisation.

The Lesser Himalayan crystallines rocks or the Bomdila crystallines show inverted metamorphism,

however, due to lack of pelitic material in the footwall of the MCT, the P-T condition could not be estimated. The dynamic recrystallisation of feldspars suggest that the temperature of deformation was >450°C. The presence of garnet in the gneisses below the MCT indicates upper green schist to lower amphibolite facies condition. There exists a break in both temperature and pressure across the MCT.

The Main Central Thrust a prominent feature of the Himalaya has been traced in western Arunachal particularly in Subansiri and Siyom sections. In comparison to Nepal, the MCT is not precisely located at Kyanite grade rather garnet-sillimanite gneisses are dominant at the lower levels of HHC in which occurrence of kyanite is poor. The HHC or the Se La crystallines consists of the two units: The lower gneissic unit with biotite schist containing garnet-kyanite-sillimanite and the upper schistose unit (graphitic at places) with gneisses bands contain garnet-staurolite-kyanite + sillimanite. Minor veins of pegmatite and granite are also present. Sillimanite is present throughout the HHC. Whether the Kyanite- staurolite represent an early metamorphic phase and sillimanite belong the second phase of metamorphism is not established and it is being worked out.

The P-T conditions of metamorphism of the Higher Himalayan crystallines exposed along the Siyom valley has been estimated by using various geothermo–barometric calibrations. Since minerals do not show any zoning, the mineral compositions have been averaged. The calculated (average) P-T of the lower garnet-sillimanite gneissic unit is 752$\pm$ 39°C at 10.4 $\pm$ 0.9 kbar while the upper schistose unit shows 674$\pm$ 64°C at 9.2 $\pm$ 0.9 kbar. Sillimanite (fibrolite) is invariably present in the lower gneisses and it also occur throught the HHC. The ocurence of sillimanite in the form of fibrolitization of biotite in the lower gneisses is interpreted as due to increasing temperature and or pressure supported by the P-T data. However the kyanite ($\pm$ staurolite) bearing upper schistose unit also contain fibrolite sillimanite, which can be related to a second phase of metamorphism. Detailed thermo-barometric studies are needed to understand reverse metamorphism across the MCT in this area.

Structural studies on the western limb of the eastern syntaxis, along the Siyom valley have been carried out. Trace of the first phase of deformation D_1 cannot be observed, probably due to superimposition of subsequent phases of deformation. The folds related to D_2 deformation are mostly tight, isoclinal and asymmetric in nature. The third phase of deformation D_3 has produced major cross folds roughly N-S orientation and the eastern syntaxis belongs to this deformation phase. The antiformal nature of the syntaxis is supported by the style of the drag folds that are mostly of S type in the western limb of the syntaxis whereas those in the eastern part show Z type.

Petrography and geochemistry of the volcanics in the Tuting-Tidding ophiolitic mélange, which is the southeastern continuation of the Indus Suture Zone of eastern Arunachal Pradesh, has been carried out. In the Lohit Plutonic Complex, the acidic rocks, particularly the high alumina trondhjemite with geochemical characters similar to those of adakites have been analysed. The leucogranite within the (LPC) also falls in the trondjemitic field. In this connection detailed trace element analysis, particularly Y and Sr and Y/Sr ratio are being analysed to understand their chemistry, genesis and tectonic setting and also their relationship with high potash volcanics in south Tibet and in general with the Cenozoic adakites.

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)

Study was mainly focused along Subansiri and Siang river sections of Arunachal Pradesh to identify lithotectonic terranes and neotectonic features of the region. Eight major tectonic units have been identified from south to north. Each unit is separated from the other by a major thrust plane. The Siang segment of the NE Himalaya has a unique NE-SW trend in the west to NW-SE trend in the east across the Siang gorge. Considerable neotectonic movements have taken place along the 'boundary thrusts' that define the boundaries of lithotectonic terranes and along many 'tear faults' cutting the terrain transversely. To the south at Pasighat, the contact between Brahmaputra alluvium and rocks of the Siwalic Group is referred to as Himalayan Frontal Thrust (HFT) which is very sharp. Along the tectonic contact, there is abrupt rise of 2000m high mountain from a flat area of the Brahmaputra alluvial plain. The SW facing slope of the mountain is not smooth but furrowed and cut by multiple landslide scars, debris fan and ungullied fresh triangular fault facets devoid of vegetation. The junction between flat plain area and mountain front is almost rectilinear. All these evidences and facts indicate neotectonic activity along the Himalayan Frontal Thrust.

Three levels of river terraces have been observed in the Pasighat area of Siang vally. It is observed that Pasighat, the district headquarter of East Siang , is situated on the gravelly fluvial terraces (T1 , T2 and T3). The degree college, main market and the air strip is located on T1(150m), T2 (130m) and T3(120m) gravelly fluvial terraces respectively. The younger/present sandy alluvial flood plain(T0) of river Siang is exposed at an altitude of 100m above mean sea level. This indicates that the Pasighat area is uplifted by 50 meters above the Siang River Bed in three pulses. A major 10 km long transverse N-S trending active fault namely Pasighat Fault has been recognized. This fault has uplifted the gravelly fluvial terrace (T1) by 50 meters just west of the degree college. Movements along faults and thrusts are also responsible for pronounced deflection of rivers and streams, damage to river bridges, subsidence of roads, abrupt rise of mountain front, huge landslides, abrupt narrowing down of wide meandering rivers, uplifted fluvial terraces and blockage of streams.

6.3 SUB PROJECT

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

(V.C. Tewari)

Field studies were carried out along Pashighat-Panging-Yinkiong, Daring-Igo- Basar, Garu-Igo-Bame-Sododoke-Nikte-Kaying and Daporijo-Taliha sections. Samples collected were processed for various laboratory investigations. Carbon and oxygen isotopic excursions were compared and interpreted in terms of Terminal Proterozoic marine conditions. The diamictites of the Subansiri Valley indicate a glaciomarine depositional environment. (Fig. 17). Petrographic thin sections of the Buxa Dolomite from Arunachal and Sikkim Lesser Himalaya in the NE Himalaya were studied in detail. Stromatolitic microstructures, microfacies, microbiota and diagenetic features have been recorded and sedimentary depositional environment for these carbonate facies suggest that they were formed in shallow marine (tidal flat) environment. Insoluble residue analysis, X-ray diffraction and carbon and oxygen isotopic analysis was also carried for the selected samples from Gondwana carbonates. The C and O isotope values strongly indicate primary marine signatures during the formation of these carbonates and the diagenetic features have not altered the original fabric in oolites and stromatolitic laminae.

Fig. 17. The diamictites (glacier deposit) in the Subansiri Valley.

6.4 SUB PROJECT

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

(A. Krishnakanta Singh)

Abor basic volcanic rocks exposed in the core of Siang window of Arunachal Himalaya are classified into basalt and basaltic andesite of dark grayish, greenish or dark reddish colours. They are amygdaloidal as well as hard and massive in nature. The massive types are either phyric or aphyric in nature. Phyric type exhibits subophitic, glomeroporphyritic and variolitic textures whereas aphyric type shows intergranular, intersertal and trachytic textures. They predominantly consist of plagioclase (labradorite-andesine), pyroxene (augite-pigeonite), Fe-Ti oxides (magnetite, ilmenite) and volcanic glasses. These rocks are subalkaline and tholeiitic in composition, enriched in large ion lithophile elements (LILE), light rare earth elements (LREE), depleted in high field strength elements (HFSE) and show fractionated nature [$(La/Yb)_N$ = 3.01-6.99)] with insignificant Eu anomaly. They show similar characteristics of the low-Ti continental tholeiitic basalt including TiO_2 (1.59-2.82), Zr (104-244), Ti/Y (< 500), Zr/Y (3.92-9.03) values. Normalized trace elements patterns show erratic behaviour in LILEs (Rb, Ba, K, Th) as compared with HFSEs (Nb, Zr, P, Ti, Y) and REEs, indicating mobile nature of LILEs. Fractional crystallization of clinopyroxene played a major role in the evolution of magma. Similarity in immobile trace element compositions together with primitive mantle and chondrite-normalized patterns of these basic volcanic rocks indicate their cogenetic nature. On the basis of HFSE discrimination diagrams, it is suggested that these rocks are emplaced in

the 'within plate' tectonic setting. Geochemical and petrogenetic studies reveal that they were probably derived by high degree of partial melting from enriched mantle source at shallow depth.

6.5 SUB PROJECT

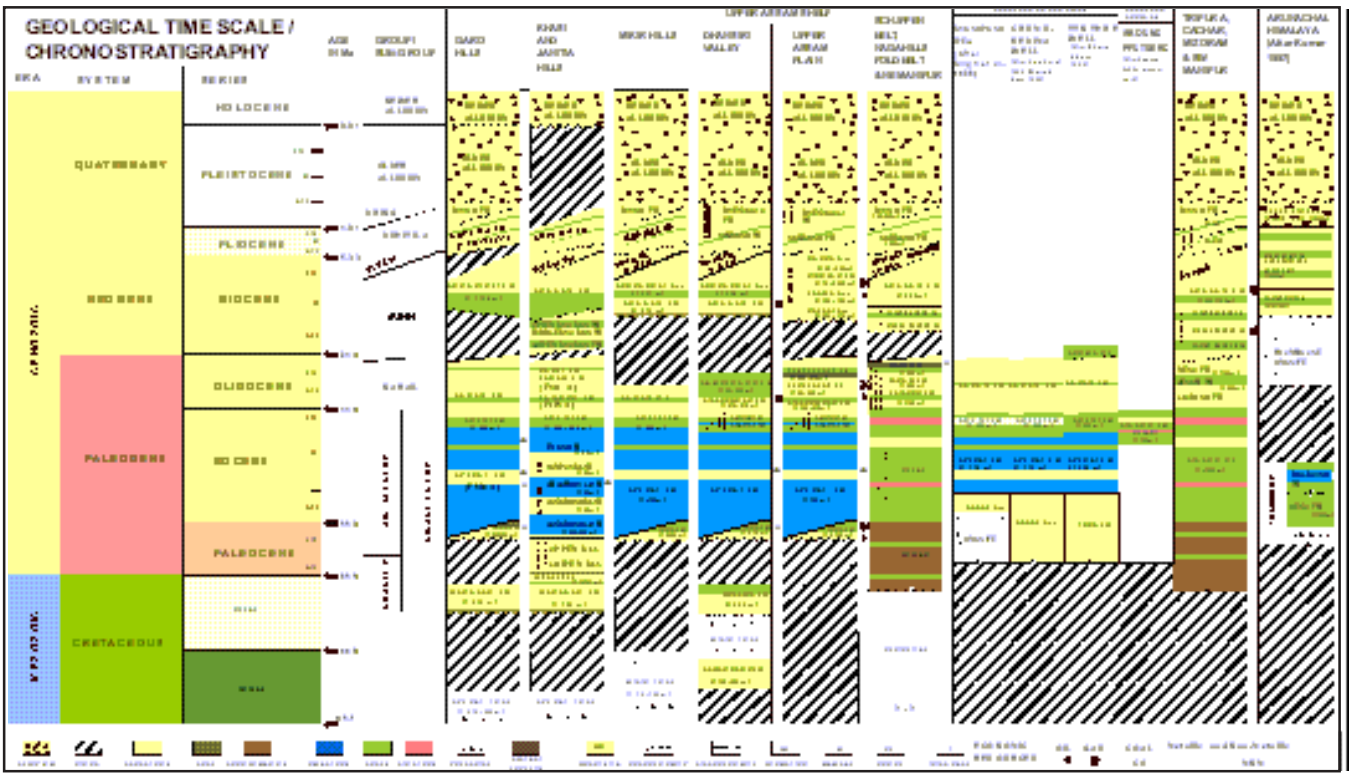
Foraminiferal Biostratigraphy and Paleoecology of the Tertiary sediments of parts of Nagaland, Mizoram and Arunachal Pradesh.

(Kapesa Lokho)

Published data on the stratigraphy of the Disang Group of Nagaland suggests a geosynclinal or deep marine set-up, but direct evidences for foraminifera and other paleontological and sedimentological data are not documented so far. The present study on Uvigerinids, smaller benthic and planktonic foraminifera from the south-central part of Nagaland (around Pfutsero), and the published data from outcrops and deep wells from the western and northern part suggests: 1) Inner shelf facies for Tehai Reu and Lotsu Section in the western part, based on reported occurrence of *Pellatispira*, *Nummulites* and *Discocyclina*. 2) Middle to outershelf set-up by an association of larger benthic and planktic foraminifera and some Uvigerinids (*Uvigerina* cf. *jacksonensis*) from a locality of Heina Reu Section and, 3) Lower part of upper bathyal set-up supported by dominant *Uvigerina* facies consisting of *Uvigerina cocoaensis*, *U. continuosa*, *U. eocaena*, *U. glabrans*, *U. jacksonensis*, *U. longa*, *U. moravia*, *U. cf. steyeri* and *U. vicksburgensis* from the localities of Pfutsero I, II, Chobama and Leshemi. The morphological features of some cosmopolitan species of Uvigerinids and their dominance in central Nagaland suggest an anoxic set-up to some parts connected to Tethyan Sea. Disang black shales are generally considered by some geologists to be a good source rock for Hydrocarbon exploration.

Two stratigraphic tables covering the time span of the Cretaceous and Cenozoic of Northeastern basins of India-including the states of Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Tripura and Mizoram are compiled and presented to provide an overview and framework of the succession, which may be a basis for future research. (Table 3)

Table 3. Stratigraphic units, lithology, thickness and major hiatuses of the Mesozoic and Cenozoic of northeast, India. *Compiled by kapesa lokho, D.S.N.. Raju, P. Ramesh, Gopendra Kumar and R. Venkatachalapathy*



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 Himalayan region, the occurrence of recent earthquakes suggests that the active crustal deformation is going on due to the continued under thrusting of the Indian Plate beneath the Himalaya. This subsurface accumulation of elastic strain is manifest upon the earth as the surface-deformation and development of tectonic landforms, including the faulting in mechanically weak-bedrocks and as well as in the Quaternary sediments.

In the frontal part of the Eastern Himalayan Syntaxial Bend, Arunachal Pradesh, the basic field-data, related to structure and neotectonics, have been generated to understand the nature of active deformation in the hanging walls of the Himalayan Frontal Thrust (HFT) and Main Boundary Thrust (MBT). The study reveals that both the reverse and normal faults are neotectonically active. South of the HFT, broadly the SE-NW trending faults have truncated out the northeastern parts of uplifted river-terraces. In the HFT zone the footwall has been downthrown, and however the counterpart of strath terrace resting on hanging wall is not deformed. The well-stratified Quaternary deposits are tilted 10^0 towards both south and north directions, suggesting that the thrust faults and back thrusts, associated with the HFT system, are active. The hanging wall bed rotation, and development of normal drags are discernible along intra-formational faults, which have shaped the local topography. In the hanging wall rocks of both the HFT and MBT, steep and vertical dipping conjugate set of normal faults, offsetting the earlier sedimentary and tectonic fabrics, has developed. These faults seem to be the latest generation of gravity collapse structures. Thus, the earlier compressional tectonic fabrics are superposed by later-developed extensional tectonic structures, depicting the change of maximum stress-orientation from horizontal to vertical.

The field-investigation on landslides and tectonic landforms, in relation to neotectonics, has been carried out in the East Siang District. The MBT is also a geomorphic demarcation line across which there is an abrupt increase in elevation of the Lesser Himalaya as compared to the Sub-Himalaya. The thrust zone is characterized by the development of steep fault scarps. Various geomorphic features, suggesting neotectonic activity, were studied in the foothills along the Siang river valley. The Siwalik rocks have thrust over the Quaternary deposits along the Mingo Thrust, which has also substantially tilted the alluvial fan deposits. A linear discontinuous chain of NE - SW trending fault scarps has developed in Pasighat - Ledum section. Four to five levels of river terraces are observed in Pasighat - Roing, and - Rengging sections. Other neotectonic evidence include the lateral shifting of Remi river course, abrupt disappearance of Mingo river, an anomalous development of wide - narrow - wide - narrow pattern of Sidha river course before crossing the Mingo Thrust, and a sudden change in flow direction of Sille river from NW - SE trend to NE – SW trend. The recognized soft-sediment deformation features are flame structures, pillar structures, pseudo-nodules, sedimentary dykes, convolute structures, and swirled sand body, developed in the Quaternary deposits.

Between Pasighat and Rengging there are a number of old and active landslides. To distinguish these slides, a wedge-failure analysis has been carried out for different rock types, which form the hill-slopes. The analysis shows that the Siwalik sandstones have three to four wedges, while the Miri quartzites and the Lower Gondwana sandstones have three and four wedges, respectively. The prominent sets of joint planes, dipping 74^{-0} due $N30^{-0}E$, 80^{-0} due $S40^{-0}W$, 80^{-0} due $N50^{-0}W$ and 70^{-0} due $S60^{-0}E$, might be some of the factors responsible for initiating the landslides. Due to slope failure and toe erosion by the Siang River along Pasighat - Along road, a new approach road has been constructed. However, in spite if this realignment, the new road is not free from slope failures.

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)

The Satengal and Banali klippen, occurring in the core of the Mussoorie Syncline were described earlier as pop-up klippen. In order to understand the mechanism of their formation, a series of experiments were performed using modeling clay models. One such experiment is described here.

The external dimension of the model was 15x11x7 cm. Five layers of modeling clay, each approximately 1mm thick, formed the multilayer packet, which was sandwiched between two slabs of modeling clay. The model was deformed in a biaxial press under the general strain boundary condition.

The early deformation resulted in formation of cylindrical asymmetric folds as fault propagation folds in the multilayer. Deformation and folding was concentrated near the thrust. The blind thrust ramp was reflected in the orientation of fold hinge lines in the cover. Noncylindrical buckle folds did not initiate because the stresses were released on the fault surface. The geometry of cross-sections on two sides of the deformed model was different and revealed that the amount of displacement varied along the two frontal ramps. The leading frontal ramp showed a larger displacement compared to the trailing frontal ramp. The model was compressed up to 12% overall shortening during the first phase of deformation and then it was compressed in the horizontal direction normal to the earlier maximum compression direction under the general strain boundary condition.

The superposed deformation resulted in reversal of displacement along the oblique ramp and formation of superposed folds (Fig.18a). In contrast to the early folds, these folds were mostly buckle folds and initiated, both on the hanging wall and the footwall, irrespective of the location of the thrust. Polyharmonic fold geometry and interference effects between the superposed folds and the thrust were observed. After 17% shortening, a horizontal slice was cut from the deformed hanging wall layers to expose the internal structures above the blind thrust (Fig. 18b). Noncylindrical geometry of the antiformal superposed folds revealed closed outcrop patterns marked by partial klippe structures (i.e. older rocks completely or partially encircled by younger rock and parts of the contact is a thrust. The experimental results confirmed that the Satengal and Banali klippen ate pop-up structures.

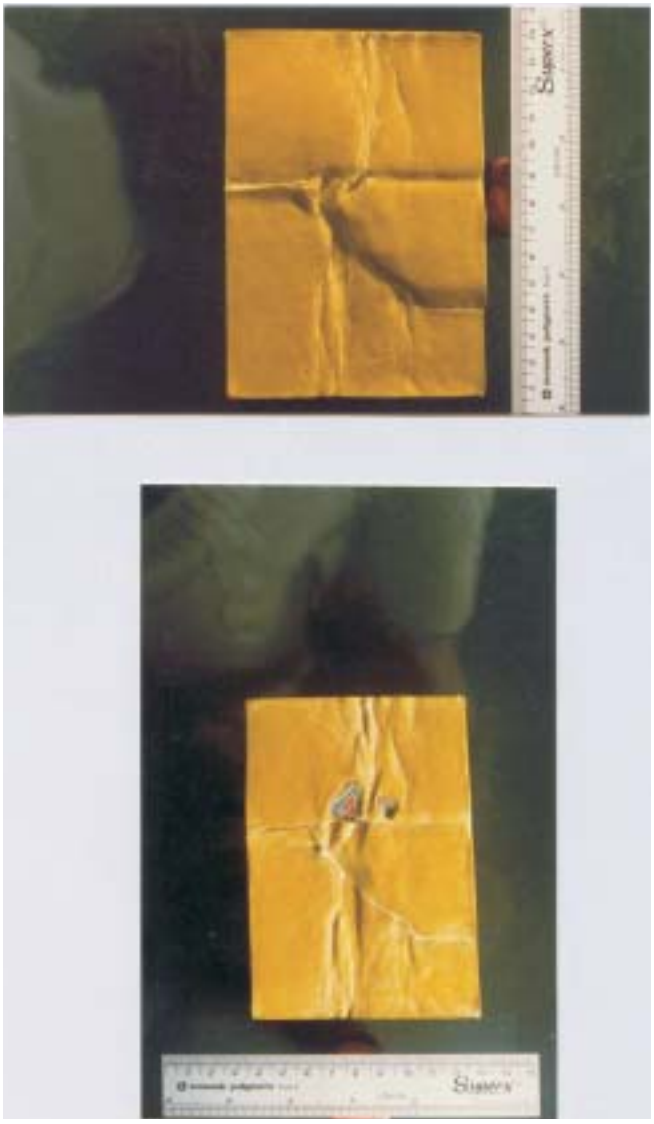


Fig.18 a. Development of early folds (fold hinge lines trending left to right) and superposed folds (trending top to bottom) on a deformed layer surface (after 12% early shortening and 17% superposed shortening). **b**. Removal of a horizontal slice from the upper part of the model revealing a partial klippe and inlier

PROJECT

Petrogenesis and tectonic significance of igneous rocks associated with Permian argillites of southeast Karakoram.

(DST-Deep Continental Studies)

(H.Rai and D.R. Rao)

Main emphasis was given to the study of dyke rocks that are associated with the granitoids and argillites. Nature, frequency and composition of dykes vary from south to north of batholith as well as within lower and upper Permian argillites of Karakoram. Within the batholith dykes are of acidic composition, however, these vary from granitic to olivine dolerites in the Permian argillites.

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 discovery of microdiamond and its *in situ* occurrence in the Himalaya from Tso-Morari Crystalline Complex, Eastern Ladakh, is consequential to deep incursion of the Indian plate beneath the Eurasian plate with coexisting primordial fluid. In the ultra-high pressure eclogite rock, the stable occurrance of microdiamond within zircon and garnet, present as inclusions varies in ~12-18 microns size. The microdiamond of zircon show multigrowth and are star shaped, whereas microdiamond of garnet has crystalline multifaceted (feebly fibrous) morphology. Its identification has proven by using Raman Spectroscopy at very sharp peak of 1332.4 cm –1. The SEM image of microdiamond grains showing fibrous seed structure is possibly govern due to the variable rate of crystallization. The formation of Ultra-high pressure rock i.e. carbonates bearing coesite-eclogite at the peak metamorphism with synchronous presence of primeval supercritical fluid $CO_2 \pm H_2O$ and/or $N_2 + CH_4 \pm H_2O$, has led the system under thermal relaxation. Due to the sudden temperature fluctuation, as the system supported by mantle condition T > 838°C and P, 36-40 kbar, could be the valid explanation for the nucleation of microdiamond, when the leading edge of Indian subducting plate touched the depth >125 km.

PROJECT

Cretaceous-Eocene biotas from northern margin of the Indian Plate and Indus Suture Zone of Ladakh Himalaya and their palaeobiogeograhic significance.

(DST-SERC-Earth Sciences)

(N. S. Mathur, K. P. Juyal and Kishor Kumar)

More rock samples from different sections of the Nummulitic Member (Ilerdian-early Cuisian) of the Indus Formation (Palaeocene-Early Eocene), Indus Suture Zone, Ladakh as well as of the Marpo (Late Maastrichtian-earliest Thanetian), Dibling/Lingshet (Thanetian–middle Ilerdian), and Kong (late Ilerdian-Cuisian) Formations of the Zanskar Tethyan Zone, Ladakh were processed for separation of larger foraminifers. Additional larger foraminifers from these lithounits were studied in oriented and/or rock sections, and were identified up to species level. The larger foraminifers identified from various assemblage biozones have been delineated.

Most of these taxa occur in the Tethyan sediments elsewhere. Correlation of the assemblage zones delineated in the various lithounits with the Shallow Benthic Zones (SBZ) proposed by Serra-Kiel et al. (1998) was carried out.

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 and S.K. Parcha)

Biostratigraphic investigations carried out in the Hundiri Formation exposed at Hora Sostan locality have yielded age diagnostic foraminiferal taxa. A detailed laboratory work revealed the occurrence of several foraminiferal taxa which have been recovered from this succession: *Mesorbitolina* sp. Schroeder, *Orbitolina* aff. *O. tibetica* Sun Dongali and Xu Juntao, *Mesorbitolina texana* (Roemer), cf. *M. parva* Douglass, *Palorbolnoides hedini* Cherchi and Schroeder, and *Praeorbitolina cormyi* Schroeder. In addition to these taxa, these samples have also yielded rudists (bivalves), and algal taxa including *Salpingoporella* sp., and *Cayeuxia* sp, bryozans, corals and echinoid spines which

were also observed in thin sections. This fossil assemblage indicates an Aptian- Albian age to the Hundiri Formation.

The various fossil assemblages have been recognized at the Hore-Sostan locality in the Hundiri Fm. This unit is most interesting because of abundance of *Orbitolina* and other fossil assemblages. The other two sections (Sukar *Nala* and Dosam), though have similar lithology, have yielded bryozoans and algae indicative of similar age. The faunal assemblages (in ascending order) recognized in this unit based on characteristic taxa are Rudist and fragmentary orbitolinid, *Praeorbitolina cormy-Orbitolina* aff. *O. tibetica* , *Mesorbitolina texana and Mesorbitolina* sp.

In the lower Shyok area the marine Hundiri Formation is represented by dark grey, massive to platy limestone in the lower part and grey to green siliceous rocks in the upper part. This formation has yielded a cheilostome bryozoan of late Jurassic age from the lower part south of Khalsar village. The present biostratigraphic investigation in the Hundiri Formation revealed the occurrence of foraminiferal taxa belonging to *Praeorbitolina*, *Palorbitolina Mesorbitolina* and *Orbitolina*. The faunal assemblage is characteristic of Aptian –Albian age. This faunal assemblage is correlated with the fauna recorded from the Khalsi Limestone and Dras Formation in Ladakh, Limestone of lower Cretaceous succession of Dros, Chitral, Yashin Group (Indo- Pak region), Rutog and Ngari in Tibet and *Orbitolina* bearing rocks in Irrawaddy valley, upper Burma (Myanmar). The fossil data suggests existence of transgressive Neo-Tethys sea during Aptian-Albian times in the area. This short lived transgressive phase due to tectonic activity resulted in withdrawal of Tethys from the area.

Comparison of fossiliferous horizons from the lower and upper Shyok areas reveals that both the areas have different fossil assemblages and environments of deposition. These differences in fauna in both areas are considered to have occurred due to tectonic activity which was initiated due to India – Asia collision in the Shyok Suture Zone after Albian (early Cretaceous) times.

PROJECT

Evolution of bioevents in early Paleozoic Tethyan sequence of Zanskar-Spiti and their relation to global event stratigraphy.

(DST-SERC-Earth Sciences)

(S. K. Parcha and B. P. Singh)

The studies have revealed that proven Cambrian rocks outcrop along the Niri-Tsarap Chu and Kurgiakh valley in SE part of the Zanskar basin. The stratigraphic disposition of the Cambrian rocks in Kurgiakh valley was investigated and a large variety of new faunal elements (trilobites and ichnofossils) was collected and superimposed on detailed lithocolumn with their precise GPS positions. Besides the earlier reported faunal horizons in the Zanskar basin new trilobite bearing horizons were also recorded. In addition to this the new faunal bearing horizons was also measured. Furthermore, three phases of compressional deformation were recognized and extension gravity induced normal faulting identified in the basal Cambrian rocks.

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)

Joint field work was carried out under the NSF sponsored project in the Tibet plateau, particularly in the Lower Paleozoic successions. The fauna was collected from different levels along the measured section. The specimens were collected for palaeontological and sedimentological studies from the different sections.

PROJECT

The Palaeobiology and biosedimentology of the Proterozoic-Cambrian sediments in carbonate belt of eastern Kumaun Himalaya, India.

(DST-SERC-Earth Sciences)

(Meera Tiwari)

The Proterozoic carbonate rocks were studied extensively for biostratigraphy, paleoecology and palaeo-environmental aspects, as well as gathering information on biotic evolution throughout the world. In the Lesser Himalayan succession of India, the Krol-Tal sequence, Deoban Formation, Vaishnodevi Limestone and Gangolihat Dolomite have proved to be significant as they have revealed well-preserved prokaryotic, eukaryotic and multicellular life forms. These formations have created immense interest among palaeobiologists for exploring the antiquity of multicellular life in the Proterozoic carbonates.

A diverse microbiota was reported and described from dark black phosphatic stringers within magnesite in the Jhiroli magnesite (Almora). Fossiliferous samples were collected from pit 1 of magnesite at Jhiroli (79º 45´ 07": 29º 45´ 50.03"). In the Jhiroli magnesite section, Gangolihat Dolomite consists of limestone, cherty limestone, stromatolitic dolomite and phyllitic unit. The magnesite horizon is conspicuous within the section. The individual magnesite bodies are elongate and dome – shaped and often stromatolitic. At places , magnesite has completely replaced the stromatolites and the magnesitized stromatolites not only preserve the original stromatolitic structure but also the parts already phosphatized. Within the cherty phosphatic bands microbiotic remains of cyanobacteria and phytoplankton were found well preserved. The microfossils were obtained in thin sections only and are generally black, indicating moderate to high degree of organic maturation. The non-septate filaments having diameters ranging from 2 to 40µm are considered under the genus *Siphonophycus*. The present population contains three species of *Siphonophycus*. *These are S. robustum* (2.5 to 3µm in cross sectional diameter), *S. typicum* (4 to 8µm) and *S. capitaneum* (16-32µm). The genus likely to represent the preserved extracellular sheaths of oscillatorian or nostocalean cyanobacteria. *Siphonophycus* species constitutes the principal filamentous constituent of Proterozoic benthic mat communities. Small septate filaments (1 to 2µm in cross sectional diameter) are considered as *Gunflintia minuta*. These are uniseriate, unbranched, curved and septate filaments with variable spacing of cells. The systematic affinity of *Gunflintia* is unclear. Barghoorn and Tyler (1965) regarded it as filamentous cyanobacteria. Cloud (1965) noted the similarity of *Gunflintia* filaments to *Sphaerotilus* and *Leptothrix*-type iron bacteria. Golubic et al(1995) showed differences between heterotrophic *Sphaerotilus* and chemolithotrophic *Leptothrix* that may prove *Gunflintia* is the ancestor of *Leptothrix* but not of *Sphaerotilus*. Compressed cylindrical aggregate 7 to 25µm wide and up to 100-110µm long, and composed of two distinct row of 10 to 12µm are identified as *Chlorogloeaopsis contexta*. Uniseriate trichome fragments, identified as *Oscillatoriopsis obtusa*, are multicellular, unbranched filaments, 5 to 7µm in diameter. Spheroidal vesicles 15 to 20µm in diameter identified as *Leiosphaeridium* are a common component in the Proterozoic.

Well preserved acanthomorphic acritarchs identified as *Trachihystrichospheara vidalii* are the most important constituent of the assemblage. The type specimen of T. vidalii is reported from upper Riphean Hunnberg Formation and Draken Formation, Svalbard (Knoll et al.1991; Knoll, 1984), Upper Riphean in Russia (Jankauskas, 1989; Vidal et al.,1993),and Vendian Chichkan Formation of Malokaroy Group of Central Asia(Sergeev, 1989). Zhang suggested that the assemblage represented by Trachyhystrichosphaera vidalii- *T. aimica-Cymatiosphaera kullingi* has been used for global correlation in the early Neoproterozoic. It was observed that late Riphean forms are comparatively smaller in size. By comparison with other regions, the present microbiotic assemblage of cyanobacteria, coccoids, and mainly acanthomorphic acritarchs support the concept of Neoproterozoic (Vendian) or younger age for Gangolihat Dolomite.

PROJECT

Influence of Lesser Himalaya Dhauladhar ranges on evolution of the foreland basin in Kangra valley, Punjab re-entrant.

(DST-SERC-Earth Sciences)

(Rohtash Kumar, Sumit K Ghosh and S. J. Sangode)

The main highlights of the work are:

- Two drainage systems are observed; one external (trunk) and the other internal (piedmont).
- Episodic nature of tectonic pulsation resulted in the creation of accommodation space in which sedimentation by internal drainage on alluvial slope took place and external drainage shifted to and fro along the basin margin.
- Overlapping of alluvial slope deposits by alluvial fan deposit at 8.25 Ma due to enhanced tectonic activity along the Main Boundary Thrust with the appearance of recycled clasts of the granitoids.
- Grey sandstones are sublithic arenitic to lithic greywacke ($Q_{53\pm3.2}F_{23\pm6.0}R_{24\pm5}Mx_{13\pm6.1}$); buff sandstones are more quartzose ($Q_{80\pm6.3}F_{8\pm3}R_{12\pm3.5}Mx_{8\pm5}$) and classified as lithic arenite.
- Collective (sedimentology, petrography and geochemistry) data analysis suggests that the influence of Dhauladhar Range on the drainage basins started before 12.77Ma.

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 and N.S. Mathur)

Field and laboratory studies were carried on the sediments of the Kakara-Subathu Formations in Dogadda area of Uttaranchal to understand lithological and mineralogical changes across late Paleocene–Eocene transition. The Kakara Formation comprises fossiliferous limestone, shale and oolitic limestone. It is overlain by the Subathu Formation, which comprises of black shale with patches of coal, and shale (grey, green and red) with thin lenses of limestone and sandstones along with oolitic iron stone.

Petrographic studies indicate the occurrence of berthierine/chamosite ooids in a matrix of pyrite globule within the fine grained carbonaceous ferruginous shale (Fig. 19). The pyrite globules are 1-2 cm in diameter Berthierine/chamosite ooids are spherical with almost uniform size (1-2 mm diameter) and have concentric layer structure (Fig. 20). They have quartz (with tapered width) as the outer cortex. Most ooids exhibit exceptional petrographic preservation consistent with minimum diagenetic alteration. The mineralogy and textural characteristics of the ooids indicate that they were deposited under shallow, moderate water turbulence, oxygenated conditions and experienced slow net sediment accumulation rates.

Fig.19. Photograph of a polished slice showing occurrence of Berthierine/ chamosite ooids (1-2 mm in dia) in pyrite matrix (1-2 cm dia) within carbonaceous shale at Dogadda.

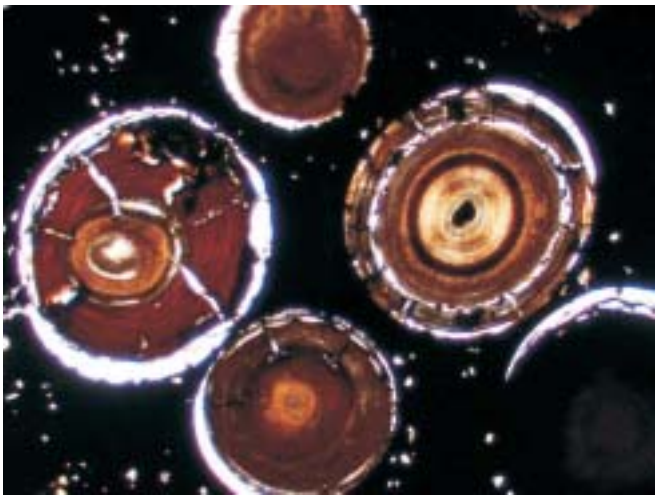


Fig.20. Photomicrograph of a thin section showing tree ring texture within berthierine/ chamosite ooids (transmitted light, crossed nicols).

Palaeomagnetic study on the Kakara-Subathu formations of Dogadda area reveals that, at the time of deposition of the Kakara sediments and base of the Subathu sediments, the corresponding place in the Indian plate was 36º and 12º south of equator respectively. These palaeolatitude are consistent with the biostratigraphic ages. However, the significant difference in the calculated palaeolatitudes for Kakara and basal part of the Subathu indicates probable existence of stratigraphic gap between the two units.

PROJECT

Rock magnetic and geochemical characterization of Plio-Pleistocene Siwalik Paleosols from the Indo-Gangetic Foreland Basin, NW Himalaya.

(DST-SERC-Earth Sciences)

(S. J. Sangode, N. Siva Siddaiah and Rohtash Kumar)

Macromorphological documentation based on field examination of more than 50 paleosol profiles starting from Mohand to Patiali Rao (spread in an area of 500 Km^2) from 9 to 0.5 Ma was carried out. Sampling and analysis of the representative profiles were continued with the first years work. Magnetic polarity stratigraphy for Ghaggar and Moginand sections has been established (Kumaravel, et al., 2005a). A total of 83 oriented sites from the 1030 m thick Ghaggar section gave ages of ~2.7 to ~<0.5 Ma and 23 sites from 310 m thick Moginand section deduce age estimates of ~2 to ~0.86 Ma. The average sediment

accumulation rate for the Ghaggar section is ~45 cm/Ka and for the Moginand section is ~26 cm/Ka. In the Ghaggar section, the rate of sedimentation is relatively less (47 cm/Ka) for the Pinjor Formation up to ~350 m and increases rapidly to 62 cm/Ka in the interval of 350 – 475 m startigraphic level during the Olduvai normal event (1.95 – 1.77 Ma) corresponding to the conglomerate comprising of Tertiary clasts appear to be the result of the reactivation of the Nahan Thrust at 1.77 Ma.

Detailed rock magnetic and geochemical studies were carried out for Mio-Pliocene Mohand Rao paleosols (Kumaravel, et al., 2005b). CIA values (75-80 % for paleosols) and the observed weathering trends from A-CN-K diagram signify the moderate degree of pedogenesis (Kumaravel et al., *communicated*). In addition, CIA shows positive correlation with Al_2O_3 (R^2 = 0.5) and TiO_2 (R^2 = 0.7) and higher negative correlation with base loss (R^2 = -0.9). Paleosol samples show very little increase in K_2O and CIA-K_2O shows significant positive correlation with CIA (R^2 = 0.97) indicating that the effect of diagenesis/K-metasomatism/groundwater processes subsequent to their burial is possibly insignificant. We attempt to distinguish multiple soil forming events (composite paleosol), Plan of soil interface / soil welding point from the abrupt change in the pedo-chemical parameters.

PROJECT

High resolution studies on the Holocene climate change and monsoon variability in the Kumaun-Garhwal Himalaya.

(DST-SERC-Earth Sciences)

(N.R.Phadtare)

Palynological studies supported by other data on about one meter thick well-dated *Dayara Peat* peat sequence in *Bhagirathi valley, NW Garhwal Himalaya* (continuously sampled at one-centimeter interval) has revealed past 6000 years' sub-century-scale (ca 40 years) vegetation and climate history of the area (Fig. 21). Multiple proxy (pollen, total organic matter, and magsus) paleoclimate data revealed four wet phases (6100 – 5900, 5300 – 2400, and 920 – 210 cal yr BP) separated by three relatively dry episodes (5900 – 5300, 2400 – 920, and 210 – present). Detailed interpretation and regional correlation, however, is still in progress.

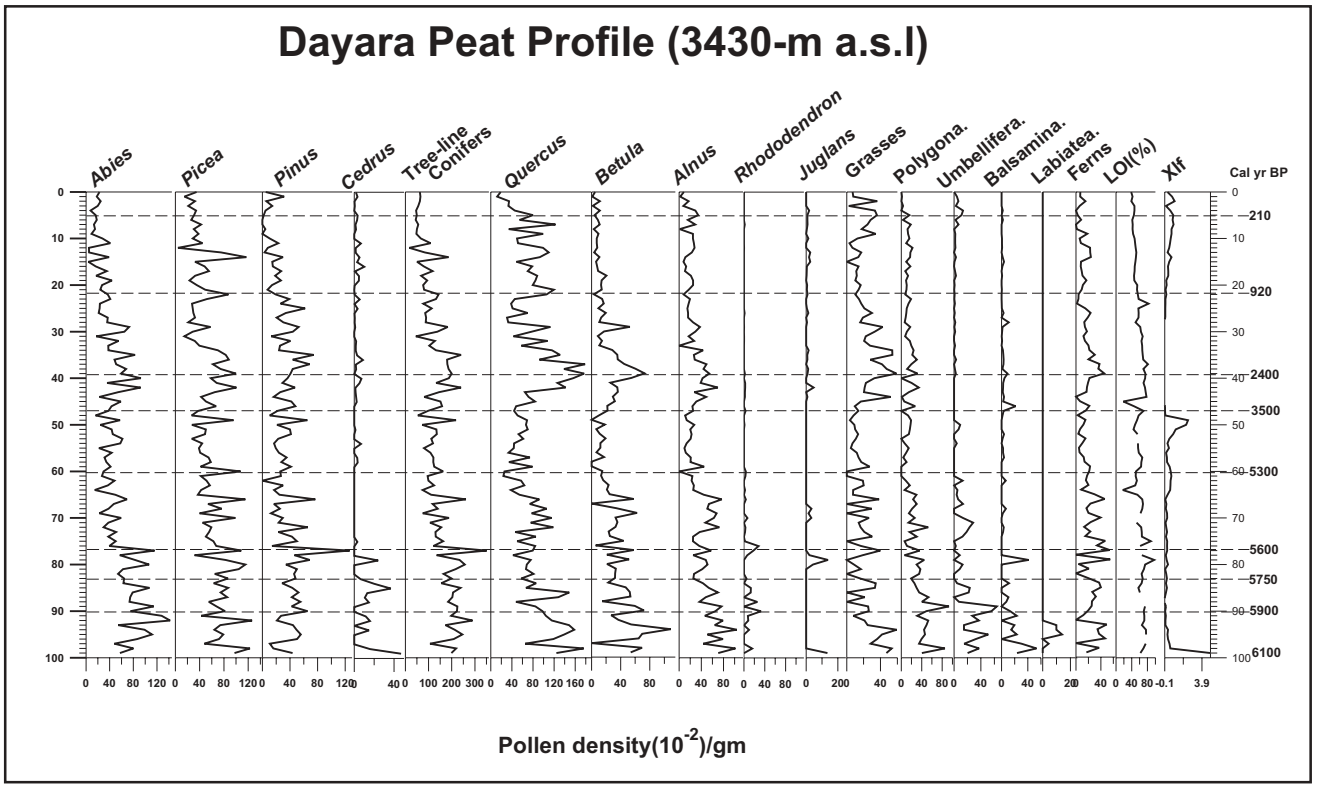


Fig. 21. Pollen diagram of the Dayara peat profile.

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)

Work carried out in the Yamuna, Tons, Giri, Bata, Markanda and Sirsa river val1eys has revealed traces of active faults and tectonic landforms indicating drainage changes, Quaternary tectonics, and block uplift. Beside, blocking of river channels by slope failure, creation of lakes and development of lacustrine deposits have also been observed in the above area. Eight to ten interesting locations were identified and studied, where drainage channels have been diverted and captured by other streams and wind gaps have been created in the process. Detailed tectonic and geomorphologic maps of each site are being prepared on 1:25,000 scales.

The piedmont zone adjacent to the Himalayan frontal belt is geomorphologically very important, where a number of major alluvial fans have been mapped using Survey of India toposheets on 1:50,000 and 1:25,000 scale and satellite images on 1:25,000 and 1:250,000 scales. These fans show uplift in their median segments due to influence of subsurface faults and lineaments. These faults have been encountered in seismic profiles published by the ONGC.

Another interesting feature in the piedmont fans is the behaviour of the axial streams, which have been shifting laterally, and often in the apex region no drainage channel is observed at present. This is in contrast to the alluvial fans observed in the Duns, where the axial streams are deeply entrenched and often have cut chasms in the proximal region. In the area between Tons-Yamuna junction at Dakpathar and Giri-Yamuna junction at Paonta Sahib, a series of active faults have been mapped. The active faults between Tons and Giri earlier described as Trans-Yamuna Active Fault System (TYAFS) extends for nearly 30 kms from Pre Tertiaries into the Siwaliks and cuts across the MBT and the MBF (Bilaspur Thrusts). The segment between Sirmuri Tal and Bharli is south side up while the eastern extension in the Tons valley well displayed at Kalawar is north side up. A series of faults/lineaments have also been observed in the Krol Belt north of TYAFS and may represent old now inactive faults. Their linear nature and control on drainage channels is well displayed on satellite images.

Bata and Markanda are important rivers in the Kiarda Dun flowing due east and west respectively separated by a geomorphic high at Uttamwala-KatasanDevi. This high is formed by a fan deposited by Bata (Jalmuse Ka Khala), which blocked the old channel of Vedic Saraswati and created a drainage divide. Thus, Markanda, which occupies the channel of a major river and flows due west and receives water only from Nahan-Jamtah-Baila ridge constituting watershed between Jalal and Markanda. A fault trending along Bata and extending below Katasan-Uttarmwala uplift into upper Markanda shows north side uplifted since terraces at Kolar abut against Lower Siwaliks. Lower Siwaliks exposed at Phandi (opposite Kolar) are overlain by fan material. The uplift seems to be of the order of 20m and the fault may be post 5ka since upto that time Yamuna used to flow westward through the present Bata-Markanda channel to emerge into the plains at Adh Badri as Vedic Sarswati.

A Digital Terrain Model (DTM) of the Markanda and Bata rivers has also been prepared using IRS-1C/1D LISS-III and PAN data. A morphotectonic approach including drainage basin asymmetry analysis has been employed in the uppermost reaches of Markanda and Bata rivers to identify block tilting in the region. Drainage asymmetry analysis of the Markanda and Bata rivers reveals that the northern segments of the catchments are tilted towards south with respect to the trunk streams as the tributaries joining from north are much longer than those joining from the south. The uplift of northern block in Bata-Markanda valleys is also substantiated by the distribution of terraces.

The HFT was studied between Badshahi Bagh (Yamuna's exit point) and Chandigarh for its folding along N-S axis and strike slip behaviour and influence on streams emerging from the Siwaliks into the plains. Both right lateral/left lateral movement along the HFT have been deciphered and the stream channels have been deflected. Further analysis is in progress.

PROJECT

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.

(WIHG-ICIMOD Project)

(M.P. Sah and G.Philip)

A digital database of glaciers and glacial lakes of Uttaranchal State has been prepared based on Landsat

7ETM+ satellite images of October and November 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 altogether 1439 glaciers inventoried within the Uttaranchal State cover an area of 4060.04 sq. km with an ice reserve of 475.43 $km^{3.}$ Apart from the glaciers 127 glacial lakes with a total area of 2.49 sq. km have also been identified. Though there are no major GLOF events documented in the historical past, few supraglacial lakes are being developed in the glacier tongue. Since the Himalayan glaciers are retreating at an alarming rate, these lakes are likely to grow in their size and may pose potential GLOF in future. It is therefore recommended to monitor such supraglacial lakes developed within the debris glacier tongue. The draft version of the inventory is in the process of finalization and the digital database is expected to be made available to the users by July 2005.

PROJECT

Earthquake geology aspects and seismic hazard assessment in Garhwal Himalaya.

(CSIR Emeritus Scientist Scheme)

(V.C. Thakur and G.K. Ghosh)

Late Quaternary tectonics of Dehra Dun in Garhwal Sub Himalaya has been elaborated explaining kinematics and age constraints to different structures in their evolution. In northern part the Siwalik strata are folded into Santaurgarh anticline with both limbs dipping NE at steep to moderate angles. The anticlinal fold was developed as a fault-propagated fold over the Santaurgarh Thrust, its uplifted hanging wall constituting the dissected Siwalik and footwall forming the pedimented Siwalik. In the frontal Siwalik range, south of Dun valley, Mohand anticline was formed as a fault-bend fold over the Himalayan Frontal Thrust. Between the two anticlines of Santaurgarh and Mohand, synclinal valley of Dun is covered by alluvial fan sediments of Dun gravels. Extrapolation of earlier published OSL age data and our own observations suggest initiation of HFT between 500 Ka and 100 Ka (most probably ~ 100-200 Ka). The Santaurgarh thrust was initiated in post- 500 Ka and continued to propagate till ~ 40 Ka. The Bhauwala Thrust was developed between 29 Ka and 20 Ka and Asan Fault post-dated 10 Ka. An active-tectonic zone is recognized between the MBT and HFT including piedmont zone, showing active faulting and uplift during Holocene. Evidence of large to great historical earthquakes are observed in trenches excavated for paleoseismological study along the HFT.

PROJECT

Probabilistic seismic hazard assessment of Himalayan arc and its adjoining region between latitude 74-82 degree East and 26-35 degree North.

(DST-Seismicity Programme)

(A.K. Mahajan)

The seismic hazard analysis depends upon the seismicity and tectonic pattern of the area. The seismotectonic information makes the basis for delineation of seismic source zones for the seismic hazard computation. On the basis of seismicity pattern emerging from the plot of epicenters in the region in conjuncture with the tectonic information and knowledge of fault plane solutions, the study area has been divided into nineteen source zones from northwest of Jammu region to northeast of Pithoragarh covering up to 86º east. The minimum magnitude was assigned as 3.5 for all the seismic source zones and the maximum magnitude were estimated from the past seismicity for each source zone separately. The seismic parameters 'a' and 'b' were estimated by applying the maximum likelihood method which go as input to the hazard computation. To facilitate the steps for source zone characterization, a software developed by Dojcinvoski and Mihailov (2001) has been used to perform the essential data handling like, 1) merging different catalogue and sorting in chronological order, 2) Scanning of event from catalogue for each source zones 3) plotting of epicenters by superimposing the same zones and tectonic features and 4) estimation of a and b value. The data has been put as an input to the hazard analysis programme Haz.81 using the data of 500 years since 1552- 2003 and calculated the peak ground acceleration values for different regions of Northwest Himalaya Accordingly to the first results the PGA varies from .017 g to .33g for the 50 % probability in 10 years. The maps are under preparation.

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 Him-SCOPE Himalayan School Observatory programme in earthquakes is one of the important components of the Mission Mode Project, which is directed towards developing the measurement skills amoung school children and passing the knowledge through them to the community at large. The programme has multifold objectives with direct emphasis on earthquake recording, analysis and management of seismic stations at selected schools in earthquake prone areas. HIMSCOPE is an initiative tom build a network of earthquake recoding stations in schools across the Himalayan states to enrich the secondary school education. The goal of HIMSCOPE is to create fruitful links between research institutions, colleges and secondary schools. It seeks to engage students in the acquisition of seismological data, to help teachers bring the applicability of science into classrooms, and to motivate scientists to spread knowledge and activities beyond the boundaries of their departments. Low cost earthquake recording equipment called seismometers, will be installed and maintained in each selected school. The recording of earth's vibrations will be made round the clock at all selected sites. It is also proposed to add GPS system at these labs for capturing earthquake related data.

Under this programme, 25 schools have been selected from Uttaranchal region and 25 schools from Himachal region. The names of the schools teachers have been identified who will be responsible for the project. Under this project a brochure has been released which gives the basic objectives of the project towards awareness of earthquakes among school children. Two prototype pits have been constructed at GIC, Gujrara, Dehradun and GIC Mussorrie for the installation of seismographs. The training of schools teachers will be organized after the installation of seismometers.

PROJECT

Establishment of eight permanent GPS stations by WIHG for studying manifestation of India-Asia convergence process in the Himalaya from GPS geodesy under the national program of GPS.

(DST-National GPS Program)

(P. Banerjee)

Under this project, three new permanent GPS stations were established at Munsiari, Pithoragarh and Bhatwari. With these three new stations, total number of Permanent stations installed and being maintained under this project becomes nine. Others are located at Dhanbad, Delhi, Dehradun, Naddi, Kothi and Panamik. 30 new campaign mode GPS stations were established covering entire Delhi state and surrounding region.

Campaign mode GPS measurements were carried out in Himachal Pradesh and Ladakh region. Repeat measurements were carried out over 19 existing stations. Four new GPS stations were established at very remote and difficult locations of Pangong Tso, More Plain, Sorchu and Kaza. Five days of data were collected from all the stations.

Campaign mode measurements in Ladakh region and establishment of Permanent GPS stations in Panamik has helped us to model the westward splay of Himalayan mass, where Karakorum fault is working as its northern limit. To better constrain it, new campaign mode stations have been installed at More Plain and Sarchu (between Keylang and Leh) and also at Pangong Tso, Shakti and Tangtse (near Pangong Tso lake).

These new sites fill up the gap area where no earlier GPS station existed, in Keylang-Leh sector. We also established a new station at Kaza, a very remote and tough terrain in Spiti. This will help us to constrain lateral segmentation of Lesser Himalayan tectonics. Repeat measurements of Himachal stations were carried out to better constrain already established campaign mode stations. It shows a zone of maximum strain accumulation in the Lesser Himalaya.

Static offsets from far-field sites of the 26th Dec 2004 great Sumatra earthquake was computed from the GPS data. Nearly 4500km range around the epicenter was found to have experienced deformation because of the earthquake. Deformation modelling of the offsets was

carried out and kinematics of the earthquake rupture zone was modeled. The work was carried out in collaboration with Dr. F F Pollitz of the USGS, and Prof. R Burgmann of the University of California, Berkeley.

PROJECT

Gravity and GPS aided geoid studies in Ladakh, NW Himalaya.

(DST-National GPS Program)

(P. Banerjee)

The project was completed on 6 August, 2004. Gravity, leveling and GPS measurements were earlier carried out along 90km long (Upshi)-Karu-ChangLa-TangTse-Pangong Tso transect in Ladakh. Bouguer gravity anomaly and geoid undulation along the transect was derived. The transect cuts across the Ladakh batholith and Karakorum fault. Earlier, we had found a steep gravity gradient and geoid undulation across the Rumtse-Leh-Panamik sector.

Relative geoid undulation was derived from the GPS measured ellipsoidal height and leveling measured orthometric heights. Because of large error introduced in the leveling measurements, geoid undulation is found to be varying with amplitude of nearly 1m. However, the value of the geoid separation agrees well with the measurements earlier made along Rumtse-Leh-Panamik section. Both in Leh and Karu, geoid undulation value is of the order of -22m. We did not find the expected sharp fall in geoid on southern fringe of Changla as was on Khardungla.

Bouguer gravity anomaly along the transect was found to be varying between 475mgal to -550 mgal. Similar to Leh-Panamik section, we found a strong negative gravity gradient on northern slope of Changla granite. The Bouguer anomaly becomes almost flat further north.

PROJECT

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

(DST-Seismicity Programme)

(V. C. Tewari and Ambika Sharma)

Palaeobiological and biosedimentological studies of the Buxa Dolomite were carried out in the Siang and Subansiri districts of the Arunachal Lesser Himalaya. Detailed litho columns of the Buxa Dolomite showing facies variations, sedimentary structures, stromatolites, chert bands etc. have been prepared from Panging, and Igo-Daring road sections in the Siang area and the Menga-Taliha road section in the Subansiri valley.

The Buxa Dolomite is an important Terminal Neoproterozoic carbonate buildup, well developed in Arunachal Lesser Himalaya, NE India. The thick succession of Buxa Dolomite (Menga Limestone) is exposed in a tectonic window in Subansiri river section which falls in the Upper Subansiri district of Arunachal Pradesh. It is also developed as lenses and thick bands in the West Siang district between Igo and Panging. It is known as Panging Limestone/ Dali Limestone/Chisi/Igo Dolomite etc. in the Siang area.The Buxa Dolomite is characterized by cherty dolomite, intraclastic-oolitic dolomite, Vendian stratified and domal stromatolitic buildups and fenestral dolomite represent shallow subtidal to intertidal depositional environment of the Buxa Dolomite. Buxa Dolomite overlies a diamictite horizon which indicates Neoproterozoic glacial deposit corresponding to the global Cryogenian Period. The megascopic Terminal Proterozoic life forms recorded from the Buxa Dolomite are cyanobacteria generated stratified and domal stromatolites. The microscopic life forms include microstromatolites, cyanobacteria, acritarchs, vase shaped microfossils and micro meatazoans (sponge spicules and sponges). These microbial assemblages are benthic as well as planktonic and confirm the shallow marine depositional environment of the Buxa Dolomite. The present fossil record of the Terminal Neoproterozoic age from the Buxa Dolomite of the Arunachal Lesser Himalaya (Subansiri and Siang districts) is quite significant for palaeobiological evolution from prokaryotic to eukaryotic life.

PROJECT

Mass balance, glacial hydrology and sediment transfer studies of Dokriani glacier.

(DST-Glaciology Programme)

(J.T.Gergan)

The results of hydrological studies of Dokriani glacier show that the discharge at the glacier snout during the ablation period (May-October) reduced remarkably from 62x $10^6 m^3$ in 2003 to, 42 x $10^6 m^3$ in 2004. These variations are found to be effected by the variations in the winter snow accumulation. Studies revealed that this reduction is mainly attributed to the reduction in base flow of Tela catchment, mainly because of reduced winter precipitation in these

years. Highest yearly variations in discharge at Gujjar Hut station was also recorded during this period. Discharge at these stations reduced from 94x $10^6 m^3$ in 2003 to 56x $10^6 m^3$ in 2004. Discharge at Tela station reduced by 58% from 1998 to 2004. It is evident from this study that the variations in the discharge from the glacier catchment and catchment close to the glacier, where annual contributions from the glacier is half of the total discharge is the least affected by the input conditions. Result of this study is vital for developing runoff model for Himalayan glaciers.

Snowfall in the Din Gad catchment during 2002-03 and 2003-04 winter months was 295 and 190 mm respectively. Snowfall pattern in 2004 is similar to 1999 winter snowfall, in the Din Gad catchment. This resulted into lower snow cover duration in the mountain catchment and influenced the stream discharge hydrology. Rainfall during the study period ranged between 1054 mm in 2001 and 1382 in 2003 at Base camp and 1158 and 1582mm at Gujjar Hut and 1057 and 1235mm at Tela station respectively.

Sediment flux at all the three stations was highest since 1994 and 1999. Sediment flex from glacier was 7.7x 10^4 Tones and at Gujjar Hut 8.9x 10^4 Tonnes and Tela station recorded 7.8x10^4 Tones in 2001. In 2001 variability in sediment flux between the stations was minimum and suggests that very high percentage of sediments in the headwater streams are contributed by the glacier. The mean temperature variation data observed at Base camp, Gujjar hut and Tela during the last few years show distnict variation in lapse rate as compared to the valley scale lapse rate (Fig.22).

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)

The study revealed that landslides are occurring all along the roads in the Itanagar capital complex. Nearly 46 landslides have been identified, particularly on (i) Itanagar-

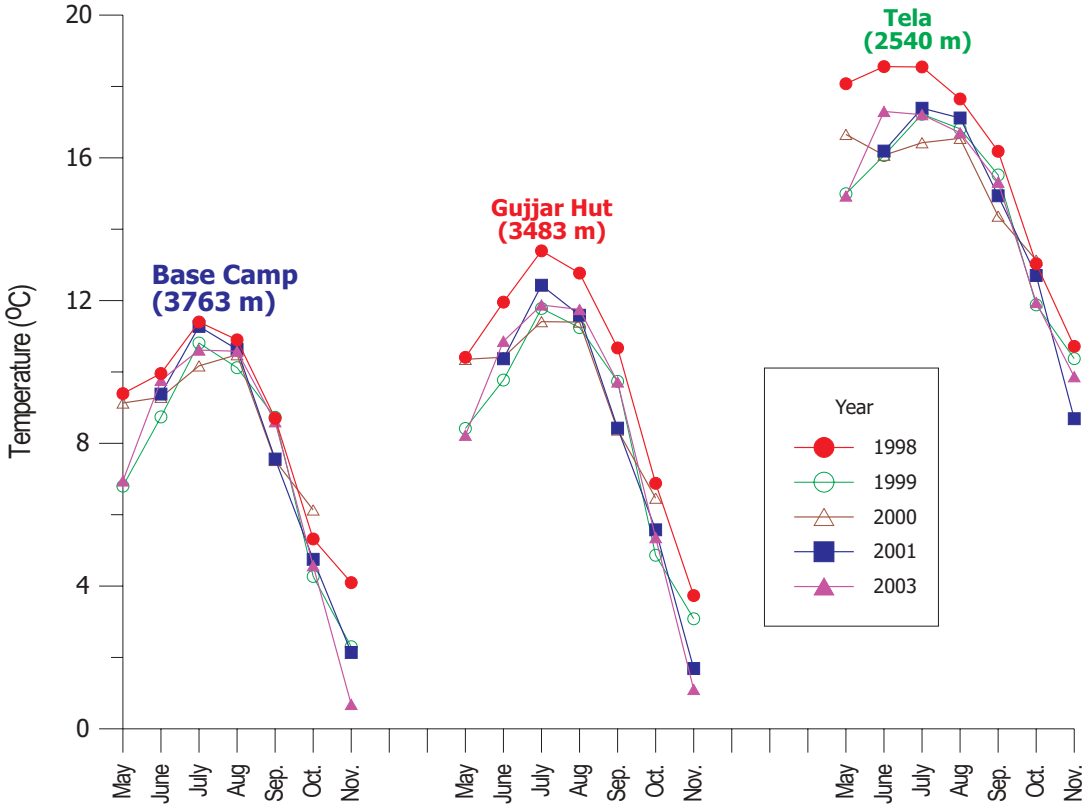


Fig.22. Mean monthly temperature variations at Base camp, Gujjar Hut and Tela stations during the last few years.

Naharlagun-Banderdewa road (18), (ii) Itanagar-Julie-Papu road (9), (iii) Papu-Yupia-Doimukh road (7) and (iv) Itanagar-Gohpur road, also covering Ganga Lake-Jotte road (12). Other than these, landslides of small magnitude have also been noticed on approach roads to villages/ settlements. Detailed landslide inventory has been prepared. It is observed that a number of old and presently active slides are located within the unconsolidated Quaternary deposits and poorly cemented Siwalik sediments. The Itanagar capital complex is situated entirely on the Siwalik sediments and unconsolidated Quaternary deposits. The area is highly fragile and geodynamically active with a number of thrusts and active faults. Various evidences of neotectonic activity in the area have been observed and documented. The soils of the area fall under the Class VII category with a few falling under Class III, VI and VIII of the soil capability classification, which indicate risk of high erosion. Water is playing a major role in the landslide occurrences and this process is also aided by the presence fragile rocks criss-cross joint planes. Human interference is also contributing to the landslides in the area.

Risk due to landslide occurrences in the Itanagar capital complex was assessed in terms of damage potential to loss of life, land and property. The risk assessment indicates that most of the Itanagar urban conglomeration falls under the low to moderate risk category. A few isolated areas of this conglomeration, however, fall under high to very high risk category, which is mainly due to disturbance of natural stable slope, alteration in the natural course of drains/streams and gully erosion. The Banderdewa-Itanagar road mostly falls on low to moderate risk slopes, whereas the Itanagar-Gohpur road falls in high to very high risk category, particularly between Chimpu and Holangi.

Detailed topographic survey and geotechnical investigations were carried out on three landslide sites to find out the causative factors and suggest for suitable mitigation measures. This included preparation of detailed contour map on 1:1000 scale with 1 m of contour interval, geological map and soil testing, both in the field and laboratory, to assess the nature of soil and sub soil strata, and to evaluate various parameters like, shear strength, safety factor of the slope and assessment of slope instability, responsible for the cause of landslide. It was observed that out of the three landslides, one of the landslide sites has a critical situation and the other two are superficial in nature. Besides the above-mentioned factors road widening activity contributes to the occurrence of these landslides.

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TECHNICAL REPORT

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Philip, G. 2004. Satellite Data Analysis for Change Detection Around Vishnuprayag Hydroelectric Project in Chamoli District, Uttaranchal submitted to M/s Jaiprakash Power Ventures Limited, New Delhi.

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Sah, M.P., Philip, G., Mool, & Bajracharya, S.R. 2005. 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. Draft Report submitted to APN.

SEMINAR/SYMPOSIA/WORKSHOPS ORGANISED

(a) Workshop on Indian Geotransects (WinGeo-2004)

A workshop on Indian Geotransects (WInGeo-2004) was organized by the institute from November 25-26, 2004 under the aegis of Deep Continental Studies Programme, Department of Science & Technology. Two days vigorous scientific discussions were conducted on (i) Overview and future of Indian Geo-Transects programme, (ii) Himalayan Transects, (iii) Northwest and East India Transects, (iv) Central and Southern Transects and (v) on the New perspective and future directions. A total number of forty one research papers were presented by the participants. The workshop was attended by about 65 participants from various research institutes and universities, this included most dynamic and experienced Indian earth scientists. The interaction reviewed the status of the research particularly on the deep continental evolution of the Indian lithosphere in different Geo Transects and the future directions for the research under DCS programme. The participants also recognized the dedicated services of Dr. K.R. Gupta as Head of the DCS programme of DST. A special volume of Himalayan Geology, vol. 26(1) was released in honour of Dr. K.R.Gupta.

A Special volume of Himalayan Geology and Abstract Volume (WINGEO-2004) being released during WINGEO workshop.

b) Workshop on Disaster Management

The Wadia Institute of Himalayan Geology coordinated a workshop on **Disaster Management** at WIHG Dehra Dun from 6-12 December, 2004 which jointly organized by the Department of Science & Technology, Govt. of India, New Delhi and Asian Disaster Preparedness Center (ADPC) Thailand. Sh. N.D. Tiwari, Hon'ble Chief Minister of Uttranchal inaugurated the workshop. The workshop was aimed at improving disaster management for earthquakes and landslides by enhancing linkages between science and technology sectors and disaster management organizations. The broad themes of the workshop were: 1) Disaster Management Principals and Practices 2) India's Disaster Management Arrangements (Natioanl/State), 3) Technological Advances and its Applications. The workshop was well attended by Eminent Scientists like Prof. V.K. Gaur, Distinguished Scientist, IIA Banglore, Dr G.D. Gupta, Advisor, Seismology Division, DST, Dr Merrick Chatfield, Director and Team Leader Strategic Disaster Management Center, Dr Earl Kesseler, Deputy Director, Disaster Management, ADPC, Bangkok, Prof. B.R. Arora and several other experts from the Geological Survey of India, Indian Institute of Remote Sensing (IIRS), Dehradun, SEEDS, NGO, Good Governance of India Foundation(GGIF), New Delhi, Disaster Management Center, New Delhi, Wadia Institute of Himalayan Geology, Uttaranchal Disaster Management Centre, Delhi University, DAV College Dehra Dun, UNDP, Town and Country Planning, Dehra Dun, Christ College, Irinjalakuda, Kerela, G.B. Pant Institute, Almora, IIT Roorkee etc. In the workshop, 15 renowned experts from different fields of disaster management were also invited to deliver lectures on the issues of disaster management arrangements.

Shri N.D. Tiwari Hon'ble Chief Minister of Uttaranchal inagurating the workshop on Disaster Management.

c) Workshop on Great Tsunami of 26th December, 2004

The Wadia Institute of Himalayan Geology coordinated "*Brain Storming Session on the Great Tsunami of 26 December, 2004 in South Asia*". The workshop was Organized by the Department of Science & Technology in association with Department of Ocean Development and Indian National Science Academy, the Workshop was held at the Indian National Science Academy, New Delhi from 21-22 January, 2005. The meeting was attended by Hon'ble Minister of Science & Technology, Govt. of India, Secretary, DST, DOD, Dr. R.A. Mashelkar, D.G. CSIR, Prof. C.N.R. Rao and several other dignitaries (about 150 delegates) from India and abroad.

Shri Kapil Sibbal Hon'ble Minister of Science & Technology, Prof. V.S. Ramamurthy, Secretary DST, Dr. R.A. Mashelkar, D.G. CSIR and Prof. C.N.R. Rao inagurating the workshop on Great Tsunami.

VISITS ABROAD

- Dr. V.C. Tewari participated in 4th Nepal Geological Congress held at Kathmandu April 9-11, 2004.
- Dr. H.K. Sachan visited Department of Earth Sciences, Waseda University, Tokyo, Japan and Department of Earth and Planetary Sciences,Tokyo Institute of Technology,Tokyo in connection with collaborative research work from 4 April-5 May 2004.
- Dr. A.K. Mahajan visited International Institute for Geo-information and Earth Observations (ITC), Eushede, The Netherland as visisting scientist during April-June, 2004.
- Dr. A.K.Mundepi visited ITC Netherlands from 7 May 2004 to 16 June 2004.
- Dr. A.K. Dubey, Dr. N.R. Phadtare and Dr. T.N. Jowhar participated and presented papers in the 19th Himalaya-Karakoram-Tibet Workshop held at Hokkaido University, Japan on July 10-12, 2004.
- Dr. V.C. Tewari and Dr. P.K. Mukherjee participated and presented papers in the 32nd International Geological Congress (IGC) held in Florence, Italy on August 20-28, 2004.
- Dr. V.M. Choubey and Dr. S.K. Bartarya visited Luxembourg University (Nuclear Radiation laboratory) for 45 days under collaborative research program with Prof. A. Kies to understand the behavior of radon in groundwater flow system of different hydrogeological regimes and also to study the environment through Natural Radioactivity and Monitoring of Radiological Pollutions during April-June 2004.
- Dr. V.M. Choubey and Dr S.K.Bartarya visited Department of Geology, The Delft University of Technology and UNESCO-IHE, The Delft, The Netherland on June 3, 2004.
- Dr. V.M. Choubey participated in International Conference on "Radiation in Education, Nagasaki, Japan on August 22-26, 2004.
- Dr. N.Siva Siddaiah participated in International Conference on "Behavior of Elements in the Environment" held at Bordeaux, France from 28 August to 2 September, 2004.
- Dr. V.C. Tewari attended the I.G.C.P 493 Workshop on Rise and Fall of Vendian biota, Monash University Centre, Prato, Italy on August 30-31, 2004.
- Dr. V. Gupta visited Institute of Earthquake Engineering and Engineering Seismology, University St. Cyril and Methodius, Skopje, Republic of Macedonia to complete Post-Graduate Course on Aseismic Design and Construction (CADAC) during September– November 2004.
- Dr Sushil Kumar visited Armenia to participate in the 5th General Assembly of the Asian Seismological Commission and Symposium on Seismic Hazard Evaluation and Risk Reduction on October 4-22, 2004.
- Dr. M. P Sah and Dr. G. Philip visited ICIMOD, Nepal in connection with joint project 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 August 9-21, 2004 and February 13-25, 2005.
- Dr. S.K. Parcha visited China and Tibet and carried out joint field work along with the Prof. Shanchi Penj of Narjing Institute of Geology and Palaeontology of China from 21 May to 15 June, 2004.

AWARDS AND HONOURS

- Dr. A.K. Dubey Member, Editorial Board, Journal of Asian Earth Sciences (Elsevier Publications)
- Dr. V.M. Choubey and Dr. S.K. Bartarya were awarded for their best research paper entitled "Geohydrological controls on emanation of radon in outer Himalaya, India for the year 2004.
- P.S. Negi awarded first prize for Best Scientific Research Work in Hindi for the year 2003-2004 (under Govt. of India scheme) on WIHG Foundation Day ceremony, 29 June 2004.
- Dr. T.Singh nominated as Adviser on the roll of Life Safety Fronts- an Itanagar based NGO, March 5, 2005.
- Dr. V.C. Tewari awarded TRIL Fellowship and senior associateship of ICTP, Italy.

Ph. D THESES

Name	Supervisor/s	Title of the Thesis	University	Awarded/ Submitted
Reenu Joshi	Dr A. K. Dubey Dr A. K. Biyani	Tectonic evolution of the Doon valley with special reference to neotectonics	HNB Garhwal Univ, Srinagar Garhwal	Awarded
Deepak Joshi	Prof.S.S. Srivastava Dr.R.J.Azmi	Biostratigraphy and age of the Lower Vindhyan (Semri Group) of Eastern Vindhyan basin, India	IIT Roorkee	Awarded
S. Singh	Dr.H.K.Sachan Dr.B.P.Singh	Comparative study of Precambrian evaporites from Himachal Pradesh and Jammu region.	Jammu Univ.,	Awarded
Indu Pant	Dr.(Mrs.) M.Tiwari	Sedimentological and palaeo-biological investigation of the carbonate horizon of eastern Kumaun Lesser Himalaya	Kumaun Univ.	Awarded
P.S.Negi	Dr.B.K.Gupta Dr.P.K.Hajra	Investigation on ligneous flora of Doon valley.	HNB Garhwal Univ., Srinagar Garhwal	Awarded
Kalpna Negi	Dr.R.S.Rawat	Structural state (Triclinicity) of alkali feldspar in selected granitoids from the Northwestern Himalaya.	HNB Garhwal Univ., Srinagar Garhwal	Awarded
Kapesa Lokho	Dr.R.Venkatachalpathy	Forminiferal biostratigraphy, paleontology and the boundary events of paleogene sediments from parts of Kohima and Phek district, Nagaland.	Nagaland Univ., Kohima	Submitted

INTER INSTITUTIONAL COLLABORATION

In order to broaden the research in the interdisciplinary areas, the Institute has signed a Memorandum of Understanding (MoU), with the Birbal Sahni Institute of Paleobotany (BSIP), National Geophysical Research Institute (NGRI), and the International Institute for Geoinformation and Earth Observation (ITC), Netherlands.

MoU with BSIP, Lucknow

This Memorandum of Understanding (MOU) is drawn between Birbal Sahni Institute of Palaeobotany (BSIP), Lucknow and Wadia Institute of Himalayan Geology (WIHG), Dehradun, with the objective to undertake collaborative programmes to generate high resolution multidisciplinary data (using palynological, palaeobotanical, palaeobiological, geochemical, rock magnetic and sedimentological parameters) for interpreting age, regional correlations, palaeoclimatic and palaeoecological changes, tectonics and sedimentation history in the Precambrian and Upper Palaeozoic-Quaternary successions in the Himalaya.

MoU with NGRI, Hyderabad

The Wadia Institute of Himalayan Geology has signed a memorandum of understanding (MoU) with the National Geophysical Research Institute (NGRI). Both the organizations have agreed to collaborate in the following areas of common interest with a view to understand geodynamic evolution of Himalaya; collision dynamics, tracing the evolution model of crust and lithosphere as well as addressing the problems of seismogenesis of Himalaya; the uniqueness and lateral variability in the mountain building processes along different transects in western and eastern Himalaya; the thermo-physical processes, relationship of climate and tectonics, active tectonic in space and time (analysis and interpretation of multidisciplinary factual data); development of strategic methodologies in locating possible zones of economic interest in the plate tectonic settings of Himalaya.

MoU with ITC, Netherlands

The MoU between Wadia Institute of Himalayan Geology, Dehradun and International Institute for Geoinformation and Earth Observation (ITC), Neterland has been signed to take collaborative programmes in the areas of mutual interest such as seismic hazard assessment, landslide mapping, shallow surface studies using geophysical techniques and exchange of knowledge in the fields of remote sensing and GIS.

Dr. B.R. Arora, Director, WIHG, exchanging the documents of the MoU with Dr. V.P. Dimri, Director, NGRI

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOP / TRAINING COURSES

Seminar/Symposia/Workshop

- Seminar on Himalayan safety, Sanskriti and Social Harmony Parameter, Dehra Dun, April 6, 2004.

  Participant : R.S. Rawat

- National Workshop on Entrepreneurship and Dissemination of Renewable Energy Technologies in Rural India. Jointly organized by Tata Energy Resource Institute, New Delhi and Uttaranchal Govt., Dehra Dun, April 16, 2004.

  Participant : P.S. Negi

- 4th Nepal Geological Congress, Kathmandu, Nepal, April 9-11, 2004.

  Participant : V.C. Tewari

- Interaction Workshop on Water Conservation at National Institute of Hydrology, Roorkee, April 13-14, 2004.

  Participant : S.K. Bartarya

- Workshop on Mission Mode Project for Landslide Hazard Mitigation in Uttaranchal State, held at WIHG, Dehra Dun, April 14-15, 2004.

  Participants : K.S. Bist and Vikram Gupta

- Workshop on "Tectonic Geomorphology" , IIT, Kanpur May 3-7, 2004.

  Participant : A.K. Dubey

- International Workshop on the Indian Monsoon and Climate Variability during Holocene, Geological Society of India, Bangalore, May 17 – 18, 2004.

  Participant : N.R. Phadtare

- Workshop of Partnering and Convergence for Uttaranchal Decentralized Watershed Development Project, Dehra Dun, June 7, 2004.

  Participant : D. Pal

- 19th Himalaya-Karakoram-Tibet Workshop, Hokkaido University, Japan July10-12, 2004.

  Participants : A.K. Dubey, N.R. Phadtare and T.N. Jowhar

- Seminar on Applications of Analytical Techniques in Geosciences, WIHG, Dehra Dun, July 3, 2004

  Participants : P.P.Khanna, N.K.Saini and P.K.Mukherjee

- Seminar on Physics of the Living State at I.C.T.P. Trieste, Italy, July 7, 2004.

  Participant : V.C. Tewari

- Training programme on Twelve-Week Foundation for Scientists and Technologists sponsored by Department of Science and Technology, IIPA, New Delhi, July 5 to Sept. 24, 2004.

  Participant : R. Jayangondaperumal

- Professional level training course on Inventory of Glaciers, Glacial Lakes and Identification of Potential Glacial Lake Outburst Floods affected by global warming in Himalayan region, ICIMOD, Kathmandu, Nepal, Aug. 9-21, 2004.

  Participant : M.P. Sah and G. Philip

- Brain storming session on Earthquake Precursory Studies in India, IHC, New Delhi, India, Aug. 12-13, 2004.

  Participant : B.R. Arora and Kamal

- Indo-EU Workshop on Climate and Natural Disasters (September 2004), Preparatory Meeting organized by University of Hyderabad, Aug. 16, 2004.

  Participant : R.K. Mazari

- 32 International Geological Congress (IGC) held in Florence, Italy, Aug. 20-28, 2004.

  Participant : V.C. Tewari and P.K. Mukherjee

- AMS users' interaction meeting, Institute of Physics, Bhubaneswar, Aug. 26 – 27, 2004.

  Participant : N.R. Phadtare

- International Conference on Radiation in Education, Nagasaki, Japan, August 22-26, 2004.

  Participant : V.M. Choubey

- International Conference on Behavior of Elements in the Environment, Bordeaux, France, 28th Aug. to 2 Sept. 2004.

  Participant : N.Siva Siddaiah

- I.G.C.P 493 Workshop on Rise and Fall of Vendian Biota, Monash University Centre, Prato, Italy Aug. 30-31, 2004.

  Participant : V.C. Tewari

- Workshop on Recent Trends in Environment and Sustainable Development in North East India" Institute of Science & Technology, Nirjuli, Sept. 11, 2004.

  Participant : A.K. Singh

- Indo-EU Workshop on Climate Change and Natural Hazards jointly organized by DG, Research, European Commission and the Department of Science and Technology, Sept. 6-10, 2004.

  Participant : G. Philip

- Workshop on Recent Trends in Environment and Sustainable Dvelopment, NERIST, Nirjuli, organized by Dept. of Forestry, NERIST, Sept. 11, 2004.

  Participant : T. Singh

- Training Course on Recent Trends in Seismic Network Data Processing and Exchange, Hazard and Risk Assessment, Armenia, Oct. 4-14, 2004.

  Participant: Sushil Kumar

- Workshop on Urban Rainwater Harvesting Techniques, Dehra Dun, organized by Confederation of Indian Industries, Oct. 8, 2004.

  Participant : S.K. Bartarya

- Conference of Forest & Environment Ministers of Himalayan States, FRI, Dehra Dun, Oct. 11-12, 2004.

  Participant : R.K. Mazari

- International Workshop on Electromagnetic Induction in the Earth, at NGRI, Hyderabad, Oct. 18-23, 2004.

  Partcipants: B.R. Arora and H.K. Sachan

- 17th International Workshop on Electromagnetic Induction in the Earth. Post workshop on Multidisciplinary Studies in Himalaya, NGRI, Hyderabad, Oct. 24-25, 2004

  Participant : R. Islam, Rajesh Sharma and H.K. Sachan

- National Seminar on Recent Advances in Himalayan Geology with special reference to NW Himalaya, CAS in Geology, Panjab University, Chandigarh, Oct., 2004.

  Participants : B.R. Arora, A.C. Nanda and B.N.Tiwari

- 23rd International Post-Graduate Course on Aseismic Design and Construction in the Institute of Earthquake Engineering and Engineering Seismology, University of Cyril and Methodius, Skopje, Republic of Macedonia during September – Nov. 2004.

  Participant : V. Gupta

- National Conference of Solid State Nuclear Track Detector at DAV College, Amritsar, Nov. 1-3, 2004.

  Participant : S.K. Bartarya

- WinGeo-2004, Workshop on Indian Geotransects, WIHG, Dehra Dun, Nov. 25-26, 2004,

  Participants : P.P. Khanna, S.K. Ghosh, Rajesh Sharma, R. Islam, D.R. Rao, H.K. Sachan and A.K. Singh

- Brainstorming Session on "Receding glaciers in Indian Himalayan region (IHR) – Environmental and social implications" organized by G.B. Pant Institute of Himalayan Environment and development, Koshi-Kathmandu, Almora, U.A. Sept. 10-11, 2004.

  Participant : D.P. Dobhal

- Workshop on Disaster Management, organized jointly by DST, WIHG and ADPC at WIHG, Dehra Dun Dec. 6-11, 2004.

  Participants : B.R. Arora, Kamal and A.K. Mahajan

- DST 16th Group Monitoring Meeting in Earth Sciences held at University of Madras, Chennai, Dec. 22-24, 2004.

  Participant : N.Siva Siddaiah

- Seminar on Resources of Uttaranchal, organized by Uttaranchal State, Dehra Dun, during Dec. 2004.

  Participant : R.S. Rawat

- A training programme to develop expertise in the operation of Total Station Data by Elcome Technologies Pvt. Ltd., Mumbai, organized by the Wadia Institute of Himalayan Geology, Dehra Dun, Jan. 17-19, 2005.

  Participant : Vikram Gupta, D.P. Dobhal, K. Luirei and R.J. Thayen

- Brain storming session on The Great Tsunami Event of December 26, 2004, INSA, New Delhi, Jan. 21-22, 2005.
  Participant : B.R. Arora, Kamal and S.K.Parcha

- The role of Science & Technology in Natural Disaster reduction with focus on earthquakes, First J & K State Science Congress held at University of Jammu, Jammu, Feb. 7-9, 2005.

  Participant : N.Siva Siddaiah and A.K. Mahajan

- International Conference on Precambrian Continental Growth and Tectonism at Bundelkhand University, Jhansi, Feb. 22-27, 2005.

  Participant : V.C. Tewari

- Map India 2005, 8th International Conference on Geomatics-2005, New Delhi, Feb., 2005.

  Participants : G. Philip

- Sustainable Development in Global Perspectives. (DSDS-2005). jointly organized by World Council for Sustainable Development, Govt. of India and Tata Energy Resource Institute and others at India Habitat Center, New Delhi, Feb. 3-5, 2005.

  Participant : P.S. Negi

- Workshop on Recent Trends in GPS Surveying for Defence Engineering, Resource Management including Forestry and Disaster Management, Survey of India, Dehradun, Feb. 27, 2005.

  Participant : P. Banerjee

- National Workshop on Perspectives in Palaeoanthropology: Methodological and Conceptual Issues., Panjab University, March 15-17, 2005.

  Participant : A.C.Nanda

- Indo-Japan Joint Workshop on Tsunami at NGRI, Hyderabad, March 18-19, 2005.

  Participant : B.R.Arora and P. Banerjee

- National Seminar on Crustal Studies on the Eastern Indian Shield, Dept. of App. Geophysics, Indian School of Mines, Dhanbad, March 21-22, 2005.

  Participant : P. Banerjee

- Mass Awareness Program on Ground Water Development, Management & Protection, Vivekanand Hall, Itanagar, organized by Central Ground Water Board, March 29, 2005.

  Participant : T. Singh

LECTURES BY VISITING SCIENTISTS

Name and Address	Date	Topic
Prof. T.M. Mahadevan, Ex-Director, AMD/DAE *Sree Bagh Annummtrial Road* *Kochi-682035*	16-4-2004	Deep crust beneath Himalaya and modeling of crustal evolution
Prof. S.C. Mukhopadhyay *KolkataUniversity* *Kolkata*	31-5-2004	Geomorphology of North-Eastern Himalaya region
Prof. Biswajit Mishra Department of Geology and Geophysics I.I.T., Kharagpur	7-6-2004	Gold metallogeny in the Hutti- Maski Greenstone Belt
Prof. S.N. Bhattacharya Department of Geology and Geophysics I.I.T., Kharagpur	8-6-2004	Evolution of earthquake mechanism by P- and S-waves
Prof. K. Gopalan Emeritus Scientist NGRI	15-6-2004	Age of megascopic eukaryotic algae bearing Vindhyan sediments: implications for Precambrian atmospheric oxygen evolution
Prof. A.K. Singhvi Scientist PRL. Ahmedabad	28-6-2004	Human dimensions of Geosciences – some new international initiatives
Shri. V.K. Raina Ex-Dy Director General GSI	29-6-2004	Glaciers in the Himalayas :Gangotri glacier
Prof. Fushimi Hiroji University of Shiga Prefecture School of Environmental Sciences Japan	13-8-2004	Environmental changes of the Great Himalayan regions in relation to the climatic warming
Prof. I.B. Singh Lucknow University Lucknow	29-9-2004	Late Quaternary history of the Ganga Plain
Prof. Andrew Gross USGS, Reston U.S.A.	15-12-2004	Geochemical mapping in global, regional and local scale
Dr. Sobolev Gennady Director, Institute Physics of Earth, Moscow	23-12-2005	Earth physics and its application to earthquake prediction
Dr. A.B. Rabiu Department of Physics Federal University of Tecchnology Nigeria	11-01-2005	Prospect of equatorial geomagnetism: effects on Biological and physical processes

LECTURES DELIVERED BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
A.K.Mahajan	Survey of India, Dehra Dun	14.5.04	Seismic microzonation of Dehradun city
V.M.Choubey	Physics Dept., Radon Lab Luxembourg Luxembourg	13.5.04	Role of radon in understanding geological proceses
Kamal	ITBP Academy, M ussoorie	31.5.05	Earthquake disaster and management.
S.K.Bartarya	Dept. of Geology, Delft University , The Netherland	3.6.04	Hydrogeological controls on emanation of radon in Himalayan region
Kamal	Kendriya Vidyalaya, Birpur, Dehra Dun	9.6.04	The mysterious disaster-earthquake and its management
Vikram Gupta	Kendriya Vidyalaya, Birpur, Dehra Dun	15.6.04	Landslide hazards in the Himalayan terrain
Kamal	Town Hall, Dehra Dun	19.6.04	Earthquakes safety with special reference to the state of Uttaranchal, under UNDP GOI Urban Earthquake Vulnerability Reduction Program (UEVRP)
Kamal	Uttaranchal Academy of Administration, Nainital	22.6.04	Understanding earthquakes and getting prepared for it.
Kamal	ITBP Academy, Mussoorie	30.6.04	Earthquake disaster and its management
T.Singh	GB Pant Institute of Environment & Development, Itanagar	20.8.04	Geodynamic evolution of Himalaya
V.M.Choubey	Inst. of Radioisotope Research, Kobe (Japan)	28.8.04	Geological controls on emanation of radon
T.Singh	Dept. of Forestry,Nerist, Nirjuli	11.9.04	Recent trends in environment and sustainable development
S.K.Bartarya	Forest Research Institute Deemed University, Dehra Dun	10.9.04 to 28.9.04	Series of lectures on chemistry of Hydrosphere
B. Sharma	Govt. Inter College, Gujrara	8-9.10.04	Cloud burst and disaster management
V.Gupta	Institute of Earthquake Engineering, St. Cyril Republic of Macedonia	10.10.04	Natural hazards with special reference to landslides in Himalaya

LECTURES DELIVERED BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
R.K.Mazari	FRI, Dehra Dun	11-12.10.04	Lakes and glaciers of the Himalayan : an environmental window view
Sushil Kumar	Yearvan, Armenia	20.10.04	The 2001 Bhuj earthquake, seismic image of the source zone and its implication for the rupture nucleation
V. C.Tewari	National Antarctic Museum, University of Trieste, Italy	25.11.04	Snow ball earth, microbial life in extreme environment (Antarctica) and astrobiology
V.C.Tewari	University of Trieste	25.11.04	Extraterrestrial impact at K/T boundary and extinction of life on Earth : evidence from Indian Himalaya and Europe
H.K.Sachan	Dept. of Earth Science IIT, Mumbai	3.12.04	High to ultra-high pressure metamorphism in NW Himalaya: causes and consequences for Himalayan Orogeny
Rajesh Sharma	Kumaun Univ., Nainital	8-10.12.04	Series of lectures on ore geology and fluid inclusion study
A.K.Dubey	Dept. of Geology B.H.U., Banaras	3.12.04 to 13.12.04	Simultaneous development of folds and oblique faults in multilayered material
V.C.Tewari	Centre for Space Physics, Kolkata	8.1.05	Origin of life and astrobiology
T. Singh	Arunachal University	4.2.05	Awareness building for earthquake mitigation and rehabilitation
Rajesh Sharma	D.B.S. College, Dehra Dun	9.3.05	Fluids of sulphide mineralization
R. Islam	GSI, Delhi	18.3.05	Distribution of lower Palaeozoic granities in the NW Himalaya
S.J. Sangode	IIT, Kanpur	27.3.05 to 16.4.05	1.Magnetic Polarity stratigraphy and its applications in Quaternary sediments. SERC School on Concepts in Quaternary Geology 2. Rock magnetic theory and applications to Quaternary records. SERC School on Concepts in Quaternary Geology

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEE

Name of the Scientist	Status	Prestigious Committee/s Outside WIHG
Dr.B.R.Arora	1) Member	Executive Council, Geological Society of India
	2) Member	National Task Force for Earthquake Precursory Studies
	3) Executive Member	Executive council of the Indian Geophysical Union
	4) Fellow	Indian Academy of Sciences Bangalore
Dr. V.C.Tewari	1) Member	National Working Group for the IGCP Project 493 on Rise and Fall of Vendian biota since 2004.
	2) Member	Editorial Board as a Member of the Palaeontological Society of India, Lucknow since 2004
Dr. Kamal	1) Member	Editorial Board, Seismology Update, A biannual Newsletter of DST
	2) Key Resource Person	UEVR programme of UNDP / GOI
Dr.V.M.Choubey	1) Member	Editorial Board, Nuclear Track Society of India
Dr. A.K. Mahajan	1) Member	City Disaster Management Committee, Dehradun
	2) Convener	TEC for procuring GPS under Mission Mode Programme of Dept. of Science & Technology
	3) Member	Experts committee for selection of schools under HIM
	4) Convener	Scope project for NW Himalayan Region
Dr. K.S. Bist	1) Member	Indian Geological Congress, Roorkee
Dr.P.S. Negi	1) Member	Land rehabilitation committee of G.B.Pant Institute of Himalayan Environment & Development, Almora

FOUNDATION DAY CELEBRATIONS

The Institute celebrated its 36th Foundation Day Function on 29 June, 2004. Shri Narain Dutt Tiwari, Hon'ble Chief Minister of Uttaranchal was the Chief Guest on this occasion. Dr. B.R.Arora, Director of the Institute gave a brief account of the achievements made by the Institute during the year. Shri. V.K. Raina, Ex-Deputy Director General, GSI delivered the Foundation Day Lecture on "*Glaciers in the Himalayas – Gangotri Glacier*".

Shri N.D. Tiwari Hon'ble Chief Minister of Uttaranchal visiting the Institute Museum.

Shri V.K. Raina, Ex-Deputy Director General, GSI delivering Foundation Day Lecture.

On this occasion awards were given for the best research paper as well as for best scientific work carried out in Hindi. The first award was given to Drs. V.M.Choubey and S.K.Bartarya for their paper entitled "Geohydrological controls on emanation of radon in Outer Himalaya, India". The second award was given to Dr. P.S. Negi for his article "Parvatiya Kshetron Mein Paryavaran Sammet Udyogikaran Kee Sambhavanayein" under the scheme for promoting scientific writing in Hindi. Awards were also received by Sh. Samay Singh, Sh. B.K.Juyal, Sh. O.P.Anand, Sh. P.P. Dashmana, Mrs. Rajvinder Kaur, Sh. Navneet Kumar, Sh. A.S. Negi, Sh. Sushil Kumar, Sh. S.K. Srivastava, Mrs. Kalpana Chandel, Sh. Shyam Singh, Sh. Puran Singh, Sh.Satish Bahuguna, Sh. Ram Khilawan, Sh. Pushkar Singh and Sh. Tirath Raj for the good work done by them during the year.

NATIONAL SCIENCE DAY CELEBRATIONS

The National Science Day week was celebrated by the Institute by organising Science Quiz and Hindi Essay Competition for the students of various educational institutions of Dehra Dun. Inspite of Annual Board Exams in Schools, a total of 28 educational institutions participated in the quiz competition. The students even from far off places like Rishikesh, Sailakui, and Mohkampur also participated in the quiz competition. The topic for the essay competition in Hindi was *'Tsunami: Udhbhav Evum Prabhav'*. Studends from atleast 29 educational institutions participated in the competitions.

An open day was observed on this day and Museum and all the laboratories of the Institute were kept open to students and general public. The day started with students coming from places like Rishikesh and Vikas Nagar. In total nearly 33 educational institutions with more than 2,500 school children and a large number of general public visited the Institute Museum and various laboratories. This year a special exhibit in the form of an artistic pictorial was prepared on the initiation and effects of the Great Tsunami of December 26, 2004, which became a point of attraction to the students and general public.

School Children visiting Museum on National Science Day.

On this day an invited special science lecture was delivered by Prof. K. N. Khattri distinguished Scientist on **"Physics of the Earthquakes: Prediction Scenario"**. A large number of students and general public attended the lecture. The popular lecture was followed by the prize distribution ceremony. The prizes and certificates were distributed to the winners who stood first, second and third in the Science Quiz and Hindi Essay Competitions.

Prof. K.N. Khattri distinguished Scientist delivering Science Day Lecture.

NATIONAL TECHNOLOGY DAY

The 6th National Technology Day was celebrated by the Institute on 11 May, 2004. An Open Day was observed and the Museum and other laboratories were kept open for the general public and for the school and college children. A large number of students and people visited the Institute Museum and other laboratories.

TECHNICAL SERVICES

Analytical Services

A total number of two thousand eight hundred eighty (2880) samples were analysed in the Central Facility Laboratories, which includes 849 samples on XRF, 293 samples on XRD, 1306 samples on ICP MS and AAS and 434 samples on SEM. Out of these, 1251 samples were from outside users and the rest from the Institute scientists and scholars. During this year a new instrument XRD was procured, installed and standardized. It has started producing data.

Photography Section

During the reporting year around 107 rolls of colour negatives, 25 rolls of colour transparencies, 21 rolls of normal speed black and white negatives and 100 rolls of slow speed black and white negative films were used by the Institute scientists and research scholars. Processing of 82 rolls of colour negatives and 27 rolls of colour transparency films were arranged from the market. The WIHG laboratory exposed around 25 film rolls (black and white and colour), processed around 100 rolls of black and white films (mostly slow speed with photomicrographs) and made around 3000 prints of assorted sizes. The laboratory also arranged for the photographic coverage of most of the functions organized in the Institute during the year.

The recent purchase of around 10 digital cameras and their immense use has brought down the work load of the photography section considerably. Also, the better resolution is well reflected by the appearance of good quality field photographs in research publications. The section has also procured two Mini DV Handy camcorders for use in field.

Drawing Section

The drawing section catered to the cartographic needs of the scientists of the Institute including the sponsored projects. During the year the Section has prepared 168 geological/ geomorphological maps, litho logs and cross-sections for the scientists of the Institute. The staff of the Drawing Section has also prepared posters (15), charts (2), labels (33), identity-cards(32), certificate writing work (122), ammonia prints of different sizes(6) and modified a large number of diagrams(correction work).

Sample Preparation Lab.

The Sample Preparation Laboratory has catered to the requirements of the Institute scientists as well as various organisations/universities and sponsored projects. The Section has provided 2287 thin, polished, microprobe and fluid inclusion sections and crushed/powdered 789 rock samples for various analytical investigations.

MUSEUM

The Museum is the most significant center for education and continues to attract the students and general public not only from the remote corners of India but also from abroad. Students in large groups from different schools, universities, colleges and from other institutions visited the Museum and guided tours were provide to them . The activities of the Museum are undertaken according to the needs and the interests of the students. A large number of students continued to visit the Museum for their respective school projects. In the concluding year the visitors from Austria, Australia, Canada, England, France, Germany, Israel, Italy, Japan, Nepal, Netherland, New Zealand, Pakistan, Poland, Peru, Russia, Sri Lanka, , UAE, U.K and USA visited the Museum.. Besides this various other dignitaries also visited the Museum.

During the year the Museum observed Open Days on National Technology Day, Foundation Day, Founder's Day and National Science Day. A large number of students and general public visited the Museum on these occasions. The print media gave a wide coverage of the various functions. The Museum at present is actively planning for the preparation of database and repository section of national level and the data existing in the Museum has been computerized. The Museum also awares and propogates its activities to general public and the students through its brouchers.

Shri N.D. Tiwari Hon'ble Chief Minsiter of Uttaranchal, Prof. K.S. Valdiya, Chairman G.B. and Prof. B.R. Arora, Director WIHG having a look on Vertebrate fossils displayed in the Museum.

LIBRARY

The Library of the Wadia Institute of Himalayan Geology has a rich collection of books, monographs, journals and seminar/conference proceedings on earth sciences with special reference to Himalayan Geology. The Library subscribes to a large number of national and international scientific journals in the field of earth sciences, which are not available in any other Library in the region. The Library serves to the scientific, technical and administrative staff of the Institute as well as to the scientists, academicians and researchers of other sister organizations.

The Library subscribes to 143 journals out of which 58 are Indian and 85 are foreign. The Library received 12 titles of journals as gratis. During the year the Library has acquired a total number of 158 books, out of which 37 books were received as gratis. The Library has a good collection of Hindi books to promote Hindi language in the staff of the Institute and has acquired 89 books for the Hindi collection.

The Library has brought out the Sixth volume of HIMGEO ABSTRACTS. It consists of 289 records of bibliographic references along with abstracts on various aspects of Himalayan Geology published during the year 2003. This is the printed version of the HIMGEO database.

The Himalayan Geology database HIMGEO compiled by the Library has been updated by adding 289 bibliographic records. The Library has provided 20 annotated bibliographies on various aspects of the H Himalaya to the scientists and researchers of the Institute as well as other organizations.

Since 1992 the Library is regularly bringing out the fortnightly Current Awareness Service named Contents Information Service (CIS). It consists of table of contents of journals subscribed or received as gratis in the Library. Two volumes (24 & 25) each consisting of twelve issues were compiled during the period of this report.

The Library incorporates a reprographic cell, which serves as a central facility for xeroxing and cyclostyling. A large number of xerox copies of articles from journals/monographs were provided to the scientists as well as to the administrative and technical sections of the Institute. The xerox facility was also extended to other organizations on payment basis.

PUBLICATION & DOCUMENTATION

The Publication and Documentation Section of the Institute is mainly involved in bringing out the regular journal on "Himalayan Geology" and is publishing yearly Hindi magazine, annual report, etc. During the year the Section has published the Himalayan Geology vols. 25(2), Vol.26(1) and a Hindi magazine Ashmica Vol.10. Also annual report of the Institute for the year 2003-04 both in Hindi & English, a Book (Hazard Survival Guide) entitled "Understanding Earthquakes and Landslides: Preparing for Hazards" by Prof. K.S. Valdiya and an abstract volume for the workshop on 'Indian Geotransects', organized by the Wadia Institute of Himalayan Geology was also brought out. Apart from this various jobs such as printing of the Foundation Day Lecture entitled "Glaciers in the Himalayas- Gangotri Glacier," telephone directory, brochures, invitation cards for seminars/workshops/ lectures and certificates for celebration of Foundation Day and National Science Day were also brought out by the Section during the year.

DISTINGUISHED VISITORS TO THE INSTITUTE

Shri Narain Dutt Tiwari, Hon'ble Chief Minister of Uttaranchal Dehra Dun.

Prof. V. S. Ramamurthy, Secretary, Dept. of Science & Technology, New Delhi.

Shri. V.K. Raina, Ex-Deputy Director General, GSI.

Prof. Dr. Syed Hamiudullah, Director, National Centre of Excellence in Geology, University of Peshwar.

Dr. T.M. Mahadevan, Ex-Director, AMD/DAE, Sree Bagh Annummtrial Road, Kochi.

Sh. B.K. Rao, Former Secretary, Govt. of India, Ministry of Steel and Mines.

Prof. Vincent E. Coortiller IPGP97 France.

Sh. B.S. Rawat, Director Retd., GSI Lucknow Heritage Hose Jankipuram, Lucknow.

Prof. K. Gopalan, Emeritus Scientist, National Geophysical Research Institute, Hyderabad.

Prof. Fushimi Hiroji, University of Shiga Prefecture, School of Environmental Sciences, Japan.

Prof. I.B. Singh, Lucknow University, Lucknow.

Prof. Andrew Gross, USGS, Reston, U.S.A.

Dr. Sobolev Gennady, Director, and Dr. Zavylov, Institute Physics of Earth, Moscow.

Dr. A.B. Rabiu, Department of Physics, Federal University of Technology, Nigeria.

Prof. V.S. Ramamurthy, Secretary, Deptt. of Science & Technology, New Delhi, inagurating Institute Guest House.

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.

On the occasion of the Foundation Day of the Institute on 29 June 2004, the Hindi Magazine 'Ashmika' Volume 10 was released. A scientist of the Institute, Dr.. P.S. Negi was conferred a prize for his article in Hindi 'Parvatiya Kshetron mein Paryavaran Sammat Udyogikaran Kee Sambhavanayein', under a scheme for promoting scientific writing in Hindi.

Hindi fortnight was celebrated from 14 September 2004 to 30 September 2004, during which various competitions like poetry, essay and debate were organized. A speaker was invited to deliver Rajbhasha lecture to inspire the staff for progressive use of Hindi in their work.

The Annual Report of the Institute for the year 2003-2004 was published in bilingual form. D.N. Wadia Honour Lecture and press releases were also published in Hindi. On the occasion of the Science Day, a Hindi Essay competition was organized on 28 February 2005 for the students of various schools of Dehra Dun.

Shri N.D. Tiwari, Hon'ble Chief Minister, Uttaranchal releasing 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. Staff-strength (category-wise)

[A] NON-PLAN :

Group/ Category	Scientific	Technical	Administrative	Total
A	61	6	2	69
B	-	15	5	20
C	-	25	41	66
D	-	19	25	44
Total	61	65	73	199

[B] PLAN :

Group/ Category	Scientific	Technical	Administrative	Total
A	2	-	-	2
B	-	-	1	1
C	-	2	-	2
D	-	-	2	2
Total	2	2	3	7

Approved budget grant for the year 2004-2005

Plan	:	Rs. 7.50 crores
Non-Plan	:	Rs. 1.35 crores
Total	:	Rs. 8.85 crores.

Xth Plan approved outlay

Plan	:	Rs. 30.00 crores
Released	:	Rs. 7.50 crores (during 2004-2005)

WADIA INSTITUTE OF HIMALAYAN GEOLOGY DEHRA DUN
AS ON 31.3.2005

(A) Scientific Staff

1.	Prof. B.R. Arora	Director
2.	Dr. A.C. Nanda	Scientist 'G'
3.	Dr. A.K. Dubey	Scientist 'F'
4.	Dr. T.N. Bagati	Scientist 'F'
5.	Dr. Trilochan Singh	Scientist 'F'
6.	Dr. Devendra Pal	Scientist 'E'
7.	Dr. R.J. Azmi	Scientist 'E'
8.	Dr. R.S. Rawat	Scientist 'E'
9.	Dr. J.T. Gergan	Scientist 'E
10.	Dr. V.C. Tewari	Scientist 'E'
11.	Dr. N.S. Gururajan	Scientist 'E'
12.	Dr. R.K. Mazari	Scientist 'E'
13.	Dr. M.S. Rathi	Scientist 'E'
14.	Dr. K.S. Bist	Scientist 'E'
15.	Dr. R.A.K. Srivastava	Scientist 'E' (Compulsorily retired on 31.1.05)
16.	Dr. D.K. Misra	Scientist 'E'
17.	Dr. B.K. Choudhary	Scientist 'E'
18.	Dr. R.K.Chaujar	Scientist 'E'
19.	Dr. V.M. Choubey	Scientist 'E'
20.	Dr. N.R. Phadtare	Scientist 'E'
21.	Dr. Talat Ahmad	Scientist 'E' (on deputation)
22.	Dr. P.P. Khanna	Scientist 'E'
23.	Dr. Rohtash Kumar	Scientist 'E'
24.	Dr. Keser Singh	Scientist 'E'
25.	Dr. (Mrs.) Meera Tiwari	Scientist 'E'
26.	Dr. S.K. Ghosh	Scientist 'E'
27.	Dr. M.P. Sah	Scientist 'E'
28.	Dr. N.K. Saini	Scientist 'E'
29.	Dr. S.K. Paul	Scientist 'E'
30.	Dr. T.N. Jowhar	Scientist 'E'
31.	Dr. K.K. Purohit	Scientist 'E'
32.	Dr. Kishor Kumar	Scientist 'E'
33.	Dr. N. Siva Siddaiah	Scientist 'E'
34.	Dr. Rajesh Sharma	Scientist 'E'
35.	Dr. George Philip	Scientist 'E'
36.	Dr. Rafikul Islam	Scientist 'E'
37.	Dr. D. Rameshwar Rao	Scientist 'E'
38.	Dr. B.N. Tiwari	Scientist 'D'
39.	Dr. Kamal	Scientist 'D'
40.	Dr. S.K. Bartarya	Scientist 'D'
41.	Dr. P.K. Mukherjee	Scientist 'D'
42.	Dr. S.J. Sangode	Scientist 'D'
43.	Dr. Sushil Kumar	Scientist 'D'
44.	Dr. S.K. Parcha	Scientist 'D'
45.	Dr. H.K. Sachan	Scientist 'D'
46.	Sh. B.S. Rawat	Scientist 'C'
47.	Dr. P. Banerjee	Scientist 'C'
48.	Dr. A.K. Mahajan	Scientist 'C'
49.	Dr. D.P. Dobhal	Scientist 'C'
50.	Dr. Vikram Gupta	Scientist 'C'
51.	Dr. S.S. Bhakuni	Scientist 'C'
52.	Dr. Suresh N.	Scientist 'C' (Joined on 28.1.05)
53.	Dr. A.K. Mundepi	Scientist 'B'
54.	Sh. V. Sriram	Scientist 'B'
55.	Dr. B.P. Sharma	Scientist 'B'
56.	Dr. P.S. Negi	Scientist 'B'
57.	Dr. A.K.L. Asthana	Scientist 'B'
58.	Miss Kapesa Lokho	Scientist 'B'
59.	Dr. A.K. Singh	Scientist 'B'
60.	Dr. Jayangondaperumal	Scientist 'B'
61.	Dr. Khaying Shing Luirei	Scientist 'B'
62.	Dr. Renoj J. Thayyen	Scientist 'B' (Joined on 21.1.04)
63.	Sh. Rajesh S.	Scientist 'B'(Joined on 05.01.05)
64.	Sh. Gautam Rawat	Scientist 'B'(joined on 03.03.05)

(B) Technical Staff

1.	Sh. V.P. Singh	Sr. Pub. Doc.Officer Gr.III(5) (on deputation)
2.	Sh. Saeed Ahmad	Sr. Librarian Gr.III(5)
3.	Sh. J.J. Sharma	Sr. Technical Officer Gr.III(5)
4.	Sh. M.M.S. Rawat	Tech. Officer Gr.III(4)
5.	Sh. B.B. Sharma	Tech. Officer Gr.III(4)
6.	Sh. A.K. Pandit	Artist-cum-Modellor Gr.III(3)
7.	Sh. Sanjeev Dabral	Jr. Technical Officer Gr.III(3)
8.	Dr. R.K. Sehgal	Jr.Technical Officer Gr.III(3)
9.	Sh. Chandra Shekhar	Jr.Technical Officer Gr.III(3)
10.	Sh. V.P. Gupta	Jr. Technical Officer Gr.III(3)
11.	Sh. Samay Singh	Jr.Technical Officer Gr.III(3)
12.	Sh. Vishnu Shreshta	Sr. Lab. Asstt. Gr.II (5)
13.	Sh. S.C. Kothiyal	Sr. Lab. Asstt. Gr.II (5)
14.	Sh. Rakesh Kumar	Sr. Tech. Asstt. Gr.III(2)
15.	Sh. N.K. Juyal	Sr. Tech. Asstt. Gr. III(I)
16.	Sh. Chandra Bhan Sharma	Junior Engineer
17.	Sh. S.S. Bhandari	Technical Asstt.
18.	Sh. Rambir Kaushik	Technical Asstt.
19.	Sh. Jitendra Bhatt	Technical Asstt.(EDP) (Joined on 22.6.04)
20.	Sh. Bharat Singh Rana	Technical Asstt. (Joined on 29.12.04)
21.	Sh. V.K. Kala	Draughtsman Gr.II (5)
22.	Sh. G.S. Khattri	Draughtsman Gr.II (5)
23.	Sh. Navneet Kumar	Draughtsman Gr.II (5)
24.	Sh. B.B. Saran	Draughtsman Gr.II (2)
25.	Sh. Chandra Pal	Section Cutter Gr.II (5)
26.	Sh. Shekhara Nandan	Section Cutter Gr.II (5)
27.	Sh. D.N. Dutta	Mech.Technician (retired on 31.12.04)
28.	Sh. Pushkar Singh	Section Cutter Gr.II (4)
29.	Sh. Satya Prakash	Section Cutter Gr.II (4)
30.	Sh. Santu Das	Section Cutter Gr.II (1)
31.	Sh. Nand Ram	Elec.-cum-Pump Operator Gr.II(3)
32.	Sh. Ravindra Singh	Sr. Tech.Asstt.
33.	Sh. H.C. Pandey	Sr.Tech. Asstt.
34.	Dr. S.K.Chabak	Sr. Lab. Tech.
35.	Sh. Lokeshwar Vashistha	Sr. Lab. Tech.
36.	Sh. R.M. Sharma	Sr. Lab. Tech.
37.	Sh. C.P. Dabral	Sr. Lab. Tech.
38.	Sh. Satish Pd. Bahuguna	Field-cum-Lab.Attendant Gr. I (4)
39.	Sh. S.K.Thapliyal	Field-cum-Lab. Attendant Gr. I(4)
40.	Sh. Shiv Pd. Bahuguna	Field-cum-Lab.Attendant Gr.I(4)
41.	Sh. Sashidhar Balodi	Field-cum-Lab. Attendant Gr.I(4)
42.	Sh. Rajendra Prakash	Field-cum-Lab. Attendant Gr.I(4)
43.	Sh. A.K. Gupta	Field-cum-Lab. Attendant Gr.I(4)
44.	Sh. Tirath Raj	Field-cum-Lab. Attendant Gr.I(4)
45.	Sh. Balram Singh	Field-cum-Lab. Attendant Gr.I(4)
46.	Sh. Anoop Singh	Field-cum-Lab. Attendant Gr.I(3)
47.	Sh. Pratap Singh	Field-cum-Lab. Attendant Gr.I(3)
48.	Sh. Ram Kishor	Field-cum-Lab. Attendant Gr.I(3)

49.	Sh. Jaya Nand Khanduri	Field-cum-Lab. Attendant Gr.I(2)
50.	Sh. Ansuya Prasad	Field-cum-Lab. Attendant Gr.I(2)
51.	Sh. Puran Singh	Field-cum-Lab. Attendant Gr.I(2)
52.	Sh. Ram Khilawan	Field-cum-Lab. Attendant Gr.I(2)
53.	Sh. Madhusudan	Field-cum-Lab. Attendant Gr.I(2)
54.	Sh. Hari Singh	Field-cum-Lab. Attendant Gr.I(2)
55.	Sh. Ravi Lal	Field-cum-Lab. Attendant Gr.I(2)
56.	Sh. Preetam Singh	Field-cum-Lab. Attendant Gr.I(2)
57.	Sh S.K.Barthwal	Lab.Assistant.
58.	Sh. Nain Dass	Lab. Assistant.
59.	Mrs. Rama Pant	F.C.L.A.
60.	Sh. R.S. Negi	F.C.L.A.
61.	Sh. Ramesh Chandra	F.C.L.A.
62.	Sh. Khusi Ram	F.C.L.A.
63.	Sh. Tikam Singh	F.C.L.A.
64.	Sh. Bharosa Nand	F.C.L.A.
65.	Sh. B.B. Panthri	F.C.L.A.
66.	Sh. M.S. Rawat	F.C.L.A.

(C) Administrative Staff

1.	Sh. Dinesh Chandra	Registrar
2.	Sh. Harish Chandra	Finance & Accounts Officer
3.	Sh. R.K. Matah	Administrative Officer
4.	Sh. G.S. Negi	Asstt. Finance & Accounts Officer
5.	Sh. N.K. Sharma	Stores & Purchase Officer (resigned on 12.1.2005)
6.	Sh. Tapan Banerjee	Sr. Personal Assistant
7.	Sh. U.S. Tikha	Accountant
8.	Mrs. Manju Pant	Office Superintendent
9.	Mrs. Shamlata Kaushik	Assistant (Hindi)
10.	Mrs. Nirmal Rattan	Assistant
11.	Sh. Kishan Lal	Assistant
12.	Sh. O.P. Anand	Assistant
13.	Sh. N.B.Tewari	Assistant (on deputation)
14.	Sh. B.K. Juyal	Assistant
15.	Sh. D.P. Chowdhury	Stenographer Gr.(II)
16.	Sh. P.P.Dhasmana	Stenographer Gr.(II)
17.	Mrs. Rajvinder Kaur Nagpal	Stenographer Gr..(III)
18.	Sh. Hukam Singh	U.D.C. (Assistant Ad-hoc)
19.	Sh. D.S. Rawat	U.D.C.
20.	Sh. S.S. Bisht	U.D.C.
21.	Mrs. Sarojani Rai	U.D.C.
22.	Mrs. Sharda Saigal	U.D.C.
23.	Sh. M.M. Barthwal	U.D.C.
24.	Sh. M.C. Sharma	U.D.C.
25.	Sh. A.S. Negi	U.D.C.
26.	Sh. S.K. Chettri	U.D.C.
27.	Sh. Vinod Singh Rawat	U.D.C.
28.	Sh. Sushil Kumar	U.D.C.
29.	Sh. S.K. Srivastava	L.D.C. (UDC Ad-hoc)
30.	Sh. R.C. Arya	L.D.C.
31.	Mrs. Prabha Kharbanda	L.D.C.
32.	Mrs. Kalpana Chandel	L.D.C.
33.	Mrs. Anita Choudhari	L.D.C.
34.	Sh. Shiv Singh Negi	L.D.C.
35.	Mrs. Neelam Chabak	L.D.C.
36.	Mrs. Seema Juyal	L.D.C.
37.	Mrs. Suman Nanda	L.D.C.
38.	Sh. Kulwant Singh Manral	L.D.C. (Joined on 8.12.04)
39.	Sh. Rahul Sharma	L.D.C. (lien vacancy Joined as LDC on 7.12.04)
40.	Sh. Bhagat Singh	Bearer
41.	Mrs. Kamla Devi	Bearer
42.	Mrs. Deveshwari Rawat	Bearer
43.	Sh. Shyam Lal	Bearer
44.	Sh. S.K. Gupta	Bearer
45.	Sh. Sh. Chait Ram	Bearer
46.	Mrs. Omwati	Bearer
47.	Sh. Sh.Jeevan Lal	Bearer
48.	Sh. Surendar Singh	Bearer
49.	Sh. Vijai Ram Bhatt	Bearer (Joined on 23.4.04

(D) Ancillary Staff

1.	Sh. Puran Singh	Driver
2.	Sh. Khem Singh	Driver
3.	Sh. Dewan Singh	Driver
4.	Sh. Sohan Singh	Driver
5.	Sh. Ganga Ram	Driver
6.	Sh. Chander Pal	Driver
7.	Sh. Naresh Kumar	Driver
8.	Sh. Shyam Singh	Driver
9.	Sh. M.K. Tamang	Driver
10.	Sh. R.S. Yadav	Driver
11.	Sh. Girish Chander Singh	Guest House Attendant cum Cook
12.	Sh. D.P. Saklani	Guest House Attendant cum Cook (Joined on 19.3.04)
13.	Sh. Lal Bahadur	Chowkidar
14.	Sh. Har Prasad	Chowkidar
15.	Sh. Mahendra Singh	Chowkidar
16.	Sh. Mine Ram	Chowkidar
17.	Sh. Rohlu Ram	Chowkidar
18.	Sh. H.S. Manral	Chowkidar
19.	Sh. G.D. Sharma	Chowkidar
20.	Sh. Swaroop Singh	Mali
21.	Sh. Ashok Kumar	Mali
22.	Sh. Satya Narayan	Mali
23.	Mrs. Dukhni Devi	Mali
24.	Sh. Ram Singh	Safaiwala
25.	Sh. Ramesh	Safaiwala
26.	Sh. Hari Kishan	Safaiwala

(E) 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

LIST OF 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	Geology Department 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	228/B, 2nd Avenue Sainik Puri SECUNDERABAD - 500 094	Member
8.	Prof. A.K. Jain	Department of Earth Sciences Indian Institute of Technology ROORKEE - 247 667	Member
9.	The Scientific Advisor	To the Defence Minister Ministry of Defence South Block NEW DELHI - 110 002	Member
10.	Shri Arun Sharma	Joint Secretary (F&A) Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member
11.	Shri P.C. Mandal	Director General Geological Survey of India 27, Jawaharlal Nehru Road KOLKATA - 760 016	Member

12.	Shri Y.B. Sinha	Director (Exploration) Jeevan Bharti Building Tower -II, 9th Floor, O.N.G.C. 124, Indira Chowk NEW DELHI - 110 001	Member
13.	Dr. P. Nag	Surveyor General of India Surveyor General's Office Hathibarkala DEHRA DUN - 248 001	Member
14.	Dr. G.D. Gupta	Adviser & Head Seismology Division Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	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 – 248001	Non-Member Asstt. Secretary

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

Sl. No.	Name	Address	Status
1.	Prof. S.K. Tandon	Dept. of Geology University of Delhi 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	House No.1-10-284/ Lane - 5, Brahmanwadi Begumpet, HYDERABAD - 500 016	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 Navranpura 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	G.M.(Geology) KDMIPE, ONGC Ltd.9, Kaulagarh 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.258Sector - 17PANCHKULA - 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.	Representative of the Secretary	Member Department of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI – 110 016.	
4.	Shri Arun Sharma	Joint Secretary (F&A) Department of Science & Technology Technology Bhawan 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	Jt. Controller of Defence Accounts (R&D) 107, Rajpur Road, DEHRA DUN - 248 001	Member
7.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member
9.	Shri Harish Chandra	F&AO 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.	Dr.A.C. Nanda	Scientist 'G' Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member
3.	Shri A.K. Sharma	Suptt. Engineer Dehra Dun Central Circle C.P.W.D. Nirman Bhawan 20, Subhash Road DEHRA DUN - 248 001	Member
4.	Shri Rajesh Agrawal	Chief Engineer (Civil) Deptt. of Civil Engineer Shed No.32 Oil & Natural Gas Corporation DEHRA DUN - 248 001	Member
5.	Shri A.J.Kurian	Director Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member
6.	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 2005 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 2005.
2) In the case of Income & Expenditure Account of the surplus for the year ended on 31st March 2005.
3) In the case of Receipt & Payment Account of the receipts and payments for the year ended on 31st March 2005.

For A.K. Kashyap & Co.
Chartered Accontants

Sd/-

(Ashok Kashyap)
F.C.A. Partner

Date : 26th September, 2005
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 31.03.2005

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. Depreciation on Fixed Assets has not been provided as per past convention. Those fixed assets that have become obsolete and out dated are written off from the books of accounts at the time of disposal of the same at its book value.
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 31.03.05.
ii) Balance of Debtors and Creditors as on 31.03.05 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 expenses 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 2005

Amount in Rupees

Particulars		Current Year	Previous Year
LIABILITIES			
Corpus/ Capital Fund	1	404,389,287	297,051,440
Reserves and Surplus	2	-	-
Earmaked/ Endowment Fund	3	2,754,647	447,748
Secured Loans & Borrowings	4	-	-
Unsecured Loans & Borrowings	5	-	-
Deferred Credit Liabilities	6	-	-
Current Liabilities & Provisions	7	3,700,604	1,746,287
Pension Fund	8	32,594,111	27,581,513
CPF/GPF Fund	9	32,520,662	28,388,885
Total		**475,959,311**	**355,215,873**
ASSETS			
Fixed Assets	10	276,677,235	242,865,288
Investment from Earmaked/ Endowment Fund	11	19,255	17,773
Investment- others	12	-	-
Current Assets Loans & Advances	13	134,148,048	56,362,414
Pension Fund	14	32,594,111	27,581,513
CPF/GPF Fund	15	32,520,662	28,388,885
Total		**475,959,311**	**355,215,873**

STATEMENT OF ACCOUNTS

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 : 26.09.2005
Place : Dehradun

Sd/-	Sd/-	Sd/-
(B.R. Arora)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
Income & Expenditure A/c for the period ended 31st March 2005

Amount in Rupees

S.No.	Particulars		Current Year	Previous Year
A	**INCOME**			
	Income from sales/ services	16	-	-
	Grants/ Subsidies	17	74,950,000	58,300,000
	Fees/Subscription	18	19,370	9,000
	Income from Investments (Income on Invest from Earmarked/ Endowment - Fund)	19	121,544	43,100
	Income from Royalty, Publication etc.	20	58,391	62,160
	Interest earned	21	1,159,488	1,334,257
	Other Income	22	2,843,280	1,445,308
	Increase/ Decrease in stock of Finished goods & WIP	23	-	-
	TOTAL (A)		**79,152,073**	**61,193,825**
B	**EXPENDITURE**			
	Establishment Expenses	24	45,651,833	43,564,683
	Other Research & Administrative Expenses	25	12,210,716	9,923,113
	Expenditure on Grant/ Subsidies etc.	26	-	-
	Interest/ Bank Charges	27	8,190	7,426
	TOTAL (B)		**57,870,739**	**53,495,222**
	Surplus/ (Deficit) being excess of Income over Expenditure (A - B)		21,281,334	7,698,603
	Transfer to Special Reserve (Specify each)		-	-
	Transfer to / from General Reserve		-	-
	GRAND TOTAL		**79,152,073**	**61,193,825**

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 : 26.09.2005
Place : Dehradun

Sd/-	Sd/-	Sd/-
(B.R. Arora)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

STATEMENT OF ACCOUNTS

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
Receipts & Payments Account for the year ended 31st March 2005

Amount in Rupees

Particulars		Current Year	Previous Year
RECEIPTS			
Opening Balance	30	7,786,329	16,016,961
Grants - in - Aids	35	88,500,000	77,300,000
Grants - in - Aids (Ear Marked)	36	5,500,175	705,000
Loan & Advances	28	20,519,828	12,243,845
Fees/Subscription	18	19,370	9,000
Income from Investments	19	121,544	43,100
Income from Royalty, Publication etc.	20	58,391	62,160
Interest earned on Loan to Staff	21	1,159,488	1,334,257
Other Income	22	2,843,280	1,445,308
Investment	32	15,783,000	6,786,426
Decrease in stock (publications)		-	17,655
		142,291,405	**115,963,712**
PAYMENTS			
Establishment Expenses	24	45,651,833	43,564,683
Other Administrative Expenses	25	12,210,716	9,923,113
Interest/ Bank Charges	27	8,190	7,426
Loans & Advances	29	20,257,280	10,453,608
Investments	33	9,500,000	15,784,426
Fixed Assets	34	29,194,398	27,953,380
Ear Marked Fund Expenses	37	3,194,758	459,055
Grant - in - Aid (Ear Marked) Refunded	38	-	31,692
Closing Balance	31	22,246,227	7,786,329
Increase in value of closing Stock (Publications)		28,002	-
		142,291,405	**115,963,712**

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 : 26.09.2005
Place : Dehradun

Sd/-	Sd/-	Sd/-
(B.R. Arora)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

STATEMENT OF ACCOUNTS