WADIA INSTITUTE OF HIMALAYAN GEOLOGY

ANNUAL REPORT

2003 - 2004

जय विज्ञान JAI VIGYAN

2004

वैज्ञानिक जागरूकता वर्ष

Year of Scientific Awareness

Cover Photo :

- Isolated tooth of Eocene primates from the Subathu Group of Kalakot, Jammu & Kashmir.
- Lithological cross section of newly discovered Peat deposit of Dayara Grassland, Bhagirathi Valley, Garhwal Himalaya.

Credits : D.R. Rao, V.P. Singh, Rambir Kaushik

Text Typed : D. P. Chowdhary

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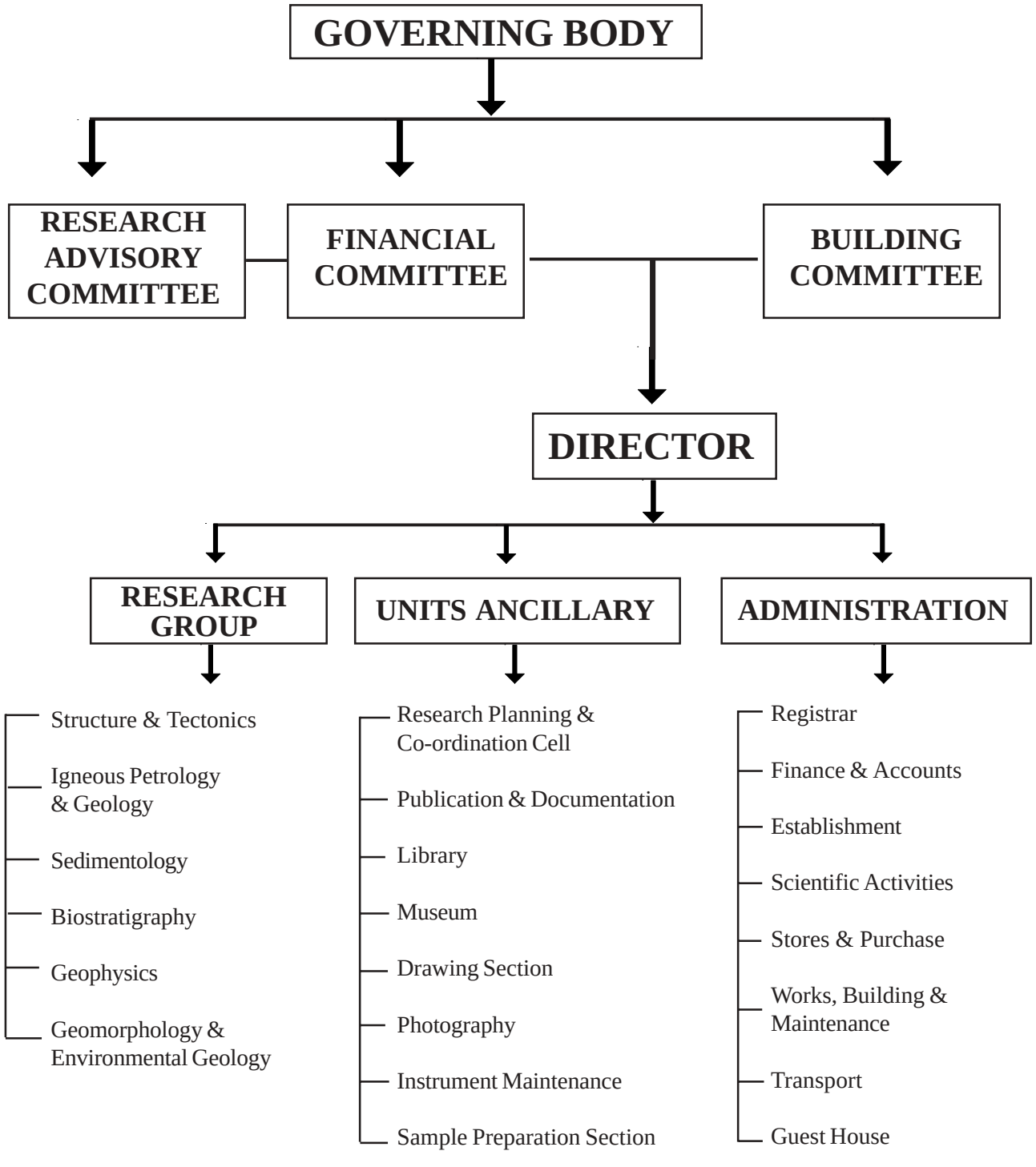
WIHG ORGANISATIONAL SET-UP



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OVERVIEW

Baldev Raj Arora, Director

Wadia Institute of Himalayan Geology is an autonomous Institute of the Department of Science & Technology, Government of India, devoted to basic and applied research on geology, natural resources, environment, and natural disasters in the Himalaya. The scientific activities of the Institute are grouped under six divisions viz., Structure and Tectonics, Petrology and Geochemistry, Biostratigraphy, Sedimentology, Geophysics, Geomorphology and Environmental Geology. To promote inter-disciplinary research under the 10th Five Year Plan, research activities of the Institute are grouped into following thrust areas.

- Geodynamic 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

Structural studies supported by clay model experiments along with geochemical and mineralogical inputs from Ladakh, Himachal Pradesh and Uttaranchal were pursued to understand the geodynamic and crustal evolution of the Himalaya.

The laboratory clay deformation studies under controlled boundary conditions indicate that inhomogeneous strain at late stages of deformation, in models with frontal and oblique thrust ramp geometries, results in the formation of extension faults on the hanging wall parallel to the axis of maximum compression.

Geochemical and mineralogical studies carried out on gabbroic rocks of the Nidar Ophiolitic sequence suggest their island arc affinity. For the first time 'plagiogranites', considered to be end products of differentiation of tholeiitic magmas, were reported from the north of Kyun Tso in eastern Nidar Ophiolitic sequence.

The geochemical and fluid inclusion studies of granitoid rocks of Askot Crystallines of eastern Kumaun Himalaya suggest that the hybrid compositions observed in granitoids indicate a two stage development, with early crystallized magmatic rocks undergoing assimilation of host rocks at a later stage. Studies on Dudatoli-Almora crystallines show that they are potential source of tin and tungsten mineralization.

Basin Evolution

Studies on sedimentary facies, stromatolitic buildups and carbon isotope excursions revealed that the deposition of the Meso-Neoproterozoic carbonates of the Lesser Himalayan sedimentary belt took place in a rimmed shelf carbonate platform. The presence of acanthomorphic acritarchs and small shelly fossils have helped in assigning the age of these carbonates (Gangolihat Dololmite and its equivalent limestones) as Vendian to earliest Cambrian. However, opinion varies to fix the position of Deoban and its equivalents above the Jaunsars (not below as commonly believed), like the Krol carbonates. This important conceptual change in stratigraphy needs further investigation. The CIA and PIA values of Berinag and Sor formations, representing deeper part of the Lesser Himalayan Basin, suggest their deposition in a warm and moist climate.

Ichnofossils recovered from the Cambrian succession of the Zanskar-Spiti region suggest the age range from Chiungchussuian stage of Lower Cambrian to Maochuangian stage of late Middle Cambrian. Ichnofossils assemblage of the Spiti basin belonging mostly to the *Cruziana* ichnofacies indicates rapid storm-generated accreting sand deposition during the early Cambrian.

Sedimentologic, magnetostratigraphic and rock magnetic studies have constrained the timing of the emergence of the Chail Thrust around 10 Ma. Palaeontological studies of the Himalayan Foreland Basin indicate the process of the Pinjor fauna (2.58 Ma to 0.6 Ma) extinction and migration around 1.72 Ma and 0.6 Ma respectively. About 45 ky ago, the present course of the Yamuna river had a depression which acted as the route for migration of the faunas that dominated the post-Siwalik time.

Natural Hazards

Analysis of data on the geoenvironmental studies of the Kullu valley in Himachal Pradesh shows an increase in

flash floods since 1988 with average recurrence interval of three years, which far exceeds the reported occurrence in the nearly 40 year interval between 1902 and 1945, indicating a rapid environmental change in the region in recent decades. Massive loss of life and property has taken place in these flood events mainly in the valley bottom zone that is constricted and heavily influenced by human activities. Landslide studies were undertaken in the Sutlej valley, and the MCT Zone in the Yamuna valley and thematic maps pertaining to slope, land use, land cover and geomorphology were prepared to depict the relationship between structure, rock type, slope angle, and moisture regime. The studies also briefly deal with the devastating 2003 Varunavat landslide in Uttarkashi.

Studies on active faults were carried out in close proximity of the MBT and HFT in Dharamsala area, Himachal Pradesh using aerial photographs and high-resolution satellite data. Traces of new active faults were mapped with fault scarps, varying in height between 4 and 20 meters, which probably developed during prehistoric large magnitude seismic events in the area.

Seismicity, seismotectonics and seismic hazard assessment investigations were carried out in the northwestern Himalaya for monitoring and analysis, site response in populated areas and seismic hazard mapping. Temporal plot of seismic activity in the vicinity of Bhatwari (Uttarkashi) seismic observatory shows an outburst of small ($M < 3$) events during the first quarter of 2003, where after quiescence followed for four months. Besides collecting phase data of more than 1500 earthquakes recorded by the analog stations in the region for further analysis, the data bulletin for May 2001 was sent to various geophysical groups in the country. Among other studies, accelerograms of 1986 Dharamsala, 1991 Uttarkashi and 1999 Chamoli earthquakes and their aftershocks were analysed to investigate the source parameters, estimating site amplification functions, and shear wave attenuation parameter Q_B in the region. Preliminary receiver function analysis of teleseismic converted phases at Bhatwari and Kothi observatories show a sharp Moho at a depth of 57 km.

Seismic hazard mapping analysis suggests that the area shaken by certain intensity earthquake in the Himalayan region is 10 to 15 times smaller than the area shaken by shallow earthquakes of the same magnitude in the intracratonic parts of North America.

Some studies were carried out on the radon gas emission in the Uttaranchal Himalaya using water and soil samples. It was observed that radon concentrations show positive relationship between depth of tube wells/hand pumps and the various geohydrological units of the Doon valley in both pre-and post-monsoon values and that the values were within the permissible limits.

Glaciology and Natural Resources

Geohydrological investigations were carried out in parts of the Uttaranchal Himalaya to ascertain the nature of water-bearing lithological units (rock-types and geomorphological units) that forms the basis for useful exploitation, and provides guidelines for groundwater exploration. It was found that the groundwater resources are mostly confined in three major rock units, i.e. fractured hard rocks, fluvial and colluvial fan deposits along the river slopes, and karst aquifer characterized by joint controlled cavities and channels in dolomite and limestone. The water quality belongs to $CaHCO_3$ and $CaMgSO_4$ hydrochemical facies except at few places where chemistry is dominated by $NaHCO_3$, and $KHCO_3$ reflecting weathering of Na and K rich feldspar present in granite rocks

The Lichenometric technique was used to date the events and activities of the Dokriani Bamak and Chorabari glaciers in the Garhwal Himalaya. In case of Chorabari, the growth rate of lichens is 0.66 mm per year. Chorabari glacier has retreated at an average rate of 5.29 m/y between 1962 and 2003. It is intriguing that the south facing glacier has recorded a much slower recession rate in comparison to the north facing glaciers in the same regime (cf. Gangotri, 20 m/y; Dokriani 18 m/y; both facing NNW).

Palaeoclimate and Environment

Palaeoclimatic studies carried out so far have shown that the Dayara meadow in Garhwal Himalaya was covered with perennial ice during ca. 5200 to 3400 cal yr. BP.

The geochemical mapping technique was used to evaluate the mineral potential of the Uttaranchal Himalaya. The effort was mainly concentrated in stream sediment geochemical survey in Bhagirathi and Bhilangana valleys of the Garhwal region. Selective enhancement of Th, U and Pb and depletion of Cu was observed near the MCT. Association of high Pb–Zn–Cu anomalies in the Garhwal Group with carbonates and presence of thrusts/ faults indicates that they are potentially related to sulphide mineralization. On the other hand, conspicuous high anomaly of U and Th was observed all along the MCT. The anomalous trend between Sainj and Ghuttu seems to be most potential for U-Th mineralization.

The generation of the database of natural resources was initiated in the Rudraprayag District of Uttaranchal, and the activity with time will be stretched to the other parts of the Himalayan region.

Northeast Himalaya

Structural studies in the Arunachal Himalaya (Siang, Syom and Subansiri valleys) have revealed that the Eastern Syntaxis represents a major antiformal structure across the Siang river. Crystalline rocks occupy the hinge zone of the syntaxis exposed in southern Tibet. The Bame Fault is the latest structure which represents a neotectonic dextral tear fault.

The sedimentological, palaeobiological and carbon isotopic data on the Buxa Dolomite suggest deposition in shallow marine carbonate platform in Arunachal and Sikkim Lesser Himalaya. A highly diversified organic-walled microfossil assemblage of Neoproterozoic age has been discovered from the Buxa Dolomite in West Siang district of Arunachal Pradesh.

Riphean-Vendian microbialites have been identified in the Rangit window of southern Sikkim. The carbon isotope excursions of the Buxa Dolomite suggest that the environment of deposition was highly favourable for microbial growth in photic zone. Micropalaeontological studies of Palaeogene sediments in Siang valley were initiated.

Neotectonic investigations between HFT (Himalayan Frontal Thrust) and Main Central Thrust (MCT) have revealed that the Arunachal region is tectonically active in East and West Siang districts and West Kameng district. The seismicity of the NE Himalaya is mainly related to major thrusts i.e. HFT, MBT and MCT. Neotectonic movements have been recorded along the boundary thrusts that define the boundaries of lithotectonic terranes and along the tear faults.

Permian Abor Volcanics from Arunachal Lesser Himalaya have been studied with emphasis on geochemistry and petrogenesis. Two types of basalt have been identified on the basis of petrography.

Academic Pursuits

The research progress of on-going projects were reviewed by the Research Advisory Committee and several new initiatives were suggested to promote research in new emerging areas. Several new measures are launched to provide a better working environment and to grow national and international interactions.

The research investigations carried out during the year have lead to 64 research papers both in national and international journals and 70 research papers are in press / communicated. In addition nearly 100 papers were presented in the international and national conferences/ symposia, number of these being invited/ keynote/ review talks. Further, as many as 9 Ph.D. thesis have been either awarded or submitted for the award of Ph.D. degrees.

The Institute continued the publications of "Himalayan Geology". During the year volumes 24(2) and 25(1) were brought out. The volume 9 of the in-house Hindi magazine "Ashmika" was published, including several scientific articles of societal interests.

The Institute organized a three day Seminar on "Role of Fluids in the Crustal Evolution : special emphasis on the Himalayan magmatism, tectonism and metallogeny" from February 4-6, 2004.

The Institute, in collaboration with IIRS, Dehradun and International Institute for Geoinformation Science and Earth Observation (ITC), Netherlands, organized a Workshop on "Methodology for Seismic Microzonation and its Applications for Society" during November 10-11, 2003. The Institute also acted as a host to organize the annual meeting of Indian Geological Congress and a Conference on "Natural Hazards (Earthquake and landslides) : Challenges, Perspectives and Societal Dimensions with focus on the State of Uttaranchal" during December 26-28, 2003, which was inaugurated by the Hon'ble Minister of State, Ministry of Science and Technology, Shri Bachhi Singh Rawat.

Infrastructural Developments

The Institute has launched major initiatives to upgrade its in-house analytical laboratories. A state-of-art ICP-MS facility was established and a purchase order for the new generation XRD was placed. Four broadband seismic sensors, engineering seismograph, advance polarizing research microscope with image analyzer, zoom microscope, electronic balances and dust monitoring analyser are added for accelerating research in the areas of geophysics, optical and experimental petrology, biostratigraphy, rock magnetism etc. The computational facilities are upgraded and internet and in-house networking were established.

Other Highlights

- Under the Flexible Complementary Promotional Scheme, 19 Scientific and Technical staff at different cadres were promoted. One new position of Scientist 'C' and one of Scientist 'B' was filled. In the establishment section an additional post of Office Superintendent was created, resulting in the chain promotion of 2 staff. One post of Stores & Purchase

Officer and one post of Guest House Attendant were filled.

- The long-standing need of Guest House in the campus is near realization. The civil work of 15-room Guest House is completed and auxiliary furnishing is at an advanced stage.
- The Institute celebrated National Science Day, Technology Day, Foundation Day and Founder's Day with usual enthusiasm.
- In order to promote Hindi in day-to-day work, general orders, circulars, notices, etc. were issued both in Hindi and English. The Hindi version of Annual Report of the Institute was published and circulated. The Hindi fortnight was celebrated from September 15-30, 2003 and during this period various programmes in Hindi were organized to encourage the use of our National language.

In the dynamic growth of the Institute, the 2003-2004 was a year of major transition. A new Governing Body under the Chairmanship of Prof. K.S. Valdiya was reconstituted w.e.f. November, 2003. A new Research Advisory Committee and Finance & Building Committees were also reconstituted by the Governing Body for the period of 2003-2005.

Dr. N.S. Virdi, Director, after his meritorious service of 27 years to the Institute, including the last three years as Head of the Institution, superannuated on June 30, 2003. The undersigned took over as the Director of the Institute with effect from October 1, 2003. Dr. A.C. Nanda, Scientist 'G' steered the Institute as Director-Incharge during the interim period.

The Annual Report provides major highlights of all scientific as well as related activities. We hope you will enjoy reading the report and we welcome your kind response and suggestions.

BALDEV RAJ ARORA
Director

PROGRESS IN RESEARCH PROJECTS

1. GEODYNAMIC AND CRUSTAL EVOLUTION

The structural investigations, including the clay model studies, along with geochemical and mineralogical inputs from Ladakh, Himachal Pradesh and Uttaranchal are used to understand the geodynamic and crustal evolution of the Himalaya. The structural studies carried out in eastern Ladakh reveal that the obduction has occurred in two phases. The laboratory clay deformation studies under controlled boundary conditions reveal that the inhomogeneous strain at late stages of deformation models with frontal and oblique thrust ramp geometries results in the formation of extension faults on the hanging wall. Faults with similar geometries occur in the Upper Satluj River Basin of the Tethys Himachal Himalaya. The experimental results throw light on the understanding of the present day normal faulting and related active tectonics in the region.

The geochemical and mineralogical studies carried out on gabbroic rocks of the Nidar Ophiolitic sequence suggest that they have island arc affinity. For the first time 'plagiogranites', considered to be end products of differentiation of tholeiitic magmas were reported to the north of Kyun Tso in eastern Nidar Ophiolitic sequence.

The geochemical and fluid inclusion studies of granitoid rocks of Askot Crystallines of eastern Kumaun Himalaya suggest that the hybrid compositions observed in granitoids indicate a two stage development, with early crystallized magmatic rocks undergoing assimilation of host rocks at a later stage. The P-T estimates of these host crystalline rocks in the Dudatoli-Almora region indicate temperatures in the range of 500 to 650 ^{o}C, and pressures in the range of 6 to 8 kbar.

Further, the mineralization studies carried out in the Dudatoli-Almora crystallines suggest that, they are potential source of Sn-W mineralization. The Sn-W mineralization is observed as cassiterite, scheelite and wolframite, and are quite conspicuous in the fluorine bearing pegmatites and quartz veins in the metagranitoids, and in vicinity calc silicates rocks. From the studies carried out so far, it is envisaged that the idea of fluids vis-à-vis source rock chemistry, metamorphism and deformations coupled with lithotectonic setup will help to locate new occurrences of the Sn-W mineralization and polymetallic sulphides in the crystalline rocks of Uttaranchal Himalaya.

1.1 SUB PROJECT

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

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

In northwest Himalaya the collision began in mid-Cretaceous with the suturing of island arc to the Eurasian Plate, and proceeded during Cenozoic, with the obduction of the island arc rocks on to the Indian Plate. The obduction occurred in two phases in eastern Ladakh exhibited by two different orientations in their strike continuity separated by N-S trending Tsokar Transfer Fault, indicating diachronous younging of Indus Suture Zone from west to east. In the early phase of obduction, the island arc and the ophiolitic melange trending NW-SE (equivalent to Dras Island Arc) observed to west of Rumtse and thrust southward on the Tethyan sedimentary sequence. In the later phase, the obduction involved Nidar Ophiolitic Complex, obliquely cross cutting the Eocene-Oligocene sedimentary sequence of the Indus Formation. The Nidar Ophiolitic Complex shows pop-up structures as it is thrusting over the Indian plate to the south and the Asian Plate to the north. The Tso Kar Transfer Fault separates the obducted rock of the early phase and the Nidar Ophiolitic Complex of late phase. The change in the angle of collision (about 16^{o}) between the early WNW-ESE and the late collision trend NW-SE signifies anticlockwise rotation and reorientation of the Indus Suture Zone of eastern Ladakh. The contact between the southern part of the Indus Suture Zone and the northern part of the Tethyan sedimentary sequence form a major shear zone observed to the west of Rumtse exhibit late dextral strike slip movement.

The studies of the gabbroic rocks of the Nidar ophiolitic sequence show the rocks to have ophitic to sub-ophitic texture, and are comprised of olivine, clinopyroxene, plagioclase, amphiboles, magnetite and spinel minerals. The olivine from Nidar gabbro is comparable to island arc type, and their forsterite content is around 72 %. The low Na_2O and high Mg # (81 to 99%) of clinopyroxene in these rocks are consistent with boninitic composition. The plagioclase in these rocks is very calcic rich, with anorthite content ranging from 78 to 88%. Nidar gabbros contain variable composition of amphiboles, and have mostly the paragsite, tschermakite or magnesio-hornblende compositions. The studies of fluid inclusions in these rocks showed three types of inclusions, which reveal the presence of high saline fluids. The

geochemical and mineralogical studies of Nidar Gabbro reveal that, they are formed in an island arc environment.

Also, the occurrence of high-SiO_2, low K_2O leucocratic rocks, the *'oceanic plagiogranite'*, within the basic and ultrabasic rocks of the ophiolites and modern oceanic settings are of particular interest because of their extreme composition and controversial origin. Ophiolitic sequences are considered incomplete without these rocks. However, these rocks are not present in all the known ophiolite sequences in the world. The studies carried out in eastern Ladakh reports the occurrence of plagiogranite to the north of Kyun Tso, within the Nidar ophiolitic sequence. Plagiogranites occur as intrusive within the gabbro, in the northern part of the ophiolitic sequence. Chemically, they are classified into tonalite and trondhjemite (Fig. 1). They show nearly flat REE pattern, and fractionation relation that are comparable with the host gabbro. The origin of these rocks is explained by fractional crystallization aided by filter pressing processes of sub-alkaline tholeiitic magmas.

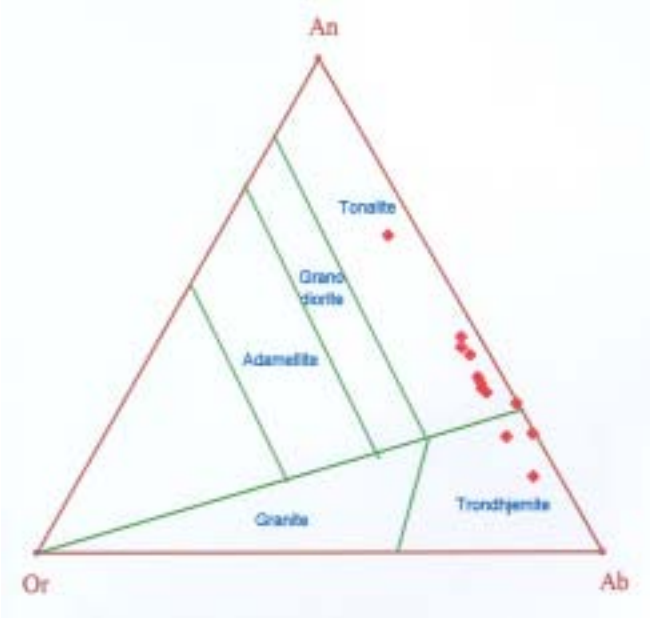


Fig. 1. The AFM ternaries plot, showing the plotting plagiogranites of Nidar Ophiolitic Complex, eastern Ladakh in tonalite to trondhjemite fields.

Further, in the recent fieldwork carried out in Tso-Morari and Pongong-Tso area of Ladakh, kyanite and sillimanite bearing eclogites were observed. The detail mineralogical and fluid inclusion studies of these rocks are in progress.

1.1 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)

The Dudatoli-Almora Crystallines are regionally deformed and metamorphosed, and are ideal for mineralization with intrusive granitoids. In the area, the granitoids are S-type, peraluminous and rich in fluids. Keeping in mind the lithotectonic setup, the grade of metamorphism in the area, the nature of fluids and probable source materials, the Dudatoli-Almora crystallines are potential source of Sn-W mineralization. The Sn-W mineralization is observed in the area as cassiterite (brown in colour), scheelite (colourless) and wolframite (dark brown in colour). These are quite conspicuous in the fluorine bearing pegmatites and quartz veins in the metagranitoids, and in vicinity calc silicates rocks.

The geological field investigations carried in Pauri district of Garhwal Himalaya during March 2004 indicate that there are definite evidences of synsedimentary polymetallic sulphide mineralizations (Fig. 2a), besides the concordant remobilized mineralization (Fig. 2b) in the Dudatoli Crystallines. In addition, galena bearing carbonate veins ranging in thickness from 0.5 to 8 cms are observed in the amphibolitic rocks (Fig. 2c). There are quite conspicuous horizons in the area in which native sulphur and '*Silajeet*' occur in the calcareous quartzites (Fig. 2d). A thick horizon – above 1 m thick band of arsenopyrite within the quartzite is also observed. Further in east, the EPMA studies of arsenopyrite occurring in Askot pollymetallic sulphides shows that it is pure Fe species, formed from high temperature metasomatic processes. The As wt% in it, suggest temperatures of formation to be around $450 \pm 20\ ^{O}C$.

The petrological and mineralogical studies carried out on the Almora crystallines indicate that, there are three distinct paragenetic sequences of minerals. On the basis of textures, three generations of garnet are observed. The P-T estimates made on Dudatoli-Almora Crystallines, using EPMA data indicate, T varying from 500 to 650 ^{o}C, and P varying from 6 to 8 kbar. The pressure estimates are based on garnet-plagioclase-muscovite-biotite-quartz geobarometers, and that of temperature are based on various models of garnet-biotite geothermometers.

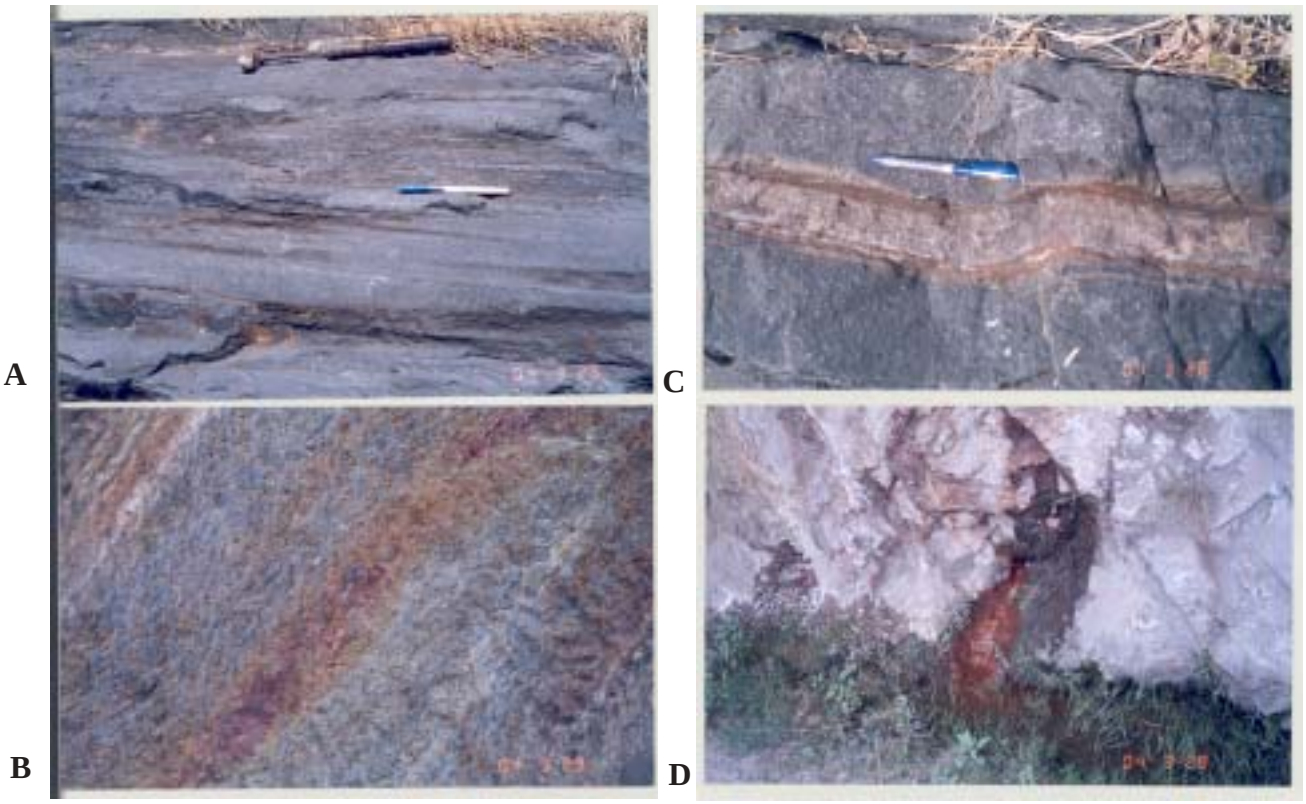


Fig. 2. Mineralization in the Dudatoli Crystallines in Pauri district, Garhwal Himalaya. A– Synsedimentary polymetallic sulphides in fine grained mica schist, B – Polymetallic mineralization in coarse mica schist, C – Galena in carbonate veins in amphibolite, and D – 'Silajeet' in quartzite.

Further, the structural state study on feldspar from granitoids indicated the alkalifeldsphar are having $\Delta > 0.3$. A melt temperature $>700^0$C at 5kbar pressure for the granitoids is determined on the basis of homogenization experiments.

The fluid inclusion studies in magnesite of the Chandak deposit were also carried out. They show inclusions varying from equant to irregular in shape, whereas they are semiregular in dolomites. The inclusions are mostly bi-phase in nature with a gas bubble forming 10 to 30 vol. %. The carbonic fluid is present in Type II bi-phase inclusions, however a gas CO_2 phase is not visible at room temperature (cf: 22^0C). Considering the abundance of inclusion types and their fluid contents, an influx of free carbonic phase from external reservoir cannot be invoked.

The SEM studies of the barite and quartzite of Kumla area, Tons valley, indicate distinct features, like stretching of the inclusions, sweeping of the cavities, decrepitation clusters and cavity deformation which envisage varied degree of re-equilibration of the trapped fluids, and also point to partial resetting of their isochors.

In addition, the geochemical and fluid inclusion studies of granitoid rocks of Askot Crystallines of eastern Kumaun Himalaya are carried out. These granitoid rocks have intrusive relations with host schistose and augen gneisses. They are medium to coarse grained and show textures varying from equigranular to porphyritic. The fluid inclusion studies of these rocks show four types of inclusions (Fig. 3): (i) type I, vapour rich biphase aqueous inclusions, (ii) type II, liquid rich biphase saline aqueous inclusions, (iii) type III, monophase carbonic inclusions, and (iv) type IV, carbonic-aqueous inclusions. The type I and type II inclusions show primary features and are interpreted to have been trapped during the initial crystallization of the granitic magma. The type III and IV inclusions are of syn- to post-granite emplacement as reflected by their primary to secondary nature. The overall distribution pattern of Type I to Type IV inclusions suggest

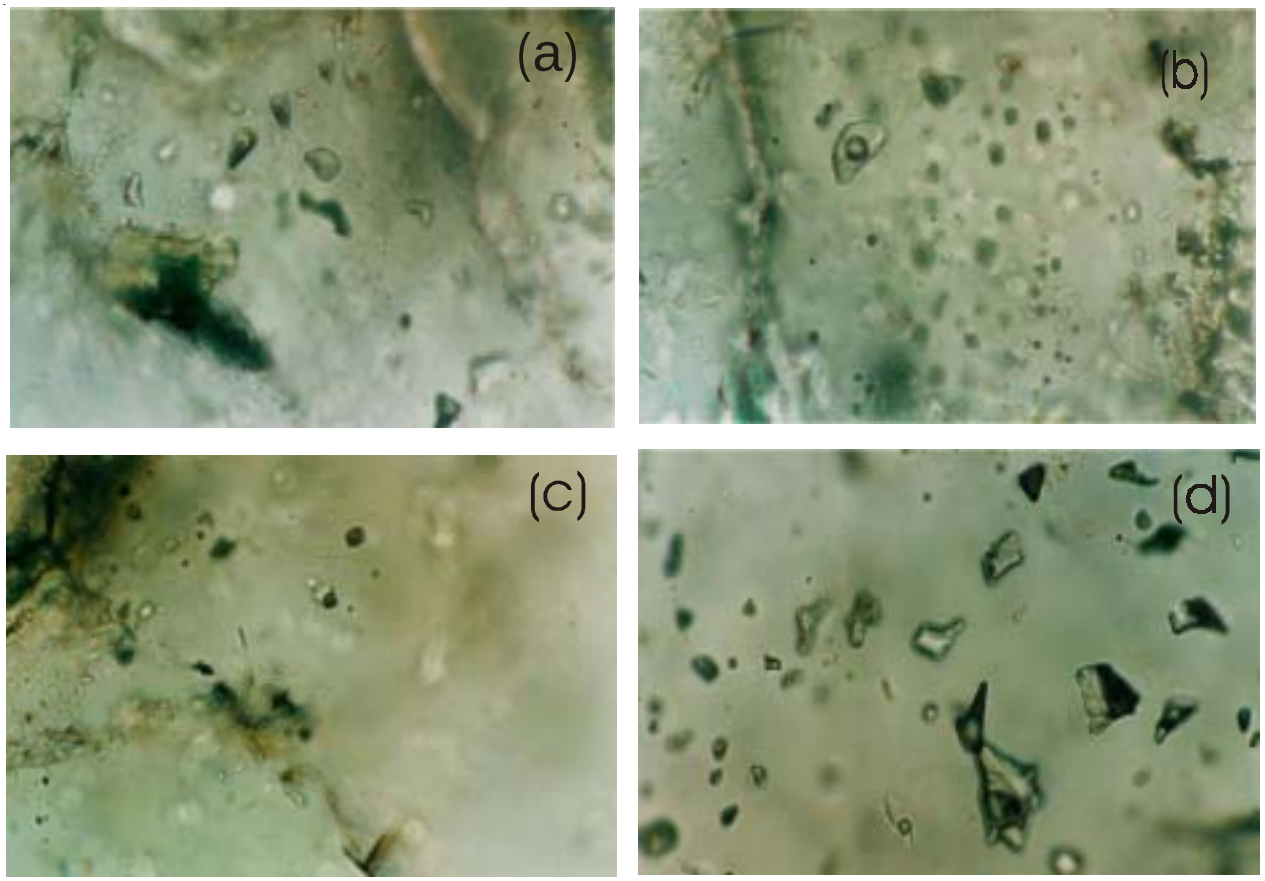


Fig. 3. The photomicrographs showing four types of fluid inclusions in the granitoid rocks of Central part of Askot Crystallines (x 500). (a) Type I vapour dominated aqueous inclusions, (b) Type II biphase liquid rich saline aqueous inclusions, (c) type III monophase carbonic inclusions coexisting with biphase inclusions, and (d) Type IV carbonic-aqueous inclusions. They collectively represent a fluid boiling as well as a metamorphic environment.

that, the early fluid trapped during the crystallization of magma are of saline aqueous nature. The studies carried out suggest that, the primary saline aqueous inclusions, type I and type II, are a part of the magmatic melts that crystallized the granitic rocks. This argument gets support from the number of geochemical and petrographic signatures observed. However, the presence of syn- to post-granite carbonic fluids, along with the boiling evidence of the aqueous fluids, also argues for a hybrid environment for these rocks. The observed high corundum normative values and peraluminous nature also reflect the change of composition in these rocks. It is concluded that the hybrid compositions observed in these rocks have a two stage developmental influence on them, with early crystallized magmatic rocks undergoing assimilation of host rocks at a later stage.

1.3 SUBPROJECT

Study of frontal and oblique ramps in the Western Himalaya

(A.K.Dubey, Keser Singh, B.S.Rawat, S.S. Bakhuni, and R.J. Perumal)

Oblique thrust ramps are very common in different parts of the Himalaya but they have been either ignored or described as strike-slip faults. These are important structures as they are associated with regional stress concentration and inhibit motion of thrust sheets. During superposed deformation they may reactivate as normal faults. Hence their study is important in the seismicity prone area. These oblique ramps were studied in the Kangra re-entrant area of the Himachal Himalaya. It was found out that the re-entrant area is in fact an oblique ramp that was formed

prior to the formation of the Himalaya as normal fault. The fault later reactivated as thrust oblique ramp during the Tertiary Himalayan orogeny.

The structures related to oblique fault ramps were simulated in the laboratory using models of modeling clay and Plasticine. The experimental results reveal that when a model is deformed under the general strain boundary condition (i.e. simultaneous extension along horizontal and vertical axes), inhomogeneous deformation ensues at late stages of deformation when the model extends beyond the height of the compressing blades. The inhomogeneous deformation of models with frontal thrust ramp geometry results in the formation of strike-slip faults. Late stages in the deformation of models with frontal and oblique thrust ramp geometries are characterized by the simultaneous development of extension faults in the hanging wall and strike slip faults in the footwall. The experimental results help in understanding the following tectonic features of the Tethys Himalaya.

(i) The formation of normal faults parallel to the axis of maximum compression.
(ii) Simultaneous development of normal faults at higher elevations and thrust faults at lower elevations, and
(iii) Absence of present day crustal shortening in Tibet.

2. BASIN EVOLUTION

In order to understand the Basin evolution aspects of sedimentary successions of Himalaya the sedimentological, palaeontological and isotopic studies have been carried out.

The sedimentary facies, stromatolitic buildups and carbon isotope excursions of Meso-Neoproterozoic carbonates of the Lesser Himalayan sedimentary belt suggest their deposition in a rimmed shelf carbonate platform. The presence of acanthomorphic acritarchs play an important role for assigning the age of these carbonates (Gangolihat Dololmite and its equivalent limestones). However, their exist other opinion that, the Deoban and its equivalents must occupy the stratigraphic position above the Jaunsars (not below as commonly believed), like the Krol carbonates. This important conceptual change in stratigraphy would thus necessitate a fresh re-interpretation of the tectono-stratigraphic set up of the Lesser Himalayan geology. Further, the discordant sedimentary and basic volcanics relationships in Berinag and Sor formations are found to be important as they gives some clue for sensing the bathymetry of the basin. It has been considered that this discordant relationship perhaps represent the deeper part of the Lesser Himalayan basin. The CIA and PIA value of these sediments suggest their deposition in a warm and moist climate.

The diverse assemblages of ichnofossils recorded from the Cambrian successions of the Zanskar-Spiti region are ranging in age from the Chiungchussuian stage of Lower Cambrian to Maochuangian stage of late Middle Cambrian. The ichnofossils of Spiti basin belong mostly to the Cruziana ichnofacies which reveal that during the early Cambrian the region was subjected to rapid storm-generated, accreting sand deposition.

The timing of emergence of Chail Thrust is constrained to be around 10 Ma based on the various sedimentologic parameters, magnetostratigraphy and rock magnetism studies. It has been inferred that proto- Beas entered the Himalayan foreland basin also around 10 Ma.

Further, from the palaeontological studies of the Himalayan Foreland basin indicate that the process of the Pinjor Fauna (2.58 Ma to 0.6 Ma) extinction and migration started respectively at 1.72 Ma and after 0.6 Ma.. Pinjor Fauna is widely compared with the equivalent faunas from Mynamar, Java, South China, Japan and Taiwan. Evidence indicates that about 45 kyrs back, the present course of River Yamuna had a depression, which acted as route for the migration of the faunas. Thus the eastern route for migration, which opened for the first time probably in the Pinjor, became dominant in post-Siwalik times.

2.1 SUB PROJECT

Evaluation of Bio-event stratigraphy in the Cambro-Ordovician succession of Zanskar–Spiti Himalaya and buildup of reproducible Palaeontological database for the Lower Paleozoic succession of Tethyan Himalayan regions

(S.K. Parcha)

Field work was carried out in the Zanskar region of Ladakh Himalaya, wherein two sections were measured to prepare the litho-biostratigraphic columns and marked new faunal horizons.

The diverse assemblages of ichnofossils recorded from the Cambrian successions of the Zanskar-Spiti region includes the ichnogenra as *Dimorphichnus* sp.; *Rusophycus* sp.; *Monomorphichnus* sp.; *Gordia* sp.; *Chondirites* sp.; *Bergaueria* sp.; *Planolites* sp.; *Gyrochorte* sp.; *Skolithos* sp.; *Phycodes* sp.; *Diplichnites* sp.; *Trichophycus* sp.; *Cruziana* sp.; *Neonerites* sp.; *Helminthopsis* sp.; *Taphrhelminthopsis* sp., trilobite scratch marks along with various worms and burrows which are ranging in age from

the Chiungchussuian stage of Lower Cambrian to Maochuangian stage of late Middle Cambrian. The ichnofossils belong mostly to the *Cruziana* ichnofacies. The presence of *Cruziana* ichnofacies in the Spiti basin revealed that during the early Cambrian the region was probably subjected to rapid storm-generated, accreting sand deposition (Fig. 4).

The trace fossil assemblage recovered from the basal part of the Lower Cambrian succession of the Spiti basin permits the interpretation of the palaeoecologic conditions. The ichnocoenosis is dominated by a high behavioral diversity ranging from the suspension feeders to deposit feeders, displaying cubichinal, fodinichnial and domichinal behaviors. The Lower Cambrian benthic palaeocommunity thus, was dominated by annelids or similar worm-like animals living principally within the sediments, whereas, the trilobites were thrashing on the sea floor. The transition from an anaerobic to aerobic condition was distinctly marked by a faunal change from endobenthic soft-bodied, deposit feeders to epibenthic grazers.

New trilobite horizons were found in the middle to upper Karsha Formation and in the Kurgiakh Formation. The new fauna identified include both polymerid and agnostid trilobites indicate an age from Middle Cambrian to early Late Cambrian. The structural framework of the rocks exposed along the Suru valley in the NW of Tangzee village of the SE part of Zanskar region of Ladakh Himalaya is indicated in Fig. 5.

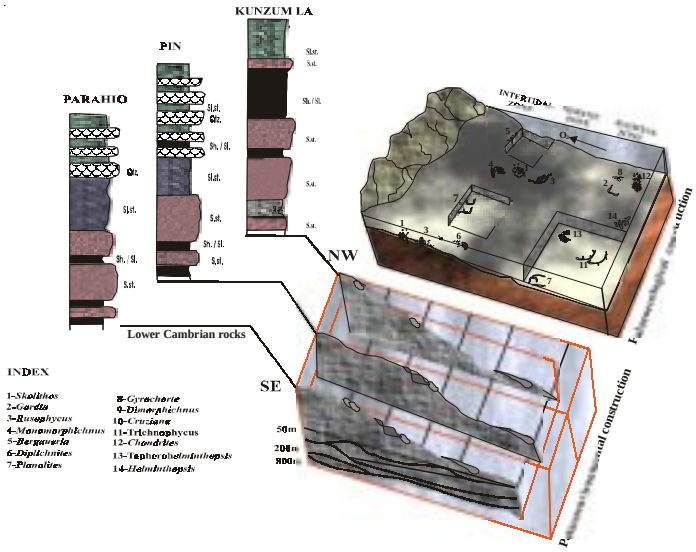


Fig. 4. Schematic representation of palaeoenvironmental depositional setting and palaeoecological distribution of Ichnofossils in the Early Cambrian rocks of the Kunzum La, Pin and Parahio sections of the Spiti region of Tethys Himalaya.

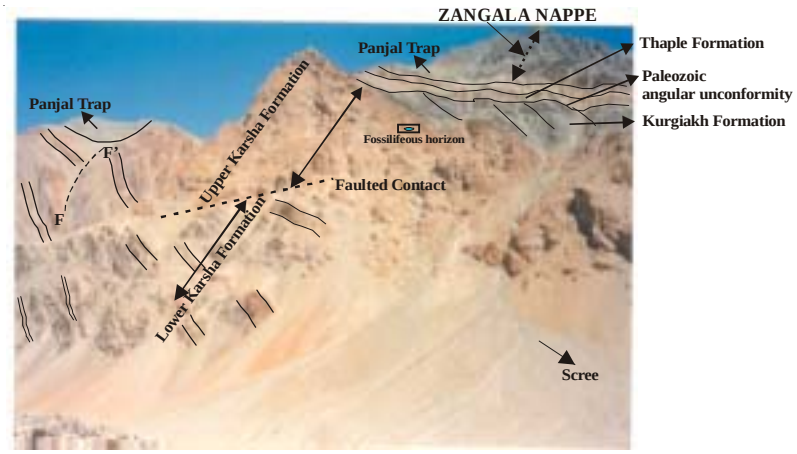


Fig. 5. Structural framework of rocks outcropped along the Suru valley in the NW of Tangzee village of the southeastern part of the Zanskar region of Ladakh Himalaya.

The Biometric analysis is being carried out jointly with Prof. P.K. Saraswati and Prof. S.V. Sabnis of I.IT., Mumbai. In this study, the Biometric analysis technique has been applied to classify the Cambrian trilobite genera *Hundwarella* and *Iranoleesia* from India.

2.2. SUBPROJECT

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

(R.J. Azmi)

The earlier report of typical Precambrian - Cambrian boundary (~544 Ma) marker protoconodonts from the *Inner Carbonate Belt* of the Kumaun Lesser Himalaya has been substantiated further by additional rich recovery of Lower Cambrian small shelly fossils [e.g. numerous specimens of mineralized cyanobacterial tubes of *Spirellus* (Fig. 6) and *Obruchevella*, agglutinated foraminiferal tubes of *Platysolenites* and hyperamminids, and large-sized hexactine sponge-spicules] from the wide-spread localities of *Inner Carbonate Belt* of the Garhwal – Kumaun region (Deoban–Tiuni area in Chakrata Hills in Garhwal and Jhiroli-Bauri and Chandak-Bans areas in Kumaun). These microfossil evidences firmly establish that the Deoban and Gangolihat carbonates of the Inner Lesser Himalaya are undoubtedly equivalent to Krol carbonates of the Outer Lesser Himalaya, and both carbonates are of Vendian to earliest Cambrian age. Thus the chronostratigraphic revision of the existing view of Riphean age (~1600 – 600 Ma) for the Deoban and its lithostratigraphic equivalents in the Inner Lesser Himalaya, based on stromatolites, is inevitable. According to this age revision, the Deoban and its equivalents must occupy the stratigraphic position above the Jaunsars (not below as commonly believed), like the Krol carbonates. This important conceptual change in stratigraphy would thus necessitate a fresh re-interpretation of the tectono-stratigraphic set up of the Lesser Himalayan geology.

Another most interesting point that comes to the fore now is that even the Vindhyan carbonates (the Vendian – Early Cambrian age recently assigned by the investigator) are also equivalent to the Krol and Deoban carbonates, suggesting that the Vendian – Early Cambrian marine carbonate platform was an extensive one that covered the large part of the Indian Peninsula and almost the entire Lesser Himalaya. This view conforms with the views of some early visionaries (e.g. Auden) who had called the Lesser Himalaya as the 'Peninsular Himalaya' and had also visualized that the 'Great Vindhyan Basin' extended right up to the Lesser Himalaya.

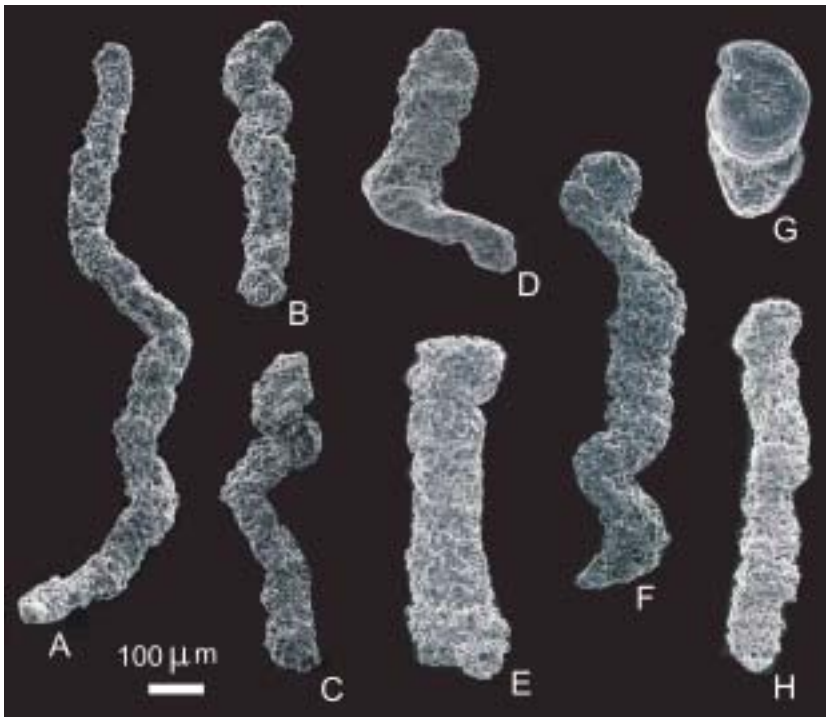


Fig.6. SEM photomicrographs of pyritized Lower Cambrian cyanobacterial tubes *Spirellus* from upper Gangolihat Dolomite (Deoban Formation) of Jhiroli Magnesite Mine (Bageshwar District), Inner Carbonate Belt, Kumaun Lesser Himalaya.

2.3. SUBPROJECT

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

(V. C. Tewari)

Meso-Neoproterozoic stromatolitic carbonates of the inner sedimentary belt (Deoban and its equivalent limestones) have been studied with special reference to sedimentation and carbon isotope Chemostratigraphy, in Garhwal Lesser Himalaya. The Uttarkashi Limestone, Khattukhal Limestone and Lameri Limestone has been systematically studied for their stromatolite assemblages and carbonate facies, microbial communities and their role in microbialite formation and depositional environment. The carbonate facies are characterized by conical stromatolites (*Conophyton*), columnar forms (*Colonnella)*, stratified forms (*Stratifera*), domal forms, branching forms (*Baicalia*) and mini digitate forms. The sedimentary facies analysis suggests that the conical stromatolitic buildups were deposited below wave base. The cherty-intraclastic-oolitic and mini-digitate stromatolites were formed in high-energy intertidal environment. The cyanobacterial remains (spheroidal, filamentous, spiral and vase shaped forms) indicate shallow subtidal environment.

Carbon and Oxygen isotope chemostratigraphy of the Uttarkashi Limestone and Lameri Limestone (between Koteshwar and Rudraprayag section and Ratura-Lameri section) has been attempted (Fig. 7). The $\delta^{13}C$ of the Uttarkashi Limestone range between + 3.4‰ PDB and + 4.3‰ PDB. $\delta^{18}O$ (SMOW) range from 24.4‰ to 27.4‰. The carbon and oxygen isotope values of the Lameri Limestone are with in a narrow range ($\delta^{13}C$ close to 0‰ PDB) and $\delta^{18}O$ (SMOW) varies from 17.2‰ to 22.8‰. The sedimentary facies, stromatolitic buildups and carbon isotope excursions suggest that Uttarkashi-Lameri carbonates are the product of rimmed shelf carbonate platform. The C isotope patterns of these carbonates are consistent and comparable with Mesoproterozoic and Neoproterozoic positive values.

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)

In recent years the acquaintance on earliest life has been enormously improved due to worldwide occurrences of

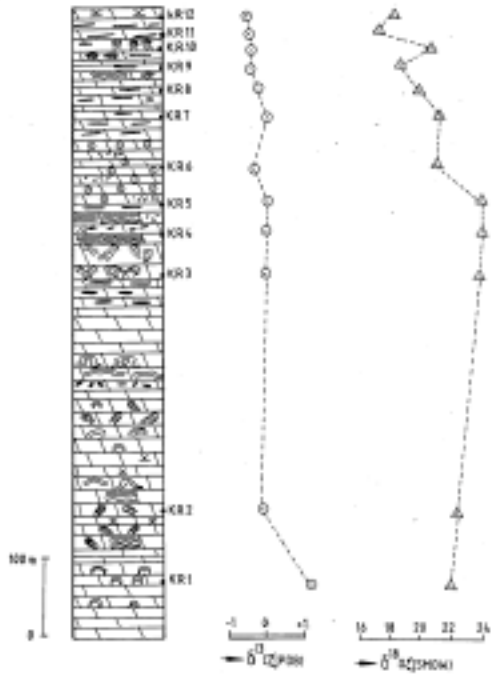


Fig. 7. Chemostratigraphy of the Lameri Limestone, Garhwal Himalaya.

microscopic fossils in Neoproterozoic– Cambrian rocks. A variety of relicts of early multicellular life is found trapped within Proterozoic sediments, which were previously seen as a province of cyanobacteria only. The present work deals with a diverse microbiota in dark black phosphatic stringers within magnesite in the Jhiroli magnesite, ~45km from Almora, in the eastern part of Kumaun Lesser Himalaya. Earlier, an early Vendian organic-walled microfossils and sponge-spicules from Gangolihat Dolomite were already documented. A well preserved microbiotic assemblage is recorded here from the Jhiroli magnesite, eastern Kumaun Lesser Himalaya. The assemblage contains mainly cyanobacterial filaments, coccoids and acritarchs identified mainly as *Siphonophycus robustum*, *S. typicum, S. capitaneum, Gunflintia minuta, Oscillatoriopsis obtusa, Chlorogloecapsis contexta*, *Sphaerophycus parvum*, *Leiosphaeridia crassa*, *Trachyhystrichosphaera vidalii*, *Trachyhystrichosphaera* sp., *Micrhystridium pallidum* and *Cymatiosphaera minuta*. Presence of acanthomorphic acritarchs such as, *Trachyhystrichosphaera, Cymatiosphaera* and *Micrhystridium* are quite interesting and play an important role for assigning the age of Gangolihat Dolomite.

2.5 SUB PROJECT

Sedimentology of the Inner Carbonate Belt

(T.N. Bagati)

A new project on the sedimentology of the Inner Carbonate, Lesser Himalaya has been initiated during

November 2003 and literature survey as well as compilation of existing geological maps were carried out during the remaining period. It was observed that the detailed and systematic sedimentological work is lacking. These unfossiliferous sediments are dominated by carbonates and shows presence of stromatolites at few stratigraphic levels. They have been assigned Precambrian age. The aim of the present study is to carry out detailed field work with systematic sampling for establishing the microfacies, detailed mineralogy and geochemistry of these carbonates. The field and laboratory work will help in establishing depositional milieu, onlap and offlap facies complex, palaeogeography and sequence stratigraphy.

2.6 SUB PROJECT

Geochemical and sedimentological studies of Proterozoic clastic successions of Lesser Himalaya

(S.K. Ghosh and R. Islam)

The areno-argillaceous shallow marine sediments and associated basic volcanic rocks are studied to understand their inter-relationship. Nagthat and Berinag constitute essentially siliciclastic ranging in composition from sublithic arenite to quartz arenite, later type is abundant in Berinag formation. The Chandpur and Blaini formations are mainly represented as argillite and subordinate siliciclastics. Mandhali and Sor formations are mainly constituted of calcareous shale (slate), limestone and argillites. Basic volcanics are generally restricted in Nagthat, Berinag and Sor formations of Kumaun Lesser Himalaya, mostly exhibit concordant relationship. However, at places discordant relationship with Nagthat (near Ratighat section, in three localities), Berinag and Sor has been noticed. This relationship is very important because it gives some clue for sensing the bathymetry of the basin – it has been considered that the discordant relationships perhaps represent the deeper part of the basin.

The major oxide data of these arigillo-arenaceous packages suggest clay mineral control on major oxide. The majority of the arenitic (quartzitic) rocks show the common presence of plagioclase, K-feldspar and clay minerals, but lacks ferromagmesian minerals, therefore indicate minimal decomposition of feldspar and greater decomposition of ferromagnesium minerals. The chemical index of alteration (CIA) value of the Outer and Inner Lesser Himalaya is quite high indicating intense weathering condition in the source region. The CIA and PIA values also suggest their deposition in a warm and moist climate. However, this is to be further substantiated by more geochemical and isotopic data.

2.7 SUB PROJECT

Evolution of the Himalayan Foreland Basin

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

Study was mainly concentrated in the Cenozoic succession of Himalayan foreland basin. Field data suggest that transition from marine to fluvial succession is gradual and does not support the hiatus between this transition. However, the vertebrate material from the poorly fossiliferous Murree Group suggests an early Miocene age for the fossiliferous beds and supports the view that the Murree and the underlying Subathu (Paleocene-Middle Eocene) successions may be separated by a considerable time gap. This time gap can plausibly be explained as the manifestation of forced regression thereby destroying terrestrial vertebrate habitat in the region due to lowering of global sea-level. This insight is achieved by invoking latest sequence stratigraphic paradigm in the sequence and is important in understanding the geological evolution of the Tertiary sequence.

The field evidence shows that the *Nummulites* bearing black shale and limestone of Subathu Formation gradually pass upward into red pedogenic siltstone with trace fossils and concretions in mature soil profile. These soils are deeply incised by channel due to base level change by tectonic process or by change in the ratio of fluvial discharge to sediment load. These paleosol represent interfluve deposits near the coastal plain. The channel deposits are typical ribbon shaped and laterally merge into paleosol bound siltstone.

The Daghsai Formation is represented by grey silt/mudstone dominated succession with ribbon shaped sandstone bodies and gradually passes upward into sandstone dominated Kasauli Formation. Sandstones are multistorey in nature having sheet geometry. Nature of sandstone bodies supports big river system with broad inter-channel area. It further suggest increased catchment area during Kasauli. Daghsai and Kasauli Formations are similar to Lower and Middle Siwalik succession in terms of sandstone body geometry and mudstone content. Magnetostratigraphy, rock magnetism, petrography and geochemistry are under progress.

A new locality in Subathu, yield material comprising of an isolated rodent tooth, a few fragmentary teeth of some larger mammals and several crocodilian (including ziphodonts) teeth. The occurrence of rodent tooth is significant as this is only the third locality in the type area of the Subathu Formation to have yielded rodent

teeth. Some test samples from the Dagshai Formation have shown potential for microvertebrates. Ongoing study of the Eocene cetaceans (whales) based on fossil material from India and Pakistan was continued. The evolutionary changes in the outer and middle ear (these control sound transmission mechanisms) in response to adoption of aquatic habit are being investigated. This is throwing new light on Eocene evolution of hearing in whales.

Using various sedimentologic parameters, magnetostratigraphy and rock magnetism, the timing of emergence of Chail Thrust in Kangra sub-basin is constrained around 10 Ma. Two types of conglomerate, deposited by stream flow (between 10 and 7 Ma) and sheet flood (6 Ma onwards) process are recognized in Kangra sub-basin, which have syn- and post- tectonic setting. The deposition of the stream flow conglomerate was controlled by a combination of Chail thrust and Manali-Ropar lineament activities. Whereas progradation of sheet flood conglomerate was related to the activity along Main Boundary Thrust. Based on clast composition, paleoflow direction and similarity of clast composition of Siwalik and recent Beas River, it is inferred that proto- Beas entered in the Himalayan foreland basin around 10 Ma.

Pedogenic calcareous nodules from the paleosol profile of the Haripur section have 117 to 122 ppm (ΣREE) of rare earth element. They have 90 to 30 x chondrite on LREE and 27 to 5 x on the HREE abundances. Their chondrite normalised REE patterns are characterized by LREE (La, Ce, and Nd) enriched, HREE (Dy, Er and Yb) depleted with negative Eu anomaly, and no Ce anomaly. Pure carbonate fractions of the same calcareous samples have very low abundances of total REE (ΣREE = 0.5 ppm). The chondrite normalized patterns of these fractions exhibits W tetrad effect suggesting the aqueous nature of the pedogenic solutions involved during paleosol development.

2.8 SUB PROJECT

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

(A.C. Nanda)

Studies were confined to the Pinjor Fauna and its relation to the post-Siwalik faunas of Peninsular India and Indo-Gangetic Plain. Migratory routes of the Siwalik mammals were worked out and Upper Siwalik faunas were correlated with the equivalent horizons of Mynamar, Indonesia, Japan and Taiwan. The generic nomenclature of various faunal lists for Standard Reference Sections and of post-Siwalik faunas were revised and updated and latest classification on nomenclature was followed.

Pinjor Fauna, ranging in age from 2.58 Ma to 0.6 Ma, is the youngest fauna of the Siwalik Group. The process of its extinction and migration started at 1.72 Ma and after 0.6 Ma there is no record of this fauna from the foothills of Himalaya. Faunal list of the Pinjor Fauna of Indian subcontinent, based on the work of last 175 years, is compiled. About ninetyeight taxa are known from the Pinjor Fauna of which eightysix taxa are marker taxa. This shows the richness of the Pinjor Fauna. To know the extinction or migration of the Pinjor Fauna, the faunal lists of the post-Siwalik faunas of Indo-Gangetic plain and Peninsular India were compiled and finalised. From Peninsular India two faunal horizons roughly of Middle Pleistocene and Upper Pleistocene ages are known. However, from Indo-Gangetic Plain only the Upper Pleistocene fauna is known. Both Peninsular and Indo-Gangetic faunas are scanty as compared to the rich Pinjor Fauna. Only sixteen and twenty six taxa are known from the Middle and Upper Pleistocene horizons of Peninsular India respectively. Upper Pleistocene of the Indo-Gangetic Plain has yielded twenty six taxa. Only six Pinjor species represented by ?*Homo erectus, Crocuta cf. C. sivalensis, Stegodon insignis, Elephas hysudricus, Potamochoerus theobaldi* and *Bubalus palaeindicus* survived in the younger Peninsular and Indo-Gangetic horizons. In addition to these, fifteen Pinjor taxa, *Hystrix, Bandicota, Tetera, Mus, Canis, Panthera, Crocuta, Rhinoceros, Cervus, Sus, Hippopotamus (= ?Hexaprotodon), Gazella, Antilope, Boselaphus* and *Bos* survived in these younger horizons. On the basis of species, post-Siwalik faunas of India do not resemble the Pinjor Fauna. However on the generic level, fifteen additional Pinjor genera survived in the post-Siwalik faunas but with different species. On species level the Pinjor Fauna shows mass extinction and not the mass migration. However, the presence of twenty one genera (including six species) indicates the presence of the Pinjor elements in post-Siwalik faunas.

Pinjor Fauna is widely compared not only with the post-Siwalik faunas of India but with the equivalent faunas from Mynamar, Java, South China, Japan and Taiwan. Evidence indicates that about 45,000 years back along the present course of River Yamuna, there was at least a depression, if not the presence of river, which acted as route of migration for the faunas. In Pinjor time, the fauna shows linkage with equivalent horizons in Myanmar, Java and Japan. This linkage became dominant in post-Siwalik time and faunas even showed linkages with Taiwan and South China. Thus the eastern route for migration,

which opened for the first time probably in the Pinjor, became dominant in post-Siwalik times. The genera of the Pinjor and post-Siwalik deposits, which occur in Mynamar, Java, Japan, Taiwan and South China include *Hystrix, Felis, Panthera, Stegodon, Elephas, Equus, Rhinoceros, Potamochoerus, Merycopotamus, Hippopotamus, Muntiacus, Cervus, Antilope, Hemibos, Bubalus, Leptobos* etc.

In addition to the faunal lists of the Upper Siwalik faunas, the faunal lists of the Lower and Middle Siwalik faunas were reinterpreted and generic nomenclature of various taxa were updated. These lists include Lower Siwalik fauna of Ramnagar, J. & K., Nurpur fauna of Kangra, and Middle Siwalik faunas of Haritalyangar. It is well known that the migratory routes of the Siwalik mammals lie at the western and eastern extremities of the Himalaya. Investigations indicate that the Lower and Middle Siwalik faunas are having affinity with their equivalent faunas in Turkey, Europe and Africa and this indicates that the western route was more active at that time.

3. NATURAL HAZARDS

Landslides, cloudbursts, flash foods, earthquakes, etc. are some of the well-known natural hazards in the Himalaya. These are a matter of concern since they affect the life in the most populous mountain belt of the world. Of late, there has been frequent recurrence of these hazards thereby calling upon mitigation policies for safeguarding the interests of the society at large. The Institute is engaged in studies of all these natural hazards in the various sectors of the Himalaya.

During the year in reference, work on geoenvironmental studies of the Kullu valley in Himachal Pradesh progressed satisfactorily. Analysis of data shows increase in flash floods since 1988 with average recurrence interval of three years. This far exceeds the reported occurrence in the nearly 40 years interval between 1902 and 1945, indicating a rapid environmental change in the region in the recent decades. Massive loss of life and property has taken place in these flood events mainly in the valley bottom zone, which is constricted, composed of Quaternary gravel and heavily influenced by human activity. Similarly, socio-economic structure of the society has witnessed several folds changes during the past 3-4 decades, sounding caution for planned development in the region.

Data pertaining to landslide zonation in the Satluj valley in Himachal Pradesh were generated previously under a sponsored research project. In the second follow up phase, it is aimed to elucidate the distribution of the landslides and upgrade the existing landslide inventory besides studying the geotechnical characteristics of two major landslides of Pawari and Nathpa. Thematic maps pertaining to slope, land use, land cover and geomorphology were prepared in this pursuit, which depict some relationship between structure, rock type, slope angle, and moisture regime. In other similar studies in the MCT Zone in the Yamuna valley between Gangani and Janki Chatti, the importance of geological parameters like lithology and structural discontinuities have been emphasized in the generation of the landslides. The studies also briefly deal with the devastating 2003 Varunavat landslide in Uttarkashi.

In regard to active faults, which behave as potential planes of weakness for releasing the accumulated stress in the lithospheric layer and ultimately, lead to earthquakes, investigations were carried out in close proximity of MBT and HFT in Dharamsala area, Himachal Pradesh using aerial photographs and high-resolution satellite data. Traces of new active faults were mapped with fault scarps varying in height between 4 and 20 meters. It is inferred that these scarps were developed during prehistoric large magnitude seismic events in the area.

Studies pertaining to seismicity, seismotectonics and seismic hazard assessment in the northwestern Himalaya made progress in monitoring and analysis, site response in populated areas, seismic hazard mapping, etc. Temporal plot of seismic activity in the vicinity of Bhatwari (Uttarkashi) seismic observatory shows an outburst of small ($M < 3$) events during the first quarter of 2003, there after quiescence followed for four months. No significantly large earthquake occurred during this period that characterized the present sequences to be as earthquake swarm. The swarm activity is confined to mainly two zones, one lying within 10-40 km of Bhatwari, and another within 50-160 km of the observatory. Besides collecting phase data of mor than 1500 earthquakes recorded by the analog stations in the region for further analysis, the data bulletin for the period May 2001 was sent to various geophysical groups in the country. A parallel attempt is being made to study radon gas emission to make this technique a useful earthquake precursor.

Among other studies, accelerograms of 1986 Dharamsala, 1991 Uttarkashi and 1999 Chamoli earthquakes and its aftershocks were analysed to investigate their source parameters, estimating site amplification functions and shear wave attenuation

parameter QB in the region. The studies show that average values of the estimated shear wave attenuation parameter QB varies from 240 in Himachal sector to 860 in Uttaranchal sector of the Himalaya and 1550 in the Delhi region. Preliminary received function analysis of teleseismic converted phases at Bhatwari and Kothi observatories shows a sharp Moho at a depth of 57 km.

Seismic hazard mapping analysis suggests that the area shaken by certain intensity earthquake in the Himalayan region is 10 to 15 times smaller than the area shaken by shallow earthquakes of the same magnitude in the intracratonic parts of North America. Besides this study, Earthquake Catalogue for the northwestern Himalaya was prepared with statistical completeness determined for the time interval for different ranges of magnitude in time windows of 50 years (1953-2002).

Radon is considered as a natural hazard, which affects human health directly or indirectly. Study of radon gas emission was undertaken in some sections of Garhwal and Kumaon Himalaya. Samples were collected from water and soil to document the concentrations. Analysis shows that radon concentration in water varies from 1 Bq/l to 198 Bq/l and in soil it varies from 0.5 KBq/m^3 to 35.2 kBq/m^3. In a landslide zone in Pinder valley measured concentration of radon varies from 3 Bq/l to 18Bq/l in the seepage section, whereas in debris portion it is between 2.3 kBq/m^3 and 10.5 kBq/m^3. Radon concentration shows positive relationship between depth of tube wells/hand pumps and the various geohydrological units of the Doon valley in both pre-and-post monsoon values.

3.1 SUB PROJECT

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

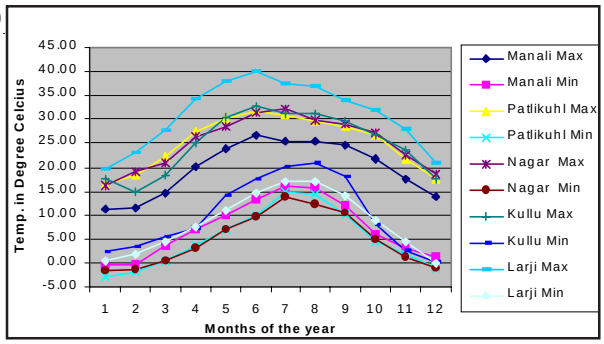
(M.P. Sah and R.K. Mazari)

The project aimed at geoenvironmental studies in the Kullu valley in Himachal Pradesh progressed in respect of preparation of geomorphological and geological maps (in part) on 1:50,000 scale, analysis of weather and hydrological data, analysis of socio-economic data, etc. Based on this, a scrutiny was made to understand the general geoenvironmental scenario of the Kullu valley. As the studies reveal the main geomorphic characteristics of the valley are its high rise valley slopes whose converging down valley ends are separated by extensive, winding and interlocking massive Quaternary alluvial fans with stretches of river terraces carved by the Beas river into the main body of the fans, and the gorge section that dominates the landscape for several kilometers downside of Kullu.

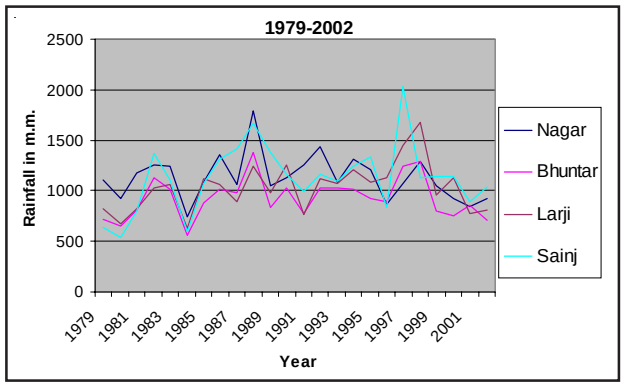
Climatically, the temperature and precipitation variations are altitudinally and orographically controlled. Winter temperature drops to as low as -6^{0}C at Kothi (2427 m) in the upper reaches of the Beas valley, whereas the maximum temperature goes up to 40^{0}C as recorded at Larji (1000 m) in the lower reaches of the valley. This indicates a high temperature gradient, which is a potential factor in the weathering of rocks that immensely influences mass wasting processes in the rainy season. Some of the weather data are shown in Fig. 8 a&b. The Kullu valley receives precipitation throughout the year, however, with a difference in its upper and lower reaches. The upper reaches experience more of snow as compared to the lower reaches, which receive more of rain. This is due to the regional climatic divide where northern portions fall in the humid temperate belt and the southern portions lie in the sub-tropical belt. The studies show that the Kullu valley is prone to seasonal flash floods, which lead to massive damage to property and loss of life occasionally. Flash floods of 1902, 1945, 1988, 1993, 1995, 2000 and 2003 are noteworthy. While recurrence interval of three years is evident between 1988 and 2003, the same is several times less i.e. 40 years between 1902 and 1945. This clearly indicates a rapid environmental change in the region in the recent decades. Analysis of discharge data of the Bears river shows that there is less than 2100 cusecs of discharge at Manali, whereas it goes up to 14,000 cusecs at Bhuntar in July-August (Fig. 8c) indicating almost 7-times increase extended by several sub-catchments falling above Bhuntar. Apparently, therefore, lower reaches of the Beas are more prone to lateral erosion and associated mass movements. The July 16, 2003 cloudburst in Pulia Nal was studied in detail to elucidate the cause and effect of this event. This cloudburst resulted in the loss of 33 lives and damage to property over a million rupees mostly belonging to the Parbati Hydropower Project (Stage II). The studies revealed that the damage could be minimized had proper attention been paid to project infrastructure including labour camps, etc. by the concerned authorities.

One of the environmental problems facing the Kullu valley is the forest fire that is a matter of concern to the local administration. Major forest fires leading to loss of vegetal cover and consequent soil erosion on the valley slopes have taken place in the years 1910, 1915, 1921, 1929, 1931, 1946, 1952, 1965 and 1970. The soil erosion problem is further compounded by grazing of sheep in highland pastures whereby compaction of soil by moving herds along the grazing tracks reduces the water

(a)



(b)



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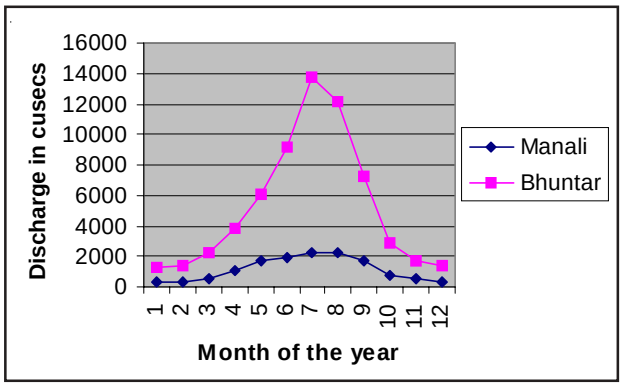

Fig. 8. a) monthly average temperature of Kullu Valley,
b) total annual rainfall pattern of Kullu Valley and
c) monthly daily average discharge (1990-2002) of Beas river at Manali and Bhuntar.

percolation and subsequently increases the surface run-off that leads to accelerated erosion particularly along the slope depressions.

Considering the socio-economic data, it shows a growth of population by 217.65 % between 1901 and 2001; population density of 28 persons/km in 1961 rising to 69 persons/km in 2001; urban population increasing by 77.81 % between 1981 and 2001; motorable road length increasing by 43.85 % between 1985 and 2001; horticultural area increasing by 60.70 % between 1975 and 2002, etc. These figures vividly indicate increasing impact of anthropogenic activities in the geoenvironment of the Kullu valley. If well-planned strategy is not adopted for further multilateral development, there is danger of massive environmental imbalance in the region in the near future.

3.2 SUB PROJECT

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

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

One of the major causes of mass movement in the Himalaya is its tectonic setting where lithology is influenced by mineral fabric and insitu stresses. Major discontinuities such as bedding, cracks, joints and faults have a predominant influence on the behavior of slopes and are significant for mass movement analysis. Size, spacing, orientation and distribution of discontinuities control the mobilization of shear strength of rocks, which collectively define the stability condition of the slopes. The orientation of a slope with respect to significant discontinuities is to a great extent responsible for determining the style of slope movement.

With this background, detailed geological and structural maps along the Yamuna valley between Gangani and Janki Chatti were prepared on 1:25,000 scales. In particular reactivated landslide at village Khanera was studied in detail.

In order to identify the mode of failure and the role of structural elements in the failure, an assessment of instability of hill slope was carried out by analysing the field data on lithology , structural discontinuities and other geological parameters supplemented with laboratory assessment of mechanical properties of the rock mass involved. An attempt was also made to work out the type of movement and the sequential episodes of movement leading to the present scenario of this highly active zone in the Lesser Himalaya.

Furthermore, field and laboratory investigation were carried out on the Varunavat landslide at Uttarkashi in the adjoining Bhagirathi valley to correlate the activity of the two areas falling in the same tectonic zone (MCT zone).

3.3 SUB PROJECT

Mapping of Active Faults Using Remote Sensing Techniques

(G. Philip)

Active faults, which irregularly abound the Himalaya, are very important as they directly reflect the impact of continental collision process. Study of active faults enriches our understanding of contemporary plate motions, their rates and related processes since these planes of weakness have been subject to recurrent movement during the late Quaternary, dislocating many landforms. The primary aim of this project is to identify characteristic geomorphic signatures/surface manifestations of active faults, initially using remote sensing techniques. This is being followed with detail mapping and documentation of Holocene surface deformation essentially to estimate hazard potential and recurrence interval of major earthquakes. Aerial photographs and high-resolution satellite data have been studied to identify the surface expression of active faults in an area lying in close proximity of the MBT and the HFT in Himalaya. Fieldwork was carried out in parts of Kangra valley particularly in and around Dharmsala in Himachal Pradesh. Few new active fault traces identified on aerospace data have been recognized in the Kangra valley. The fault scarps are modified due to the ongoing agricultural practices. The height of the fault scarps varies from 4 to 20 m. It is inferred that these scarps were developed during prehistoric large magnitude seismic events in the area. Various tectonic landforms identified in the Kangra valley require extended investigations. The study proposes to identify specific site for trench excavations across these active fault systems.

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)

A temporal plot of seismic activity observed in the vicinity of the Bhatwari (Uttarkashi) seismic observatory shows an outburst of small (M < 3) events during the 1st quarter of the year 2003 (Fig. 9). Interestingly, the activity suddenly went into quiescence during the next four months. There was no significantly large earthquake in the region during this period. This qualifies the sequence to be called an earthquake swarm. The swarm activity is confined to mainly two zones, one lying within 10-40 km of Bhatwari and other within 50-160 km of the observatory. The activity in the inner zone may have been originated from the vicinity of localities like Gangnani, Zamak or Uttarkashi

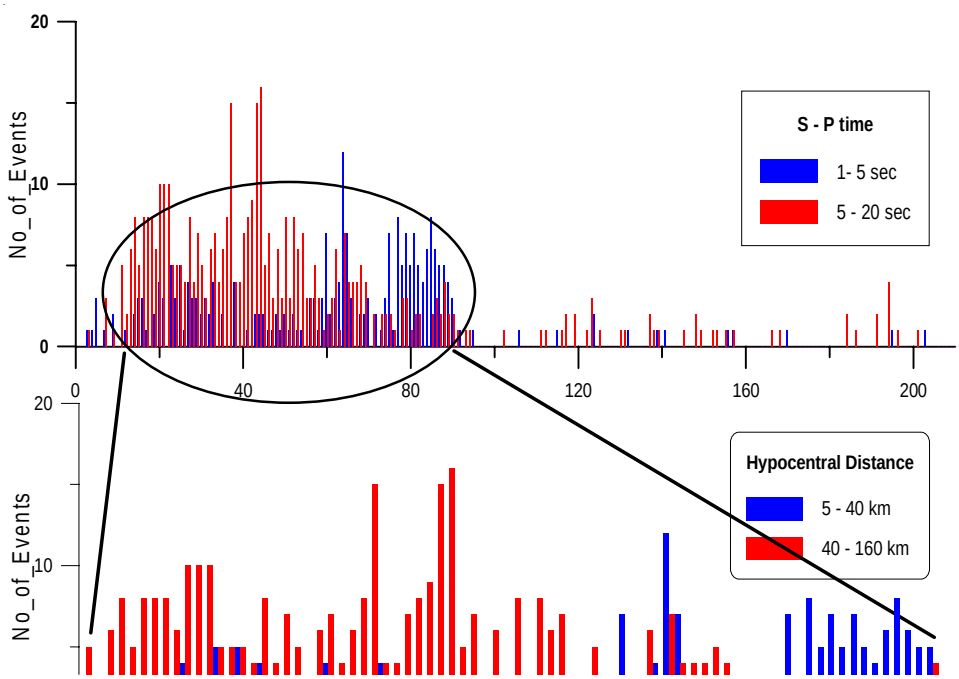

Fig. 9. The sequence of small earthquakes observed during the Jan – Sep 2003 at Bhatwari Seismic Observatory. The first quarter of the year shows high seismic activity followed by a quiescence period.

and the outer zone activity is likely to be originated from the Uttarkashi/China border.

The phase data recorded on the analog stations was analysed and the phase data bulletins for the period May 2001 was prepared and sent the same to various geophysical groups in the country. A total of 1500 earthquakes (local, regional and teleseismic) have been read for further analysis. In all, about 42 local earthquakes have been rechecked and analysed for their parameter estimation. Two stations in the array, i.e. Jadera and Kothi show high local seismicity

3.5 SUB PROJECT

Site Response Studies in Major Population Centers in NW Himalaya

(Kamal and A. K. Mundepi)

The pear-shaped city of Dehra Dun is a tectonically controlled synclinal valley, which is filled with thick heterogeneous layers of the Doon gravel. The thickness of the sedimentary column varies significantly which is directly reflected in the results of site response survey from this region. The city can be subdivided into three zones. The northern part of the city largely shows amplifications in the higher frequency band of 4-8Hz. This suggests very little thickness of the sediments in the zone.The central part of the city has the predominant frequency bands varying between 2.0-4.0Hz (Fig. 10). The lower predominant frequency in this zone is indicative of a thick sedimentary column. The southern part has a wide amplification band, almost from 0.8-2Hz. In the same zone, few sites also show amplification in very high frequency band.

3.6 SUB PROJECT

Seismicity, seismotectonics and seismic hazard assessment of NW Himalaya

(V. Sriram)

The accelerograms of the 1986 Dharamsala, 1991 Uttarkashi earthquakes and 1999 Chamoli earthquake and its aftershocks have been analyzed to investigate their source parameters, estimate the site amplification functions and the shear wave attenuation parameter Q_B in the region.

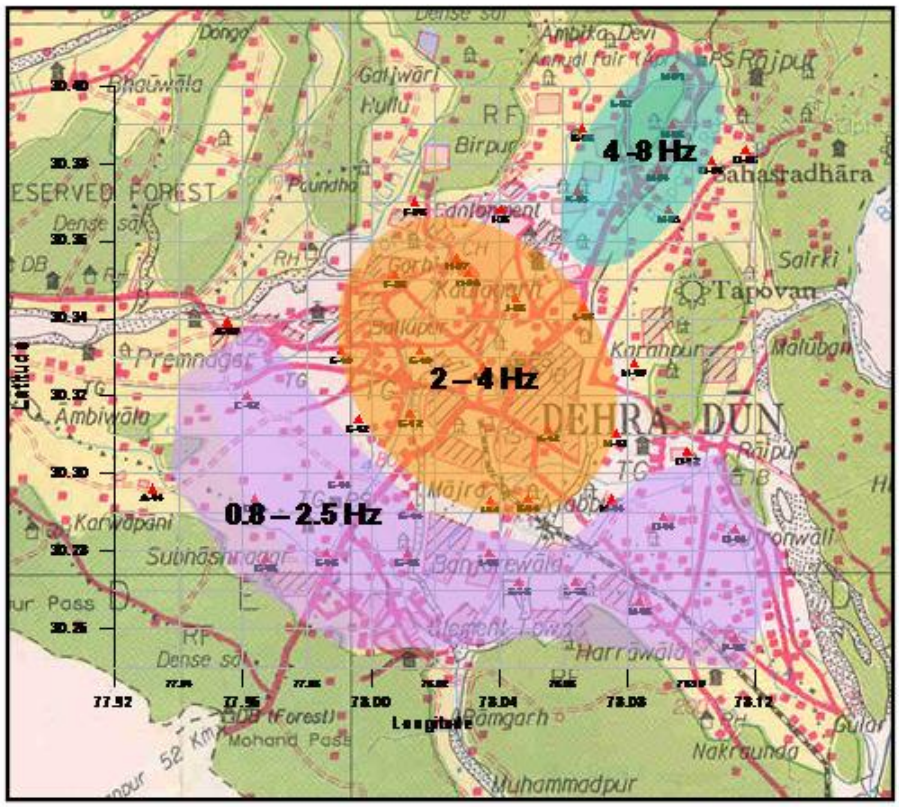

Fig. 10. Broad classification of predominant frequencies of the sedimentary column beneath Dehradun City. The results are based on the microtremor survey of the city carried out for seismic microzonation.

The fault plane solutions are obtained using the spectral amplitudes of SH waves (approximated by transverse components of accelerograms) of the high-energy packets observed in the accelerograms at close distances. The estimated earthquake moments vary from 1.2 x 10^{23} dyne-cm to 1.1 x 10^{26} dyne-cm for the earthquakes of magnitude range 4.6-7.0. The static stress drops for these events lie between 26 and 135 bars, the larger values correspond to smaller magnitude aftershocks. A regression analysis between seismic moment (M_0) and corner frequency (f_c) shows that M_0 is approximately proportional to f_c-3. The average values of the estimated shear wave attenuation parameter Q_B varies from 240 in Himachal sector to 860 in Uttaranchal sector of the Himalaya and 1550 in the Delhi region. In general, the Q_B value increases with increase in the epicentral distance reflecting the penetration of the waves into deeper layers of the crust as the epicentral distance of observation point increases. The estimated Q_B values in the Himalaya suggest a cooler thermal regime that is conducive for brittle behavior of rocks lying at depths illuminated by the waves investigated here. The decay of peak ground acceleration (PGA) values with distance has been investigated using the empirical regression curves vis-à-vis the site amplification factors, which have been estimated from the frequency bands of significant amplification observed in the spectral ratios of the horizontal to the vertical component record.

Teleseismic converted phases recorded at the broadband digital observatories at Bhatwari and Kothi are inverted for the I-D crustal structure below the stations. The preliminary results show a sharp Moho at a depth of 57 km with shear wave speed of 4.32 km/s and 9 km thick mid-crustal layer at a depth 11.2 km with Vs 3.97 km/s.

3.7 SUBPROJECT

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

(Sushil Kumar)

In Garhwal Himalaya**,** the region between Yamuna and Alaknanda valleys, small earthquake activity has been reported by many workers (Gaur *et al.* 1985, Khattri *et al.* 1989 and Sushil *et al.* 2003). To understand the current behavior of active tectonics of the Garhwal Himalaya, seismograms recorded at Bhatwari, Dehra Dun and Pipalkoti seismic observatories during 2000-2004 were analysed. The various phases of local earthquakes were read out from the seismograms manually. Bhatwari and Pipalkoti observatories lie close to the MCT but located in different sectors separated by about 100 km, whereas Dehradun seismic observatory lies very close to the MBT. The preliminary analysis of data indicates that local activity is concentrating near the MCT. The data is under process for structural analysis of NW Himalaya.

3.8 SUB PROJECT

A preliminary seismic hazard map of the Northwest Himalaya

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

An empirical curve fitting linear relation between instrumentally determined body wave magnitude and the intensity distribution of eleven shallow Northwest Himalayan earthquakes have been derived. The analysis suggests that the area shaken by certain intensity during an earthquake in the Himalayan region is 10-15 times smaller than the area shaken by shallow earthquakes of the same magnitude in the intracratonic parts of North America. Besides this, attenuation relation for the Northwest Himalayan region has been derived using the 1905 Kangra earthquake isoseismal map. Also, Earthquake Catalogue for the Northwest Himalayan region has been prepared; its statistical completeness was determined for the time interval for different ranges of magnitude in time windows 50 years (1953-2002), 110 years (1893-2002) and 120 years (1883-2002) with respect to magnitude variation of $4.0 \leq M < 5.0$, $5.0 \leq M < 6.0$ and $M \geq 6.0$ respectively

The shear wave velocity-depth investigation of Dehradun city using the Engineering Seismograph at twenty sites has been carried out as first step towards the seismic microzonation studies of Dehradun city. The technique applied is the latest technique The technique called Mutli-channel analysis of Surface waves (MASW) helped to identify variability in the lateral continuity and changes in lithology with depth. This information is very much required for predicting the ground motion response to earthquakes in areas where significant soil cover exists over firm bedrock. Twenty sites have been investigated covering almost all the representative areas of the city and accounting for the difference in lithology based on geological background. The average shear wave velocity for the surface layers has been estimated to be around 220 meter/sec for most of the sites. However, in some of the sites the velocity of the upper soil layer is less than 150 meters/sec. In general, three velocity layers model have been observed to a depth of 30-40 meters for predicting the ground motion of the region. In some cases the depth of penetration goes to 50-60 meters and four velocity layers can be observed. The shear wave velocity ranges from 150 meters/sec in the top layer to 1000 meters/sec at the bottom of the layer at 30 meters depth. The shear wave investigation of each soil column will help to derive the

natural period of the soil column, shear modulus, maximum shear stress and shear strain and average velocity of the soil column to do the site response analysis.

3.9 SUB PROJECT

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

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

Fieldwork has been carried out in Kumaun and Garhwal areas to collect soil and water samples for radon analysis. The radon in water varies from 1Bq/l to 198 Bq/l and in soil it varies from 0.5 kBq/m^3 to 35.2 kBq/m^3. Preliminary results show that lithology, structure and aquifer characteristics mainly control the radon variation in water and soil. Treatment and detailed interpretation of the data are in progress. Radon measurements were also done in the soil and spring water in and around an active landslide zone located along Pinder river in the Chamoli District of Uttaranchal. The measured concentration of radon in landslide zone varies from 3 Bq/l to 18 Bq/l in spring water and from 2.3 to 10.5 kBq/m^3 in the soil/debris. Radon values in soil are slightly higher (4.7 kBq/m^3 to 12.2 kBq/m^3) in the upper slopes i.e. towards the crown portion of the landslide as compared to distal portion. The low concentration of radon both in soil and water in the distal part of the landslide may be due to high porosity of the debris material which does not allow radon to accumulate in the soil and water. Whereas, towards the crown portion the higher intensity of fractures and near absence of debris material enhance the radon emanation in soil.

The radon concentration shows positive relationship with depth of tubewell and handpumps in different geohydrological units except in central part of the Doon valley in pre-monsoon and post-monsoon data sets. A significant decrease ranging from 4 to 54% of radon concentration was observed in post-monsoon measurements.

3.10 SUB PROJECT

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

(Vikram Gupta and M.P. Sah)

The study on landslides and related mass movement activity in the Satluj valley started in the Wadia Institute of Himalayan Geology under DST sponsored research project in 1991. The present study was undertaken with a view to have an idea about the temporal distribution of landslides and to upgrade the existing landslide inventory. The project also aims to study the geotechnical characteristics of two major landslides i.e. Pawari and Nathpa slides in the Satluj valley. The year 2003 – 2004 was devoted in the preparation of various thematic maps and in analyzing the existing data for the upper reaches of the Satluj valley between Wangtu and Khab.

It is observed that the spatial distribution of landslides is more within one km area on either side of the major thrusts. These landslides are mostly small in dimension. Most of the disastrous and large landslides occur farther away from the tectonic zones indicating control on the distribution of frequency of landslides, whereas the causes of major landslides are lithology and land use. Landslide activities are more reported in the slope group of 21° – 50° and no slides have been reported on > 50° slopes. Straight slopes having an angle of 40° and above are more prone to rock fall, whereas debris slides are common on convex and concave slopes with slope angle of 21°- 40°. Land use also influences the distribution of landslides in the area. High frequency of small size landslides are observed in areas of barren land, open scrubs and scattered trees, whereas no sliding activity has been reported from dense protected forests. The influence of anthropogenic activity on the unstable slopes has also been documented in the region.

The distribution of landslides in the area is also lithologically controlled. Augen gneiss, quartzite and graphitic quartzite though hard and compact show very high frequency of sliding in the area, however, their susceptibility to sliding is greatly attributed to the proximity of these rock types to thrust planes. Granite and granitic gneiss weather relatively easily and show high frequency of slides whereas the finely banded gneisses and the psammitic gneiss show lower frequency of slides. It is also observed that increasing rainfall conditions in the cold desert area in the upper reaches of the Satluj valley have created new slides in the Quaternary deposits in recent years.

Major joints sets in the area have also been analyzed, stress patterns inferred and these were well correlated with the slide direction of major slides.

4. GLACIOLOGY AND NATURAL RESOURCES

Himalaya is bestowed with enormous wealth of natural resources. However, reckless exploitation in unscientific

manner would result in ecological imbalance and irreparable environmental degradation. It is, therefore, important to first understand the nature and ongoing processes in detail before any attempt is made to exploit them. This area of study is, therefore, taken as thrust area that mainly deals with water and mineral resources. The water resources in Himalayan region are strongly dependent upon the glaciers and rainfall, thus it also includes studies related to glaciology.

Geohydrological investigations carried out in the Garhwal and Kumaon region to ascertain the nature of water bearing lithological units (rock-types and geomorphological units) that forms a basis for its useful exploitation and provides guidelines for groundwater exploration. It was found that the groundwater resources are mostly confined in three major rock unites, viz. fractured hard rocks, Fluvial and Colluvial fan deposits along the river slopes and Karst Aquifer characterized by joint controlled cavities and channels in dolomite and limestone. The potential water bearing aquifers in Champawat-Lohaghat-Pithoragarh are mostly confined in Valley-fill, fans and terrace deposits along the river valleys, fractured and jointed limestones, and old lake deposits. The static water levels vary from 6 to 67m below ground levels. The water quality belongs to $CaHCO_3$ and $CaMgSO_4$ hydrochemical facies except at few places where chemistry is dominated by $NaHCO_3$, and $KHCO_3$ reflecting weathering of Na and K rich feldspars present in granite rocks.

The ongoing glaciological monitoring and measurement during the current year was mainly concentrated around two important glaciers, i.e. Dokriani Bamak glacier and Chorabari Glacier. Lichenometric technique was used to date the events and activities of glaciers. In case of Chorabari, the growth rate of Lichens is established to be 0.66 mm per year. It was found that Chorabari glacier has retreated about 196 meters with an average rate of 5.29 m/y from 1962 to 2003. This preliminary result of mass balance studies shows that in spite of the fact that Chorabari is a south facing glacier, surprisingly it has a much slower recession rate in comparison to even other north facing glaciers in the same regime like Gangotri, 20 m/y; Dokriani 18 m/y (both facing NNW).

4.1 SUB PROJECT

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

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

The study area is drained by the tributary streams of the Kali, Ramganga and Pindar rivers. Though the Kali, Ramganga and Pindar rivers originate from glaciers in the Higher Himalaya, their catchment area and sub-tributaries, particularly those present in the study area in the Lesser Himalaya, are dependent predominantly on the subsurface and groundwater for their flows.The groundwater eventually returns to the surface as springs and seepages through faults, fractures, joints and permeable layers or zones that are favorably perched or are under unconfined conditions. Direct infiltration of rainwater through joints, fractures and weathered zones is the main cause of recharge to the springs. Atleast following three types of water bearing formations can be recognized in this area. 1) Fractured *hard rocks* of Saryu Formation of Almora Group, Ramgarh Group, Rautgara Formation, Mandhali Formation and Berinag Formation having secondary porosity and permeability, and characterized by springs and seepages. The zones of lineament, faults and thrusts show pockets of high secondary porosity and permeability. The groundwater/subsurface water in this zone occur largely as disconnected local bodies in favorable zones of jointing, fracturing and faulting. The springs in the rocks having secondary porosity show great variability in yield even within short distance. 2) *Fluvial and Colluvial deposits*, lying along the lower and middle valley slopes in lower reaches of the Kali, Ramganga, Pindar, Ladhiya, and Saryu, rivers or near the confluence of two streams in the form of fans and terraces (such as at Reeth Sahib, Bageshwar, near Rameshwar), old valley fill or lake deposits (such as at Pithoragarh) and old landslides deposits which are highly porous and permeable and therefore hold sufficient quantities of ground water. The springs show wide variability in discharge. 3) *Karst Aquifer* characterized by joint controlled cavities and channels in dolomite and limestone of Deoban Formation. Fault and deep-seated fractures played an important role in localization of springs in this type of aquifer. The joint controlled solution channels and cavities have got opened due to faulting. Selective solutions along these fractures and joints have created these networks of watercourses leading to lack of perennial streams over ground.

Fracture zones related to faults and other lineaments, characterized by sheared and crushed rocks are good locations of ground water, even in rocks that are otherwise impermeable. The availability of groundwater in this part of the Himalayan region is manifested in the form of springs and seepages. During the field investigations several geomorphic, structural and lithological features of the spring zones and hill aquifers have been identified. Fault, fractures, joints, slope characteristics, landforms, lineaments and karstic features control the springs. The following types of springs have been identified 1) Lineament - fault controlled springs, 2) Colluvial related springs, 3) Fluvial related springs, 4) Fracture - joint related springs, 5) Karsts related springs in the Pithoragarh area.

A number of water table springs are present along wide U shaped valleys in Champawat - Lohaghat - Pithoragarh area. The aquifer in the Pithoragarh area consists of valley fill deposits in the central part and fractured and jointed limestone along the valley sides. In the Champawat area fractured and weathered granite, gneisses and schists having secondary porosity and permeability form the aquifer. The combination of physiographic, lithological, structural, geomorphological, hydrological characteristics helped in the identification of potential aquifer of limited yield in this hard rock terrain of the Himalayan region. Several localized small aquifers of limited yield are present in Champawat area. The Static water level in these aquifers varies from 6-67 m b.g.l.

The water belongs to $CaHCO_3$ and $CaMgSO_4$ hydrochemical facies except at few places where chemistry is dominated by $NaHCO_3$ and $KHCO_3$, reflecting weathering of Na and K rich feldspars present in granite rocks. The rock weathering predominantly controls the hydro- chemistry.

4.2 SUB PROJECT

Glaciological studies of Dokriani Glacier and Chorabari Glacier, Garhwal Himalaya

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

Melting pattern of the glacier reveals that the melting of the glacier is decreasing at the lower level that is near the snout, it is increasing in the upper reaches of the glacier. The over all melting pattern of the glacier has shown overall increase in the melting of the glacier.

Lichenometric studies are one of the most reliable tools for dating past events and activities of glacier. Growth rates and Colonization delay time (CDT) of lichens i.e. the time gap between the exposure of the surface and the start of the growth of lichen, are essential to be established as accurately as possible. Whereas the growth rate is possible to estimate based on measurement of diameter of the lichens at an interval of few years, however, the colonization delay is difficult to establish in absence of lichens on monuments of known dates. Estimates of CDT at four places in Himachal Pradesh reveal wide variation (24 to 86 years, see table below) and, therefore, cannot be used in Dokiani glaciers that have much different environmental conditions. Measurement interval of about three years confirms that the growth rate of lichens is 0.66 mm per year in surroundings of Dokriani Bamak Glacier. It has been observed that the lichens are yet to start its growth on an old bridge of about 100 years near Kedarnath, at the proximity of the study area. This conclusively indicates that the CDT for the present glaciers are certainly more than 100 years. The study is still in progress for confirmation.

Location	Colonization delay (years)	Growth rate (mm/ year)
Sanjoli, Shimla	24	0.73
Kanlog, Shimla	68	0.79
Dharamshala	50	0.56
Dalhousie	86	0.54

Chorabari glacier, a small compound valley type glacier, is about 6 km long lies on the southern slope of the main mountain range of Gangotri group of glaciers. Monitoring of the glacier was initiated from 2003. Initially a network of 12 stakes along the centerline of the glacier was fixed for mass balance and snout recession studies. Stakes location over the glacier plotted on a grid map of 500 x 500m and the present snout position is demarcated. Study reveals that glacier has receded by about 196 meters with an average rate of 5.29 m/y during 1962-2003 (Figs.11). This preliminary result of glacier recession shows that in spite of the fact that Chorabari is a south facing glacier, surprisingly it has a much slower recession rate in

Fig.11. View of Snout position of Chorabari Glacier, Garhwal Himalaya in 1990 (top), and 2003 (bottom).

comparison to even other north facing glaciers in the same regime like Gangotri, 20 m/y; Dokriani 18 m/y (both facing NNW). This unique feature of glacial dynamics needs further investigation.

Ground Penetrating Radar survey of Beas Kund Glacier was carried to measure the ice thickness of the glacier ice it revealed a 40 meter thick glacier ice under the supra glacial debris cover.

In order to develop Bioengineering as effective and eco-friendly technique for landslide hazard mitigation, a preliminary, spatial, temporal affinity has been established between specific plant species and slope instability. The species of *Alnus nepalensis* has been identified as a natural indicator for landslide prone slopes and reactivated landslides zones. It is investigated that the process of initiation, development and accumulation of shear stress towards the effective level or periodic decrease in shear strength up to the threshold value of slopes is signaled qualitatively by invasion, growth pattern and floral dynamics of indicator species. The ecological dynamics of indicator species were found simultaneously corroborated with decreasing value of factor of safety which is the indicative of the ratio of shear strength and shear stress along a critical failure surface.

4.3 SUBPROJECT

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)

Deformed, metamorphosed and sheared rocks characterize the Higher Himalayan terrain. These rocks are more intensely mylonitized at the proximity of major thrusts forming a thrust zones also referred to as Main Central Thrust (MCT) zone in Alaknanda and Bhagirathi valleys. These rocks are sandwiched between two major thrusts called Jutogh and Vaikrita Thrusts, in the south and north respectively. The exposed width of this formation (Munsiari or Baijnath crystallines) ranges from few kilometres to as broad as about 35 km and are extensively deformed and mylonitized. Thus it provides a unique opportunity to study the spatial distribution of trace elemental signatures as revealed by the geochemical maps using stream sediment as medium.

It was noted that the U and Th is anomalously high in these crystalline zones (Fig. 12a) whereas Cu and Ni is relatively depleted (Fig. 12b). This behavior is nearly consistent throughout the MCT zone in the studied area. However, the high anomaly of U and Th are also noted to

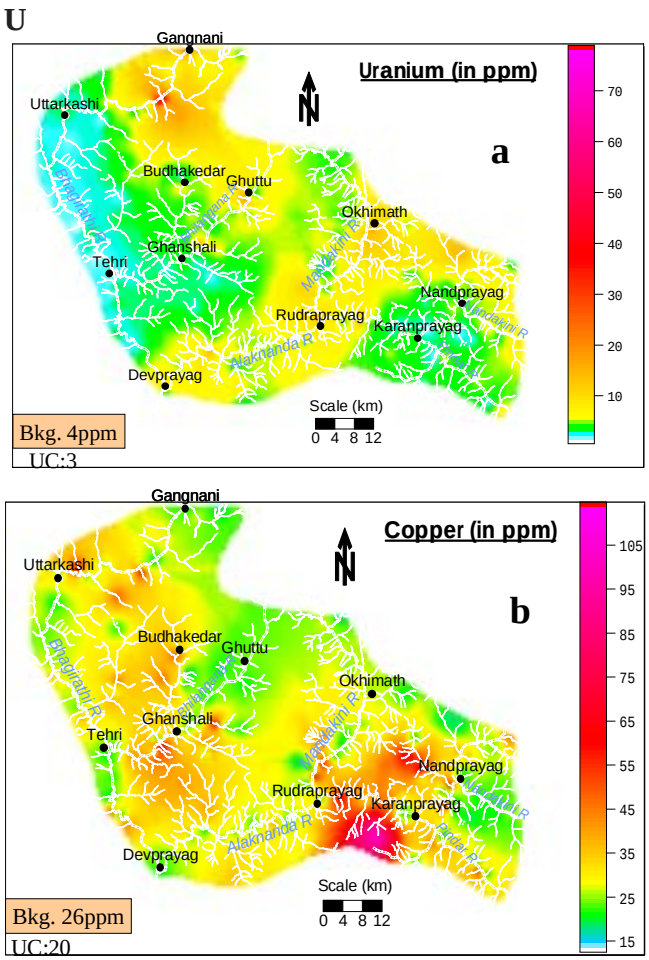

Fig. 12. Geochemical variation map based on stream sediment survey of (a) Uranium (U), and (b) Copper (Cu) in part of Garhwal Himalaya. The Upper Crustal abundance (UC) and Background concentration (Bkg) as mean value are also shown for comparison.

have perturbed down stream along the major rivers. Thus, further evaluation of the variation trends were carried out by eliminating samples of these main rivers and retaining only sample representing low order streams. The high Cu anomaly zones are invariably restricted to low-grade metamorphics of Garhwal group and are extremely depleted in MCT zone. These high Cu anomaly patches also include most of the reported mineralized locations. The median value for 67 low order stream sediment samples collected across the MCT zone is 5 and 19 ppm respectively for U and Th. A sizable number of these samples show abnormally high values up to 34 ppm for U and 135 ppm for Th, indicating potential prospects for mineralization. The correlation of U and Th with Zr is feeble and thus the high values of U and Th may not be entirely controlled by abundance of zircon in granitoids. The Pb values are also moderately high in these samples. In fact,

there are earlier reports of U mineralization at two places, both at the tip of the Jutogh thrust. Exploration activities at these sites reveal presence of radioactive ore minerals in minor veins, but were not found to be economically viable. The anomalies at these locations were also well picked-up by the present geochemical maps, however, few anomalies elsewhere are more intense, particularly near Sainj in Bhagirathi Valley, where U and Th as well as Pb show strong anomaly. Thus the present investigation provides an alternative basis for choosing and narrow down the area for mineral exploration.

Further, the Geochemical Analysis by any instrumental technique relies exclusively on calibration of the instrument with respect to matching rock standards. Though a wide range of these reference standards are available from several international agencies, but are too costly in view of our regular consumption and need. Moreover, the Himalayan rocks show unique trace elemental characteristics, and therefore, fill the gap as well as extend the concentration range of some elements that are not covered by the available geostandards. With this in mind, a programme to develop a series of reference rock standards of international quality was initiated. Further characterization process for *DG-H* and *AM-H* has also been carried out during the reporting year. More than 2500 units of data contributed by as many as 44 laboratories of international repute for about 50 constituent elements was subjected to rigorous statistical treatment for better characterization of this granitic standard i.e., *DG-H*. Similarly, contributed data from 28 laboratories for the *AM-H*, an amphibolite from Jeory, in Satluj valley, has also been compiled. Though the number of data sets from different laboratories are comparatively less, but the agreement of inter-laboratory data are excellent, suggesting proper homogenization of the bulk sample and may qualify to be characterized. Preliminary analytical characteristics of newly produced standard rock sample from Nyoma valley, Ladakh, reveal that it is a fresh sample having abundance of elements well within ultramafic clan of rocks. This standard has been named as *UM-H* that stands for Ultra Mafic sample from Himalaya.

5. PALEOCLIMATE AND ENVIRONMENT

The aim of the thrust area is to study the Late Quaternary vegetation and climatic change history. Also, to generate Geo-database of Natural Resources in Uttaranchal and make it available as a single window outlet for dessimination of information for the user agencies, and for proper monitoring of the execution work.

5.1 SUB PROJECT

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

(N.R. Phadtare)

About a meter thick well-dated Dayara peat sequence sampled at one-centimeter interval, has documented past 6000 years' sub-century-scale (ca 40 years) vegetation and climate history of the area.Preliminary data reveal that the Bhagirathi valley experienced significantly cool and dry climate during ca. 5200 to 3400 cal yr. BP. During this period, the Dayara meadow was covered with perennial ice.Detailed climate interpretation is in progress.

5.2 SUB PROJECT

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

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

Rudraprayag District is a newly created district which is carved out from Pauri Garhwal, Chamoli and Tehri Garhwal districts. It is a fairly small district of 2252 sq km area supporting a population of 227461 persons i.e. 120 persons per sq km density in the Lesser Himalaya. Lowest point is 710 m at the confluence of Alakhnanda and Mandakini rivers and highest point is 3562 m Kedarnath peak. It has 3 Developmental Blocks viz. Agastyamuni, Ukhimath and Jakholi. It has two Tehsils for revenue at Rudraprayag and Ukhimath. The area has perennial glaciers in the north i.e. Chorabari glacier. The district is drained by perennial Mandakini river and its tributaries viz. Kaliganga, Madhyamaheshwar, Kyunjagad, Lastar Gad, Helaun Gad. The area is quite rich in natural resources e.g. forest wealth, medicinal plants, wildlife in National Park (Kedarnath Musk Deer Sanctuary), perennial source of water in glaciers, places of pilgrimage, tourism and high altitude trekking.

Data collected from previous field trip was utilized in preparation of thematic maps. Emphasis was given to compilation of thematic maps by proper plotting of data and digitization of thematic maps. These maps are – drainage map, slope map, landslide distribution, landuse map, geological map. The data collected from various blocks has been partially utilized in the compilation work.

This data has also been utilized in the research papers on cloud bursts and flash floods of Mandakini valley. Slope instability map has been utilized in establishing the relationship of particular plant species to the unstable areas. All these maps are prepared on 1:50,000 scale. Soil samples collected during last year have been analysed for grain size and matrix. The samples are mainly from fluvial and glacio-fluvial deposits. These would help in understanding of palaeoclimatic changes and environmental set up. Village wise data on socio-economic aspects has been collected and put into a Data Base for Rudraprayag District.

6. NORTHEAST HIMALAYA

Wadia Institute has focused research in Eastern Syntaxial Bend of eastern Arunachal Pradesh, Western Arunachal Pradesh (Kameng) and Southern Sikkim since 2000. The geological research carried out includes aspects of tectonics and metamorphic history of the crystalline thrust sheets and geochemical evolution of the Lohit plutonic complex in eastern Arunachal Himalaya to trace the evolutionary history of crystalline thrust sheets studies has been extended to the western Arunachal Pradesh.

6.1 SUBPROJECT

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

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

The field studies carried out in Siang, Syom and Subansiri valleys of Arunachal Himalaya reveals that at present the Eastern Syntaxis represents a major antiformal structure across the Siang River, defined by the fabrics developed on both limbs. This is the youngest structure, since it folds the Indus Suture Zone. The eastern limb of this structure is considerably attenuated relative to the western limb. Crystalline rocks occupy the hinge zone of the syntaxis exposed in southern Tibet. However, its continuity towards south is complicated by a NE/SW trending fault that runs from Tuting towards NE along the Siang River. This fault has displaced the Trans Himalayan Lohit arc further SW. Hence the crystalline rocks in the hinge zone do not continue smoothly when traced towards SE in the eastern limb.

The stretching lineation associated with ductile deformation fabric in both the limbs does not indicate thrusting direction, since the lineation has been folded by the syntaxis. However, if the last generation Siang antiform is unfolded the lineation direction is parallel to the overall transport direction in the Himalaya, from NE to SW. In the crystalline rocks of the eastern limb, the fold axes of second phase isoclinal folds and the stretching lineations are sub-parallel which suggest that they are rotated during thrusting under simple shear regime. In the western limb the second-generation folds in the form of tight, asymmetric antiform and synform are developed in the Miri Quartzite sequence of the Lesser Himalaya, in the Syom valley section. The Siang antiform and the N-S oriented Bame Fault has rotated the orientation of the folds, in the western limb. This fault cut across most of the tectonic units in the western limb, showing mostly brittle- ductile deformation features. The Bame fault represents a neo- tectonic dextral tear fault, which is the latest structure.

6.2 SUB PROJECT

Lithotectonic terranes and neo-tectonic features between the valley of Kameng and Siang rivers, Arunachal Pradesh

(D.K. Misra and Trilochan Singh)

The project is aimed to standardize nomenclature in view of the fact that usuage of different nomenclature for similar formations has created confusion. It will further help to synthesise and correlate various litho-units and to understand geology of Arunachal Himalaya.

Five major tectonostratigraphic units have been demarcated during the detailed traverse mapping along the Bhalukpong-Tenga-Rupa-Bomdila-Se La-Tawang section in the Kameng valley of Western Arunachal Pradesh from south to north which are described in the following tabular form.

Se La Group	Kyanite-sillimanite bearing garnet-biotite schist and gneiss, psammitic gneiss, streaky gneiss, banded gneiss, intrusive tourmaline bearing leucogranite and amphibolite
---------- Main Central Thrust ----------	
Bomdila Group	Mylonitic augen gneiss, sericite-chlorite puckered phyllonite and foliated sericitic quartzite
---------- Bomdila Thrust ----------	
Buxa Group	Light to dark grey limestone, dolomitic limestone, green and white orthoquartzite
---------- Buxa Thrust ----------	
Gondwana Group	Carbonaceous shale, ferruginous shale with concretions, bluish grey quartzite, Khaki shale, sandstone and diamictite
---------- Main Boundary Thrust----------	
Siwalik Group	Green sandstone, green-earthy brown shale and sandstone
---------- Himalayan Frontal Thrust----------	
	Brahmaputra Alluvium

The Kameng segment of the NE Himalaya has a unique NE-SW trend in the west of 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 Bhalukpong, the contact between Brahamputra Alluvium and rocks of the Siwalik Group are referred to as Himalayan Frontal Thrust (HFT) which is very sharp. Along the tectonic contact, there is abrupt rise of 2000 m 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.

Four levels of river terraces have been observed in the Bhalukpong area of Kameng valley. It is observed that the Bhalukpong is situated on the gravelly fluvial terraces (T1, T2, T3 and T4). The telephone exchange is located on the older T1(220m), the circuit house is located on the T2 (210m), the State Bank of India is located on the T3 (200m) and the main market is located on the T4 (160m) above mean sea level. The younger/present Sandy alluvial flood plain (To) of river Kameng is exposed at an altitude of 130 m above mean sea level. This indicates that the Bhalukpong area is uplifted 90 meters above the Kameng River Bed in four pulses. A major transverse NW-SE trending active fault namely Bhalukpong Fault has been recognised. This fault has uplifted the Right Bank of river Kameng where the Bhalukpong settlement is located by 90 meters in four pulses.

The Himalaya is uplifting at the rate of 3 to 5 mm per year. The result of the faster uplift has escalated erosion in the mountain system along with widespread and severe landslides in the belts cut by the active faults. The eroded material finds their way through mountain torrents to river valleys in the foothills (which of late is subsiding). The Kameng River breaks into a large number of channels due to excessive sediment influx as it debouch into the plains across the Himalayan Frontal Thrust Thrust. The carrying capacity of the river Kameng has consequently diminished drastically, leading to frequent and uncontrollable flooding in the region.

Studies have also been carried out to study various geomorphic developments and active faults to understand recent crustal movements and their significance in the Himalayan upliftment. Various neotectonic features have been identified and delineated with ground truth. Landslides, both old and present, have been identified and mapped.The area has been mapped demarcating different Lithotectonic Terranes.

6.3 SUBPROJECT

The terminal Proterozoic-Lower Paleozoic sedimentation, Palaeo-biological and carbon isotope events in the NE Lesser Himalaya

(V.C. Tewari)

Sedimentological, Palaeobiological and Carbon Isotopic geochemistry of the Buxa Dolomite has been done. Stromatolites and chert samples were studied for the recovery of the microbiota and reconstruction of the depositional environment. Carbon isotope ratios have been used for the chemostratigraphy of the Buxa Dolomite. The petrographic thin sections were studied for the carbonate petrography, microstructures, microbial assemblages and diagentic effects. Various types of oolites were studied from the Neoproterozoic Buxa Dolomite and the Permian Gondwana carbonates exposed in the Ranjit Valley. X-Ray diffraction and Laser Raman Spectroscopic analyses of some selected carbonate samples have been done.

The chert samples studied from the Buxa Dolomite of the West Siang have yielded organic walled microfossils consisting of 27 taxa of the benthic and planktonic life in petrographic thin sections. In this assemblage (Fig. 13) 13 taxa are *Huronispora psilata*, *Eosynechococcus moorei*, *Paratetraphycus giganicus*, *Glenobotrydion aenigmatis*, *Myxococcoides minor*, *Palaeoanacystis suketensis*, *Oscillatoriopsis breviconvexa*, *O. robusta*, *O. rhomboidalis*, *Palaeolyngbya contenada*, *Siphnophycus typicum*, *S.rugosum*, *Polythrycoides lineatus*, *Obruchevella parva*, *Volyniella valdaica*, *Vetronostocale amoenum*, *Vetronostocale equale* belonging to the families Chroococcaceae, Nostocaceae and Oscillatoriaceae of cyanobacterial remains and 13 taxa of acritarchs viz. *Margominuscula rugosa*, *M. simplex*, *Leiospheridia visingsa*, *Granomarginata vetula*, *Lophospheridium rarurm*, *L. janosniusii*, *Trachisphaeridium robustum*, *Micrhystridium lanatum*, *M. ampliatum*, *Baltispheridium cerinum*, *Archaeohystrichospheridium semireticulatum*, *A. cellulare*, *Vandalosphaeridium reticulatum*, *Trachyhystrichosphera aimica*, *Gorgonisphera pindyium*, *Meghystrichosphaerium perfactum*, *Navifusa segmentatus*, *N. bacillaris* belonging to *Sphaeromorphida*, *Scaphomorphida* and *Sphaerohystrichomorphida* subgroups of acritarch as well as a single genus of VSM viz. *Melanocyrillium hexodiadema* has been recorded.

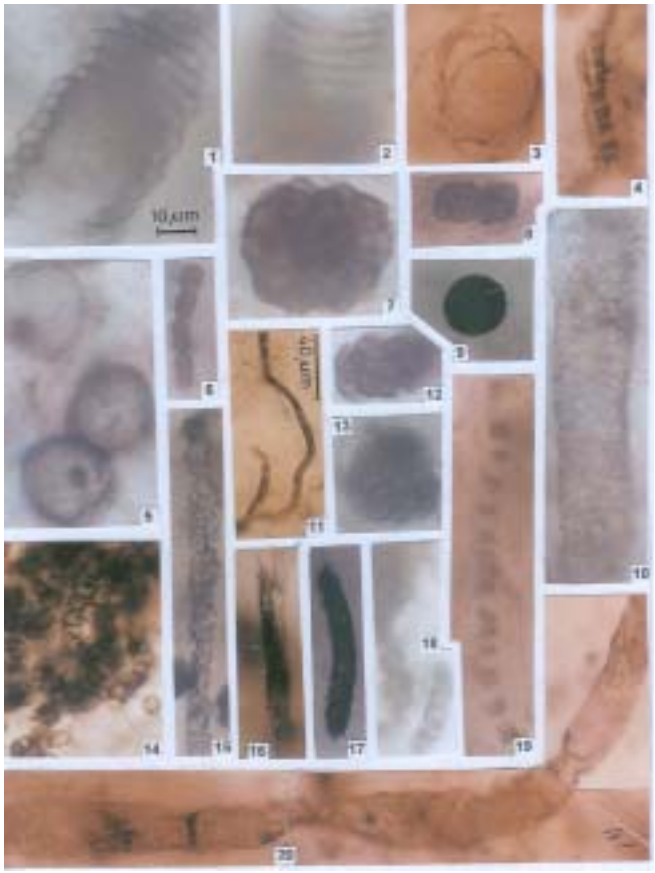

Fig. 13.Diversified Terminal Proterozoic (Vendian) Organic walled Microfossils from the Buxa Dolomite, NE Lesser Himalaya India.

The carbon and oxygen isotopic ratios of the Buxa Dolomite (Fig.14) has been studied. $\delta^{13}C$ **(**PDB**)** in the Buxa Dolomite vary in a narrow range from - 1.42 to + 1.04 ‰. Oxygen isotopes values grade from 19 to 23.9 ‰ ($\delta^{18}O$ SMOW) in the Buxa Dolomite. The Lower part of the Buxa Dolomite shows mostly positive trend of excursion and may be result of increased rate of organic matter burial in a shallow carbonate platform. Isotope data combined with sedimentological and palaeobiologocal studies suggest that Buxa Dolomite was deposited in a carbonate platform well connected with ocean. The environment was highly favourable for the luxuriant growth of the microbialites and the cyanobacterial microbial communities were flourishing in the photic zone. The positive near zero value of the Buxa Dolomite indicate that the environment of deposition was shallow marine peritidal / subtidal to intertidal.

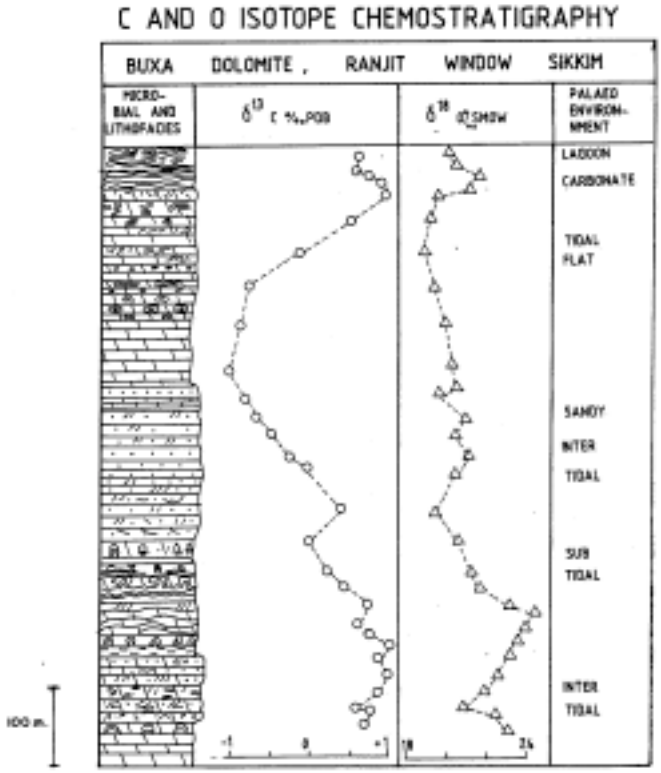

Fig. 14. Carbon and oxygen isotope chemostratigraphy of Buxa dolomite, NE Himalaya.

6.4 SUBPROJECT

Geochemical characterization and petrogenetic studies of Abor volcanics in Arunachal Himalaya

(A. Krishnakanta Singh)

The stratigraphic position and chronology of the Abor volcanics has remained problematic in the geology of Arunachal Himalaya, which are known to have associated with rocks of Miri-Buxa and Gondwana groups and also with the younger Eocene sequences. The project has aimed for detailed investigations of petrology-geochemistry and petrogenesis of the Abor volcanics and tectonic modeling of the area. This may lead to the definition of specific time slots from late Proterozoic to Tertiary for emplacement of these volcanics and in understanding their geochemical variations and petrological diversity through time.

A preliminary fieldwork around Rotung, Pangin, Boleng, Geku and Yinkiong in Siang valley was carried out. Various rock samples (basalt, agglomerte, welded tuff, trachyte, quartzite, sandstone) were collected for petrographical and geochemical analysis.Two types of

basalts viz. amygdaloidal basalt and massive basalt, have been identified based on the field studies, which show various shade of dark green, grey, black and reddish colour. Amygdaloidal basalt is more voluminous than the massive type. Minor amount of volcanic agglomerate and tuff are also associated with the basalt. The amygdules are composed of quartz, calcite, zeolite, epidote, chlorite etc. Most of the amygdules are elliptical shape and preferably orienting parallel to lineation mark probably due to the flow. At places, the basalts are extremely fractured and weathered. Veins of epidote and calcite occurred within the basalt. Variegated coloured (chocolate pink, grey and green) shale beds are also associated with basalt.

Preliminary petrographical analysis carried out for few basalts samples shows subophitic, intergrnular and glomeroporphyritic textures. Principle minerals are plagioclase, clinopyroxene with minor amount of quartz, calcite, epidote, magnetite and hematite. The detail petrographic and geochemical analysis are under process.

6.5 SUBPROJECT

Foraminiferal biostratigraphy of the Paleogene sediments of East and West Siang districts, Arunachal Pradesh

(Kapesa Lokho)

The project has been initiated to understand biostratigraphy, paleogeography and depositional environment of the Palaeogene sediments. A preliminary field work was carried out in Siang valley. Samples have been collected for micropaleontological studies from Pasighat upto Yinkiong. Processing of the samples for micropaleontological studies is under progress.

6.6 SUBPROJECT

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

(Khayingshing Luirei)

The North East India has been rocked by a number of earthquakes in the last 100 years, which suggests that this region is tectonically active. The Seismicity of the Himalaya is mainly related to major thrust viz. MCT, MBT and HFT. The project, therefore, has been initiated to undertake precise neotectonic investigations of the area between MBT and HFT in East and West Siang districts of Arunachal Himalaya.

It is planned to map the Quaternary deposits, documentation of active thrusts and faults and their effect on landforms and drainage, and analysis of geomorphic development, modifications,deformation and displacement of landforms caused by neotectonic movements in areas of identified active thrusts and faults.

SPONSORED RESEARCH PROJECTS

PROJECT

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

(DST-SERC-Earth Sciences)

(A.K. Dubey and S.S. Bhakuni)

Based on the field studies and laboratory results, a model for the structural evolution of the Kangra recess was proposed (Fig. 15). The first stage (Fig. 15a) shows the initiation of frontal and oblique ramp geometries, which were formed during an earlier tensional phase in the region. The dip of the fault varies along its length as shown in the diagram (Fig. 15a). The normal faulting was accompanied by sinistral displacement along the oblique slip leading to displacement out of the tectonic transport plane (Fig. 15b). A larger fault displacement took place along the steeper fault and resulted in formation of an extensional fault "f_1", which is a continuation of the early fault ramp. The new fault gradually propagated along its strike.

Normal faulting in the region is supported by the following geological facts.

i) The various litho-units show an increase in thickness and deepening of the basin to the east.
ii) The area west of the oblique ramp remained uplifted from the Late Proterozoic to Jurassic, and
iii) Palaeocurrents reveal palaeoslopes due east.

The compressive phase of the Tertiary Himalayan orogeny resulted in the reversal of fault displacement as thrust (Fig. 15c), and dextral oblique slip displacement along the central oblique ramp. The resulting displacement out of the tectonic transport plane led to the formation of a pull-apart basin in the central oblique ramp region where Tertiary rocks were deposited. Progressive deformation during the compressive phase produced thrusting in the pull-apart basin. The central oblique ramp propagated by extending its length (i.e. f_2, Fig. 15c). This was simultaneous with formation of early folds in the region. The strike-slip component of the oblique slip displacement varies along the length of the oblique ramp. The maximum displacement occurs in the central part of the oblique ramp and gradually decreases on either side towards the frontal ramps. The decrease in displacement is accommodated by increase in intensity of buckle folding near the frontal ramps.

The combination of normal and shear stresses results in development of minor folds with large variation in orientation pattern. After locking of the thrust and the folds, the axis of maximum compression changed to an orthogonal direction (Fig. 15d) and superposed deformation initiated in the region. The reorientation of the stress field resulted in reversal of fault displacement and formation of superposed folds. The superposed fold hinge lines have an orthogonal relationship to the early fold hinge lines. Reversal of displacement at the central oblique ramp resulted in normal fault displacement. The sinistral strike-slip displacement may be attributed to the formation of f_3 fault in the footwall at the junction of the frontal and oblique ramps (e.g. Rupar lineament).

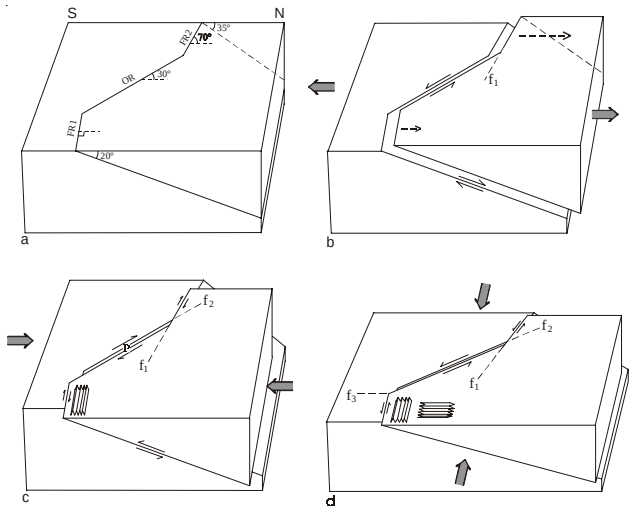

Fig. 15. A simplified model showing stages in the structural evolution of the area.
a) Initiation of fractures during tensional phase in the region. FR, frontal ramps; OR, obique ramps; N-S, North and South directions.
b) Normal faulting and formation of extensional fault f_1 as a result of variation of displacement along the leading and trailing frontal normal ramps.
c) Reactivation and reversal of the early normal fault as thrust during the compressional phase, formation of early folds, and pull-apart basin(P) at the central oblique ramp, and extension of the oblique ramp as f_2.
d) Superposed deformation during the Himalayan orogeny, formation of superposed folds and f_3 fault.

Implication of the model for understanding the Regional Seismicity

The great earthquake of Kangra (4 April, 1905) (magnitude 8.6 on Richter scale) was caused by displacement along

the MBT. The zone of the highest intensity was centered on Kangra and Dharamsala (i.e. near the trailing frontal thrust ramp) with a gradual decrease in the southeast direction towards Mandi. The southern part of the oblique ramp and the leading frontal ramp remained unaffected by the earthquake. A minor seismic zone was centered on Dehra Dun region, which is marked by another prominent oblique ramp and lies further southeast of the Kangra recess. Three possibilities can be considered for the purpose of evaluating earthquake hazards.

1. A fracture zone of ~ 280 km length relieved all the strain that had accumulated since the last earthquake(s) in the region. The lower intensity near Dehra Dun could result from strain having been relieved by a previous earthquake prior to the one near Dharamsala.

2. Two separate segments ruptured in 1905 and slip occurred aseismically in the intervening region, and

3. The earthquake was associated with only a short rupture ~100 km in length between Dharamsala and Mandi, but this could not lead to seismic activity near Dehra Dun.

The above possibilities can be seen in the light of the present study. The experimental results reveal that the rate, amount, and pattern of displacement can vary along the trailing, oblique, and frontal ramps. The trailing ramp may exhibit displacement while the frontal ramp remains inactive, at the same time. The maximum displacement along an oblique ramp can be 36% of its length. The estimated displacement of 33 km in the northern part of the oblique ramp is only 18% of the length thereby providing an indication that the thrust is still not locked. However, rotational component in the central part of the oblique ramp revealed by curvature of the fold hinge lines, and folding of the southern part of the Kangra recess along NE-SW axis (caused by large translation along the Chail-Jutogh Thrust) suggest that the thrust has acquired the locking stage. The confinement of the seismic activity around the trailing ramp further suggests that the other segments of the fault are probably locked.

With knowledge of the present structural scenario of the region, the future seismic activity in the region can be predicted with special consideration of the following points.

1. The geological structures and AMS studies suggest that superposed deformation has initiated in the region. The deformation can lead to reactivation and reversal of displacement along the oblique thrust ramp as oblique normal fault. The experimental evidence suggests that the initial rate of fault displacement at the onset of superposed deformation is very high. It was observed from a location near the junction of the trailing and oblique ramps that 33% of the total displacement, achieved during the early deformation, took place during the first 4% shortening of the superposed deformation and 70% of the early displacement took place at 8% superposed shortening. In the Kangra region 33% and 70% of the estimated early fault displacement (i.e. 33km) are 10.89 and 23.1km respectively. These enormous rates of displacement are capable of producing earthquakes of great magnitudes. In the 1905 earthquake, a total of 18,815 people lost their lives but with increase in the population of the area, a future earthquake of similar intensity can lead to many fold increase in the loss.

   It is to be noted that the Kangra area is still an active earthquake zone as minor earthquakes have occurred in 1968, 1978, and 1986. The cracks, initiated by these earthquakes, are of oblique normal fault type with left lateral displacement. The fault surfaces trend N30W to N45W (i.e. parallel to the trailing frontal ramp) and the down throw is towards northeast. This observation alarms us of an impending earthquake!

2. Fault displacement can take place along the Bilaspur-Rupar segment of the Fugtal-Manali Mega lineament. This could be very disastrous because Bhakra Dam (one of the largest dams of Asia; height, 225.6m; power generation, 1050mw) on the Satluj River is at a short distance of 30 km from the lineament and the river flows through a part of the segment.

3. Oblique thrusting in the frontal thrust ramp north of Kangra is the safest proposition but is unlikely to occur because; (i) superposed folds have already initiated indicating change in the maximum compression direction, (ii) normal faulting has been reported from the region, and (iii) the central and the leading ramps are already locked for thrusting.

The seismic record from the Himalaya reveals that no great earthquake was caused by normal faulting. However, post-thrust normal faulting near oblique ramps has been reported from a number of geological horizons. Hence the possibility of an earthquake by normal faulting cannot be ruled out.

A time frame for the evolution of the predicted structural features cannot be prescribed with the available data.The shortening estimates based on restoration of deformed sections are not reliable hence alternate methods have to be applied. These include structural studies along active faults, a close network of seismic and GPS stations for continuous monitoring of seismic activities and displacement along the MBT and subsidiary faults. The study will also help while suggesting sites for important structures (e.g. big dams, hydel projects etc) in this seismicity prone area.

PROJECT

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

(DST-Deep Continental Studies)

(Hakim Rai, D. R. Rao and J. Sentilkumar)

The Karakoram Range defines the northern limit of the Indian territory and has developed along the southern fringe of Eurasian Plate. The basal part of Karakoram Tethys is dominated by black Permo-Carboniferous argillites and is intruded by the late Cretaceous-Tertiary Karakoram Batholith. The argillites succession, in the southeastern Karakoram, has witnessed igneous activity that is confined only to the Permian in the form of lava flows, granitic pluton and dykes. There is no direct link of this body with the Karakoram Batholith, however, there may be a genetic linkage between the two.

The studies along Sasoma-Saser Brangra Section, Karakoram were initiated. The aim of the study was to provide the geological information on the Karakoram batholith and to suggest possible mechanisms that were responsible for the development of granitoids of the southern slope of the Karakoram Batholith between Sasoma-Saser Brangra regions. The studies carried out on the granitoid rocks of the region suggest that they are of metaluminous to peraluminous in nature, with mol. A/CNK values around 1. The rocks have Sr_i ratio around 0.709 and show volcanic-arc affinity. The isotopic studies carried out on these rocks suggest the emplacement age to be around 124 Ma and were derived from the reworking of lower crustal calc-alkaline parental rocks.

PROJECT

Ultrahigh-Pressure metamorphism in Tso-Morari region, Ladakh Himalaya: implications for deep crustal processes in Himalaya

(DST-Deep Continental Studies)

(H.K. Sachan, T. Ahmad and B.K. Mukherjee)

A detailed fieldwork has been carried out during July-September field season in the Tso-Morari region of Ladakh to collect suitable samples of metabasics (eclogites) and host rock for detail petrographic, mineral chemistry, fluid inclusion and isotopic studies. Preliminary petrographic studies indicate the presence of very high pressure minerals, which needs to be confirmed by Raman Probe. The preliminary fluid inclusion studies carried out on minerals like garnet, omphacite and apatite, showed biphase and triphase inclusions. These inclusions are prominently needle shaped and are aligned along the C-axis of the host grains. Further studies are in progress.

PROJECT

Cretaceous-Eocene biotas from Northern margin of the Indian Plate and Indus Suture Zone of Ladakh Himalaya and their palaeobiographic significance

(DST-SERC-Earth Sciences)

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

Biostratigraphy and biotas of the Cretaceous- Eocene succession were worked out in selected sections of the Indus Suture Zone and of the Zanskar Tethyan Zone which forms northern margin of the Indian Plate. Biostratigraphic succession in the Kong River section (South Zanskar Belt) and Kelcha section (North Zanskar Belt) were worked out. In the studied part of the Kong River section, the uppermost Cretaceous-Eocene sediments are represented by the calcareous Marpo, arenaceous Stumpata, calcareous Dibling, marly to argillaceous Kong and argillaceous to arenaceous Chulung La formations. A number of foraminiferal taxa were identified from various assemblage zones delineated in the Marpo, Dibling and Kong formations. Based on the microfauna , the Marpo Formation has been assigned a Late Maastrichtian to an Early Thanetian age encompassing interval between Gansserina gansseri Zone and lower part of Shallow Benthic Zone (SBZ) 2 of Serra – Kiel *et al.*(1998); the

Dibling Formation- a Thanetian to the earliest Ypressian age corresponding to interval between upper part of SBZ 2 and SBZ 8; and the Kong Formation –a late Early to Late Ypressian age corresponding to interval between SBZ 9 and SBZ 12. In the Kelcha section, the uppermost Cretaceous – Eocene sediments are represented by the argillaceous to calcareous Goma, calcareous Lingshet and argillaceous Kong formations. The Lingshet Formation of NZB is equivalent to the Dibling Formation of SZB . A number of larger foraminiferal taxa were identified from various assemblage zones delineated in the Lingshet Formation. The microfauna suggests that this unit ranges from Thanetian to the earliest Ypresian corresponding to interval between upper part of SBZ 2 and SBZ 8.

In the Indus Suture Zone of western Ladakh, the Lower Cretaceous sediments are represented by the Khalsi Limestone. In the Khalsi section, a number of larger foraminifers indicative of Aptian to Albian age were identified from this unit.The base of this unit is no where exposed and it is in tectonic contact with the Ladakh Molasse Group (Miocene-Pliocene) to the north. The Khalsi Limestone is overlain by the volcano- sedimentary Nindam Formation (Late Cretaceous-Early Eocene). In the Khalsi section, the latter unit is in tectonic contact with the Zanskar Tethyan sediments to the south. However, in the Sumdha Gompa section, the Nindam Formation is in tectonic contact with the flyschoid Indus Formation (Late Palaeocene – Early Eocene) to the south. Four members, namely the argillaceous to arenaceous Sumdha Gompa, calcareous to argillaceous Nummulitic, marly Jurutze, and argillaceous to arenaceous Gongmaru La (in ascending order) have been recognised in the Indus Formation. Numerous larger foraminifera were recovered from various assemblages zones delineated in the Nummulitic Member of the Indus Formation. The microfunna recovered from this member suggests an Early to early Late Ypression age corresponding to interval between lower part of SBZ 6 to lower part of SBZ 12.

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 Kunzum La Formation in Spiti valley consists dominantly of shallow marine near shore and shore line deposits.

The paleofacies analysis of the ichnofossils bearing rocks of the Kunzum *la* Formation indicates three distinctive lithofacies association.On the basis of lithological characteristic, deposition of sediment fabrics and associated ichnofabric tiers indicate the basal part of the Kunzum *la* Formation dominated by Shale-Sandstone lithofacies which characterized by deep Neritic Ichnofacies association, middle part dominated by siltstone-sandstone lithofacies characterized by Cruziana ichnofacies and upper part dominated by sandstone-quartzite lithofacies characterized by *Skolithos* ichnofacies association.

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 Shanchi Peng)

The Kunzum La Formation show coarsening upward cycles are in cases capped with fluvial sandstone deposits. The marine deposits are dominated by sedimentary structures indicative of storm generated structures. Fossiliferous carbonate beds (trilobite bearing) in top part of the Kunzumla Formation represent the initial transgressive deposits with marine flooding basal part. The paleocurrent analysis of Kunzumla Formation indicates generally towards the north-northeast direction for both marine and fluvial facies, which suggest that the hinterland was towards the south.

The detrital zircon age data from nearly age equivalent strata of higher and lesser Himalayan area reveal similar age population, but show difference in population abundance and degree of maturity of zircon grains.

Paleoenvironmental analysis and Palaeocurrent data suggest that the latest Lower to Middle Cambrain deposits of the Lesser and Tethys Himalaya are parts of the same northward prograding fluvio-deltaic depositional system on the paleo-Tethys margin of India.

An angular uncorformity with ordovician conglomeratic rocks at the top of the Parahio Formation has considerable local relief, with a valley-fill over 100m thick. Ordovician strata record northward transport of coarse debris. Structural data indicate contractional tectonics and the possible local development of Cambrian-Ordorician age folds and faults.

PROJECT

Paleobiology and Biosedimentology of the Proterozoic –Cambrian sediments in carbonate belt of Eastern Kumaun Lesser Himalaya, India.

(DST-SERC-Earth Sciences)

(Meera Tiwari, C.C. Pant and Indu Pant)

Gangolihat Dolomite exposed in Jhiroli Magnesite Mine section, Bageshwar- Kapkot section, Gangolihat – Ghat section and Chera section contain well preserved cyanobacterial filaments, acritarchs and sponge spicules. The microbiota identified as various species of *Siphonophycus,Oscillatoriopsis, Gunflintia, Nostochomorpha, Chlorogloecapsis, Eupoikilofusa, Mixococcoides, Trchyhystrichosphaeridium, Micrhystridium, Cymatiosphaeridium* and hexactinellid sponge spicules. Among the assemblage acanthomorphic acritarchs and hexactinellid sponge spicules are of special interest. These hexactinellid sponge spicules are being reported for the first time from rock of Vendian age. Detailed petrographic studies were also carried out on these samples.

PROJECT

Influence of Lesser Himalaya Dhauldhar Range on evolution of foreland basin in Kangra valley Punjab re-entrant

(DST-SERC-Earth Sciences)

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

A 2.7 km thick Mio-Pliocene Siwalik succession of Ravi re-entrant of the NW Himalayan foreland basin consisting dominantly sandstone-mudstone association in the lower part, sandstone- mudstone-conglomerate in the middle and terminates with thickly bedded conglomerate. The chronology of the sedimentary succession is constrained between 12.775-4.480 Ma using magnetic polarity stratigraphy.

The average sediment accumulation rate (SAR) derived for the lower 2590 m of the section is 31 cm/1000 yrs with two prominent peaks of high rate i) 43 cm/1000 yrs at 8.69 Ma and ii) 37 cm/1000 yrs a .93 Ma, separated by a decrease in SAR to 26 cm/1000 yrs at 8.25-6.93 Ma.

The results obtained from the temporal lithological organization, palaeoflow pattern and the net SAR are integrated to decipher the accumulation history in response to various phases of tectonic rejuvenation. The vertical accretion deposits at 9.74-8.25 Ma (1000-1500 m) having lenticular geometry correspond to an active phase of tectonism. At 8.25-6.93 Ma (1500-2000 m) a change in the formative fluvial processes is indicated by the presence of sheet geometry of the channel units and a decrease in SAR points to a quiescent phase. The later increase in the net SAR and the recurrence of the lenticular geometry indicate another phase of tectonic loading and basinal subsidence along the adjacent orogenic front. Overall channel geometry, basin subsidence and net SAR are the manifestation of tectonic activity in the hinterland.

Main Highlights

1. The base of the section dates from 12.8 Ma and represents the Chinji-type deposits, therefore, the section starts from upper part of Lower Siwaliks (cf. Burbank et al., 1996).
2. The Chinji-Nargri faunal event of Vasishat et al., 1983, which is correlated with Potwar Plateau of Pakistan, occurs at 495 m level from the base of the section at approximately 11 Ma.
3. The influx of conglomerates begins at 8.7 Ma at approximately 1200 m of the section. Thickly bedded conglomerates appear until 2200 m level at an age of 5.89 Ma.
4. Influence of piedmont drainage from the very beginning of the section (40 m) level signifies intense denudation and uplift of the outer Lesser Himalayan belt simultaneously.
5. The fluctuation in the sedimentation rate with conspicuous peaks at 8.7 Ma suggests tectonic pulses and a quiescence period thereafter, while the 6.9 Ma suggests a second phase of movement of thrust sheets in the hinterland.

PROJECT

Rock magnetic and geochemical charcterization of Plio-Pleistoncene Siwalik Paleosols from the Indo-Gangetic Forland Basin, NW Himalaya

(DST-SERC-Earth Sciences)

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

Documentation based upon field examination of lithofacies with special reference to the pedogenic horizons have been furnished for 1800 m thick Mohand Rao section, 2400 m thick Haripur Khol section, 1100 m thick Ghaggar section and 300m thick Moginand section. Magnetostratigraphic

sampling for Ghaggar and Moginand section has been undertaken, while the magnetostratigraphic dates for rest of the two were already available. More than 600 pedogenic levels have been sampled for detailed analysis using rock magnetism and geochemistry. Analysis for about 20% of samples is over.

With the available field and laboratory information, it was observed that the paleosols from different geological time (Miocene to Pleistocene) show significant abrupt changes both in time space. The rock magnetic and geochemical results infer variety of pedogenic processes remobilizing the iron oxides by oxidation, hydroxylation and dehydroxylation of primary (parent) material into majority of canted antiferromagnetic minerals (Hematite-Fe_2O_3 and Goethite-FeO.OH). The low frequency dependent magnetic susceptibility (x_{fd} mean = 2.03%) infer absence of finer pedogenic Superparamagnetic (SP) fraction that might have been incorporated during post-burial diagenetic processes. As more results are awaited, a good reconstruction of the Miocene to Pleistocene paleoclimatic and tectono-climatic changes using this interdisciplinary higher resolution approach would be possible.

PROJECT

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

(DST-SERC-Earth Sciences)

(N.R. Phadtare, R.K. Pant and Sandeep Nandi)

Himalayan mountain range plays a significant role in dynamics of the climate as well as SW monsoon system of the Indian subcontinent. Moreover, the mountain ecosystem is highly fragile and critically climate sensitive. Paleoclimate records preserved in natural archives (e.g. lake sediments, peat deposits, tree rings, etc) of the Himalaya, therefore, are of significant importance for revealing the past climate changes and monsoon variability in Indian subcontinent. In spite of this potential, the age-constrained paleoclimate data are virtually lacking particularly from the Indian part of the Himalaya. In view of this, the generation of high-resolution (decade to century-scale) data on the Holocene climate and monsoon record preserved in peat deposits of the Kumaon-Garhwal Higher Himalaya, was initiated.

As a part of this investigation, well-dated (^{14}C AMS and ^{210}Pb) multidisciplinary paleoclimate data (pollen, diatoms, phytoliths, total organic matter and magnetic properties, etc) retrieved from 1.25 m thick Dhakuri peat deposit revealed past 3500-year climate and monsoon history of the Pinder valley in Kumaon Higher Himalaya.

Wet periods	Relatively dry periods
3500 – 3300 cal yr BP	3300 – 2300 cal yr BP
2300 – 2100 cal yr BP	2100 – 1700 cal yr BP
1700 – 740 cal yr BP	740 – 640 cal yr BP
640 cal yr BP – Present	

The wet climate episodes indicate stepwise progressive increase in monsoon precipitation. This monsoon trend shows close relationship with global climate events such as El Nino-Southern Oscillation (ENSO) and the North Atlantic thermohaline circulation.

Past ca 200 year's paleo-proxy record indicate significant cooling in down-slope areas most likely due to increased glacial melting around Pindari and associated glaciers, possibly suggesting negative feedback mechanism of the climate. The cooling temperature particularly since 1950s is also documented in instrumental records from various weather stations including Mukteshwar and Joshimath in Himalaya, and western Gangetic plain. This cooling trend is contradictory to present global warming and accelerated glacial melting. This finding clearly indicates the heterogeneity and complex nature of the Himalayan climate.

PROJECT

Mountain Terrain Resource Information System (MOTIS) for Silk Route Using Remote Sensing and GIS Techniques

(ISRO-NRSA)

(G. Philip and N.S. Virdi)

The Silk route that is located barely 50 kms distance from Indo-China border is strategically very important for India and China as it connects Pakistan via Karakoram. In the present project, 8 thematic maps (including lithology, drainage, landform, lineament and structure, landuse, landslide, slope) for five satellite scenes covering Gar-Amdo sector have been prepared using IRS 1C/1D LISS III precision geocoded images. Besides the primary thematic layers, derivatives of critical thematic information for slope instability from other ancillary data have also been integrated in a GIS environment on 1:50,000 scale. The project is under progress and aimed at to create resource information along this route. The terrain is rugged and inaccessible and the database generated for such terrain

becomes a valuable resource for early warning and mitigation.

PROJECT

Active Faults and Neotectonic activity (with reference to seismic hazards) in parts of the Frontal Himalaya and the piedmont zone between Ravi and Yamuna rivers (AFNAH)

(DST-Seismicity Programme)

(N.S. Virdi and G. Philip)

The project started w.e.f., 8-10-2003. During the six month period ending March, 2004, the following three targets were laid down.

a) Collection of available information maps, satellite data procurement etc.
b) Recruitment of project staff.
c) Compilation of geological, geomorphological drainage and lineament maps from available data.

The work on aspects a and c is nearly complete. Base drainage and topographic maps of terrain between Tons-Yamuna in the east and Satluj in the west have been prepared on 1:50,000 scale. Regional structural elements and lithological boundaries, lineaments and possible active structures have been plotted. These are to be verified now after field checks.

PROJECT

Earthquake Hazard assessment through geological evidence along active fault zone (paleoseismicity) in part of Northwestern Himalaya

(DST-Seismicity Programme)

(T.N. Bagati, N.S. Virdi, Rohtash Kumar and N. Suresh)

The trenching of fault scarp at Pinjore between MBT and HFT shows presence of dykes (Fig. 16) cutting across the muddy layer. One major fault was observed which cuts across the entire sequence. At Afrik farms sand blows and flame structures with rare dykes were observed. The soft sediment deformation structures observed in fluvial terrace near Kalka includes liquefied varves, cycloids and flame structures (Fig.17) etc.

An overview shows that sedimentary deformation structures, and displacement of 2.5m due to faulting at Pinjore suggest the occurrence of major earthquakes of magnitude more than 7 (Richter scale) at that period in

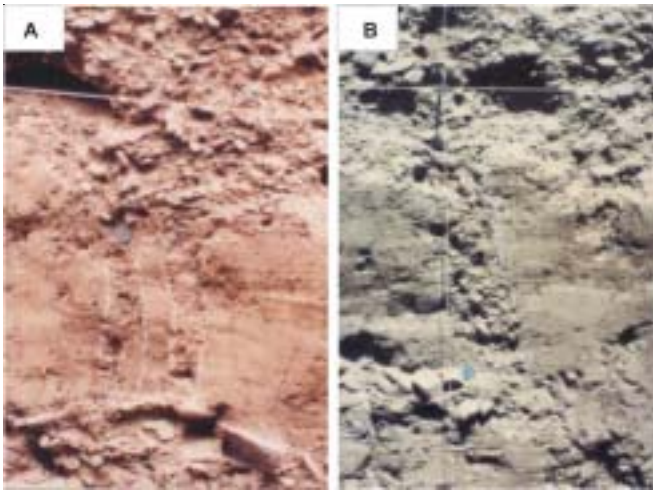

Fig. 16. Dykes cutting across the mudstone facies in the Pinjore trench.

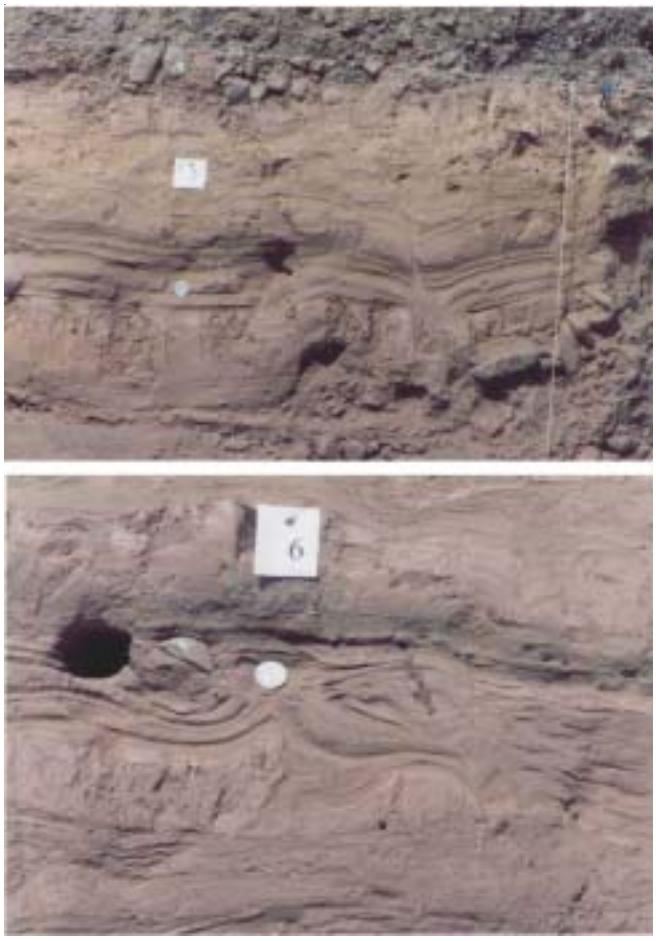

Fig. 17. Soft sediment deformation structures in fluvial terrace near Kalka.

Pinjore and earthquake almost of same magnitude at Adh Badri. The dating of these events will help us in understanding the recurrence interval.

PROJECT

Earthquake geology aspects and seismic hazard assessment in Garhwal Himalaya

(CSIR Emeritus Scientist Scheme)

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

The Himalayan Frontal Thrust (HFT) represents a zone of active deformation. South of Dun, the HFT is represented by a sharp topographic break between the NE dipping sandstone cliffs of Siwalik and the alluvium, flat plain. In trenches excavated 100 km south of surface trace of the fault, the middle Siwalik sandstone dipping NE 15^{o}-30^{o} overlies the alluvium and in turn are overlain by stream sediments. South of HFT, in an area extending in front of the foothills, an uplifted piedmont zone, 10-25 km wide, is recognized between Yamuna and Ganga. We have carried field study on the piedmont zone between Roorkee and Chuttmalpur. The piedmont zone is made of alluvial fans with proximal facies of gravels and coarse sands and distal facies of sand and silt, poorly consolidated and weakly stratified at places. The remnants of the piedmont fan is preserved as ridges, 15-20 km high from the flood plain, such as Biharigarh ridge, Sherpur, along left bank of Mohan rao, Imlikhera and Ibrahimpur. In areal photographs and satellite imagery, a NW-SE trending fault is recognized as a lineament that characterize the southern face of the scarp. The orientation and location of this fault, called Solani Piedmont Fault, corresponds to sharp knee-bend turn taken by streams flowing from northeast to southeast. The uplifted upwrap of the piedmont zone may have resulted due to deformation related to southward propagation of HFT. An imbricate branching- out of the HFT, developing on the footwall as a low-angle dipping thrust fault, may have caused the uplift of the piedmont zone. The fault may remain blind during the initial stage or may rupture on the surface as active fault.

PROJECT

Site specific response studies for seismic microzonation of the National Capital Region

(DST-Seismicity Programme)

(Kamal and A.K. Mundepi)

The field work was carried out for 6 months during April-June and November-January. Ten short period seismographs were installed in a semi mobile mode all around Delhi region.The NCR was divided in several zones and each zone was equipped with a seismograph.The basic idea was to cover all regions of Delhi at any given time. The seismographs were kept at one place for about 5-6 days and then moved to another location in their respective zones.

Seismic data were collected at a sampling rate of 100 s/s so as to include all the frequencies of interest for determining the fundamental frequencies of respective sites. About 100 Gb of seismic data were collected during this survey. Most of the NCR has been covered. Several local, regional and teleseismic events are being used for interpretation along with the microtremors recorded during the field survey. The occurrence of many local earthquakes during the survey added to get remarkable results for Delhi's seismic microzonation. Fundamental period of several sites have already been estimated. A first order site response image of Delhi for several fundamental frequencies has been obtained (Fig.18).

PROJECT

Study of earthquake source processes, delineation of active seismic zones and velocity structure in north-west Himalaya

(DST-Seismicity Programme)

(Kamal, Sushil Kumar, A.K. Mahajan, V. Sriram and A.K. Mundepi)

During the year, 1234 earthquakes (local, regional and teleseismic) of WIHG network (analog and digital instruments) have been identified for further analysis. Out of these about 143 local earthquakes has been rechecked and nalysed. The hypocentre of these local earthquakes ranges from about 4 to 20 Km. and r.m.s. ranges less than 1.0. ERZ and ERH vary depending on the epicentral location of the earthquake. Other than this it is observed that couple of our stations in Himachal region i.e. Jadera and Kothi show high local seismicity, within 1 to 3 second S-P time, which is recorded only in respective stations.

Local Seismicity has also been prominent in the MCT zone in Garhwal Himalaya. The seismic station in Uttarkashi region has recorded swarm activity of many microearthquakes. The study of these swarms is under progress.

Further west, several events seem to be occurring along a NE-SW trending lineament transverse to the regional trend in Nepal Himalaya. These events align

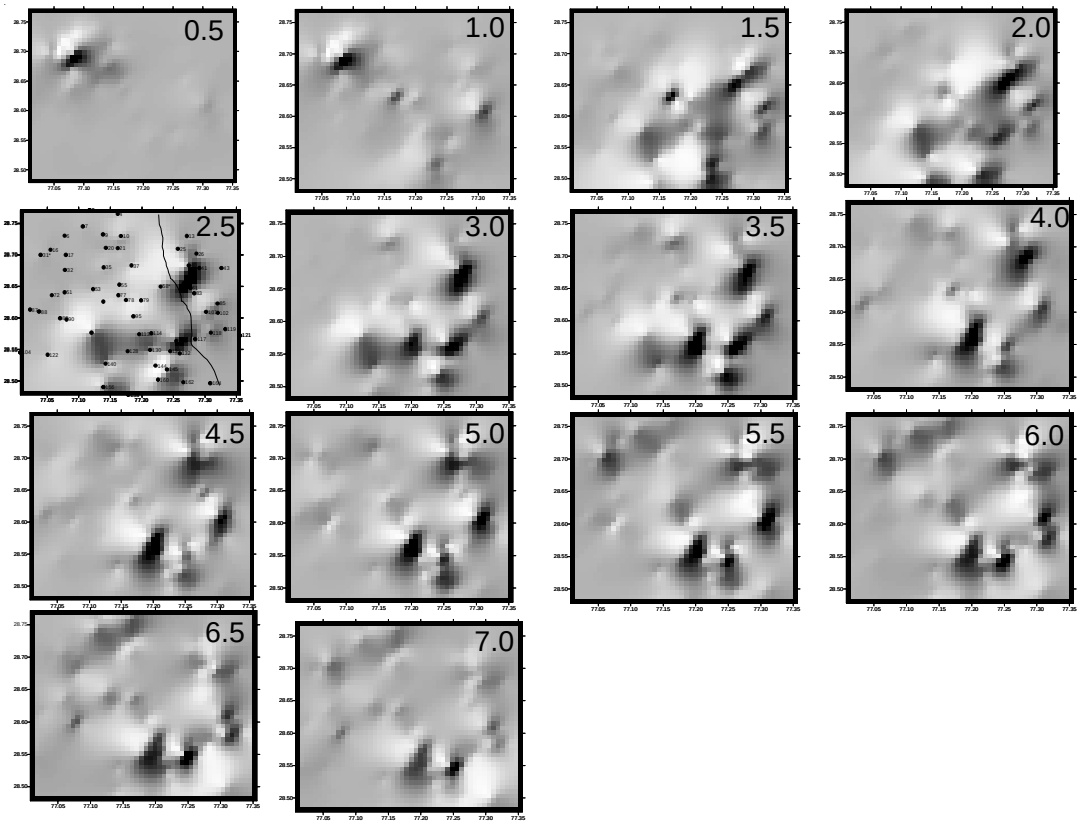

Fig. 18. First order site response image of Delhi region at several fundamental frequencies based on microtremor survey carried out in the year 2003. The alternating regions of bright and dark shades represent area of high amplification at the frequency indicated at the top right hand corner of each block. The river Yamuna and some of the recording sites are also shown in the block second from the top one.

themselves along a lineament approximately 10 km SE of the river Kali in Nepal parallel to the river. A few events occur between MCT and Vaikrita thrust.

Crustal Structure

Converted phases from layer boundaries in the crust and the upper mantle for a steeply incident P wave from deep teleseismic earthquakes can be easily mapped using Receiver Function technique, which can be inverted for the velocity structure below the observation point. One such study is taken up to estimate the crust – mantle structure below the seismological observatories in the Higher Himalaya. The data for the period April 2000 to March 2001 from the WIHG Broad-band seismological observatories at Kothi (HP), Tissa (HP) and Hanle (Ladakh) are used in the study. The preliminary results obtained are as under.

The Hanle observatory located on the Indus-Tsangpo Suture zone has a very complex structure with moho at a depth of 85-90 km. The presence of low velocity zone at 19 and around 48 km shows the possibility of existence of double crust below this station.

The Kothi seismological observatory is located on the Central Crystallines. It has s diffused moho around 52 km and a layer with 6.2 km/s P-wave velocity at 18 km.

The crust below Tissa observatory, which is located on the Tethyan metasediments in the Chamba nappe region of Himachal Pradesh has a fairly sharp structure with moho at a depth of 48 km and a prominent layer at 18 km.

These results were from 10 events from the azimuth range of 105 – 147° E. More detailed analysis with more events from different azimuths are in progress.

Seismic Hazard

Keeping in view the high seismic potential, the region bounded by 28 –35° N and 74 –82° E has been selected for computation of seismic hazard. Using the probabilistic hazard assessment approach of Cornell (1968) adapted by McGuire (1993), Peak Ground acceleration (PGA) were computed for 10% probability of exceedance in 50 years, 100 years, 500 years and 1000 years at locations defined in the grid of 0.250 x 0.250. To compute the seismic hazard

of Northwest Himalaya, sixteen different seismic source zones have been identified on the basis of tectonics, geology and spatio-temporal seismic activity. All the source zones have different geological characteristics.

Due to the different geological characteristics of each source zones, the attenuation relation given by Peng *et al*. (1985) and Hasegawa *et al.* (1981) used have been used for computing the seismic hazard of the region. The PGA values over the grid were contoured to obtain a seismic hazard map. The hazard map depicts that there are two major zones of high seismic potential. One centered around Kangra-Chamba region and other around Chamoli region having hazard level of the order of 0.7g and 0.5g respectively for 90% non exceedance in 50 years.

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)

A site-specific attenuation relation is an important parameter to carry out the study for the estimation of seismic hazard. Recognizing that the observed intensities from Kangra earthquake event, some site effects may represent average regional site effects arising due to the near surface geology or soil. A new empirical relation has been developed to estimate intensity attenuation as a function of magnitude and distance using isoseismal map of 1905 Kangra earthquake (Fig.19). To evaluate the attenuation of intensity with distance, two regression curves are calculated as below

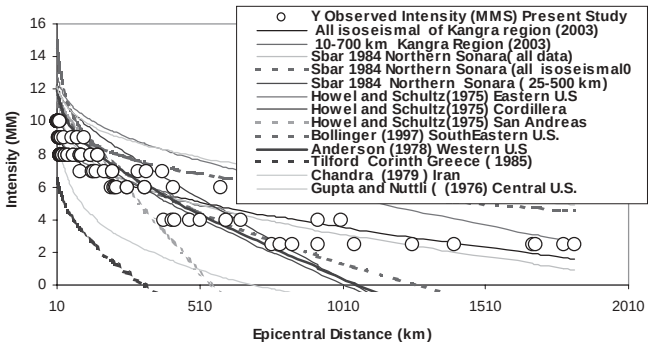

Fig. 19. The regression curves plotted using various attenuation equation and are fitted to the isoseismal data at the Kangra region and other regions of the world.

$II = 11.08 + 0.835 - 0.00173*R - 0.95975 *LnI + \sigma I; \quad (\sigma I = 0.87) > 700km$

$II = 11.08 + 0.150 - 0.00307*R - 0.73301 *LnI + \sigma I'; \quad (\sigma I' = 0.77) < 700km$

Where R is the epicentral distance in km, II is Intensity with respect to epicentral distance. The derived attenuation relations have been compared with the existing relation based on seismic intensities. It has been observed that the attenuation curve at the Northern Sonara region, Mexico is similar to that of the Kangra region. After comparing the intensity attenuation from different regions like Mexico, Greece, Iran, it has been observed that the miezoseismal intensity at R = 0 is very high at Northern Sonara (Mexico), Iran and Greece as compared to the Kangra region.

In another work the Northwest Himalayan earthquake catalogue database has been improved for the period 1553 to 2002 A.D and a revised catalogue for the past 450 years has been proposed for statistical analysis. The completeness of earthquake catalogue has been done for 1370 events from 1553 to 1964 for historical earthquakes and 1964 to 2002 for instrumental earthquakes. To obtain the statistical completeness, the time interval for different ranges of magnitude has been determined in time windows 50 years (1953-2002), 110 years (1893-2002) and 120 years (1883-2002) with respect to magnitude variation of $4.0 \leq M < 5.0$, $5.0 \leq M < 6.0$ and $M \geq 6.0$ respectively. During these periods it is estimated that there were 17.14 earthquakes of class magnitude $4.0 \leq M < 5.0$ per year for (1953-2002), 1.73636 earthquakes of class magnitude $5.0 \leq M < 6.0$ per year for (1893-2002) and just 0.21667 earthquakes per year of class magnitude $M \geq 6.0$ for (1883-2002). Using liner regression analysis between number of earthquakes and magnitude, the significant parametric constants of seismicity are determined as a = 3.72 and b = 0.706 respectively. The analysis reveals that the data are complete for the last about 50, 110 and 120 years from present in the magnitude class $4.0 \leq M < 5.0$, $5.0 \leq M < 6.0$ and $M \geq 6.0$ respectively. These values determined for Northwest Himalaya will be useful for seismic hazard assessment analysis.

PROJECT

Seisomotectonics of Northwest Himalaya

(DST-Seismicity Programme)

(Surender Kumar and A.K. Mundepi)

During the last two years the author collected huge data on topographic relief, river profiles to demarcate the active

tectonic zones – to find out the slip rates during the last major seismic activity in the region- based on slickensides first and second order structures in the rock movement surfaces.

Then the published data was also collected of the NW region on seismic and gravity values from various sources like WIHG, SOI (Dehradun), NGRI and IMD. Similarly, the data from WIHG was collected on the crustal movements by measured GPs values and from the SOI on the ground leveling also for comparison of structures affected by the regular vertical and horizontal movements of the Himalaya.

The comparative profiles of the data are plotted for comparison and correlation of geophysical processes associated with geological tectonics for interpretation of seismotectonics of the region.

The three main cross profiles are taken for comparison of the different tectonic processes and different sectors. These are :

1. Profile between Jammu and Srinagar and Kangan to Leh
2. Profile between Ropar – Manali – Leh
3. Profile along Satluj Valley

The maximum data was available along the profile Ropar – Manali – Leh. The slip-rates data of profile 1 and 3 is still in progress and comparative studies are yet to be done.

In continuation with the work as mentioned in the first progress report submitted to the DST, three more topographic profiles were prepared from the available maps (Old and New), having a time gap of nearly 30-40 years. The three main sections, which have been prepared, are (i) Kiana-Tharmala, (ii) Kufri-Shali, (iii) Dhalli-Bir Tikkar. The structural data along these profiles will be plotted during the fieldwork. Only after plotting the structural data, these profiles can be analysed for the changes in the geomorphic surfaces, which can be attributed either to geomorphic process of tectonic processes to find out the slip rates (vertical). To find out the article uplift of the Himalaya in the last 40-50 years. To calculate the other geophysical changes.

Along the comparative longitudinal profiles, four transverse (NW-SE) topographic profiles for the Garhwal Himalayan are also being analysed, for the lateral and longitudinal variation in the degree of incision by the Himalayan river valleys. These profiles are between Harshil-Joshimath-Martoli, Deoban-Bernag, Mussoorie-Champawat and Dehradun-Kathgodam.

For two dimensional gravity analysis a section was selected between Jammu to Karakoram. Along this section profiles were drawn for Airy Heiskanen and Bouguer Gravity for which gravity values were taken from Airy Heiskanen Anomaly Contour map and Bouguer Gravity Anaomalies contour map respectively. From these two profiles a Residual gravity value profile was also prepared. The regional residual separation, the isostatic anomaly map can be considered residual map generated from the bouguer anomaly map by removing a regional based on the principal of isostacy. Along the same section taken for the gravity analysis, teleseismic data between the year 1993 and 1999 for the northern Himalaya was plotted, for which a seismic depth section is also prepared, the seismic data can also be used to define the detailed characters of the structures.

The most reliable residual anomaly values are achieved when known fault displacements are slightly smaller the residual values. In such observation first or second order trends surfaces were used. Of the slip planes, which are generally smaller than the direct, values (these slip values were calculated after the comparison of the relief and river profiles).

PROJECT

Establishment of 8 permanent GPS stations by WIHG for Manifestation of India – Asia convergence process in the Himalayas from GPS geodesy under the national programme of GPs

(DST-Seismicity Programme)

(P. Banerjee and Ajay Mishra)

The project was initiated in May, 2002. Instruments were procured during July 2003. Permanent GPS stations were installed and being maintained at Delhi (Sept, 2003), Dhanbad (Feb, 2003), Kothi (Oct, 2003), Panamik (Sept, 2003) Dharamsala, and Dehra Dun (Oct,1998). Four more permanent GPS stations are being installed at Amritsar, Bhatwari (Uttarkashi), Pithoragarh and Munsiari.

Repeat measurements were carried out over more than 50 campaign mode GPS sites earlier established at Ladak, Himachal, Garhwal and parts of Central India. Important information obtained after post-processing the GPS data using GAMIT/GLOBK software include:

1. Nearly 40% of the India-Asia convergence process is being accommodated within the Himalaya in the form

of crustal shortening at the rate of 15 mm/yr. This zone of high strain build up along a 100 km wide, along-the-arc zone lies between the MBT and the Higher Himalaya.

2. Himalayan mass is splaying towards west as an escape mechanism of the collision process. The Karakorum fault zone is acting as the northern limit of this westward movement.

3. No slip movement could be detected along any major Himalayan thrusts.

4. South Indian shield is separated from its northen counter part, and is moving towards east relative to the north. This is being accommodated along the Narmada Son Lineament in the form of strike slip movement.

PROJECT

Eastern Syntaxis : Tectonomometamorphic history of the crystalline thrust sheets and geochemical evolution of the Lohit plutonic complex, Eastern Arunachal Pradesh

(DST-(SERC) Science(PAC-ES) Scheme)

(N.S. Gururajan, B.K. Choudhari and Kalpana Bhandari)

The main aim of the project is to understand the litho-tectonic set up, kinematics of the thrust sheets, metamorphism of the Mishmi crystallines (Central Crystallines) and geochemical evolution of the Lohit plutonic complex.

The litho-tectonic set up in Lohit and Dhibang valleys(located to the SE of the Eastern Syntaxis) has been worked out. Four major tectonic units have been recognized. From west to east they are: Lesser Himalayan quartzite unit, Mishmi or Central Crystallines, Ophiolitic mélange (Indus Suture Zone) and the Lohit Plutonic Complex. The discontinuous narrow Lesser Himalayan unit thrust over the Assam alluvium along the Mishmi Thrust. The Main Central Thrust (MCT) separates the Lesser Himalayan rocks from the overlying Mishmi or Central Crystallines and the latter exhibits inverted metamorphism. Detailed petrographic studies indicate that the grade of metamorphism continuously increases from southwest to northeast and mm scale shear zones occur through the unit. In this area the MCT is marked at the base of the central crystallines and the cause of the reverse metamorphism is due to post metamorphic shearing.

The subduction related Lohit Plutonic Complex represents pre-collision magmatism in this area and this belt is the southeastern continuation of the Gangdese Plutonic Belt of southern Tibet. The petrological and geochemical characteristics of the two belts are closely similar. The syn-collision convergence in this area has not only resulted in crustal shortening in the Himalayan domain by folding and thrusting but also affected the southern or southeastern margin of the Asian Continent. Two thrusts namely the Lohit thrust delimiting the complex in the west and the Walong thrust exposed to the east roughly divides the plutonic complex into the basic rocks dominated western belt and granite dominated eastern belt. The continued convergence has tilted these thrusts into steep angles and the rock types in the thrust zones possess S-C fabrics and a sub horizontal lineation indicating dextral (towards SE) sense of movement. The analysis of fabric elements in the Walong thrust zone reveal that the dextral strike slip movement must have occurred during Miocene times and this fault can be correlated with the Po Qu fault, a splay of the Jiali fault that occur to the east of the Eastern Syntaxis in southern Tibet. The above speculations can only be resolved by dating the shearing and metamorphic events along this fault and other shear zones.

PROJECT

Microzonation & risk assessment of the Land-slide affected areas between Banderdewa – Gohpur in Itanagar Capital Complex, Arunachal Pradesh, using GIS and Remote Sensing Techniques

(DST-Jai Vigyan)

(Trilochan Singh)

The geographic position of Itanagar Capital complex is unique with presence of uplifted terrace material on hill mounds, highly dissected rugged hills and unplanned human settlement. The area also experiences a number of landslides during every monsoon. Considering the importance of the area, being the capital of the State, it needs utmost attention for demarcation of landslide zonation and risk assessment.

The studies, therefore, have been carried out to generate Landslide Hazards Zonation Map of the area. Extensive field work was carried out to collect/collate/ update the data, and to check ground truth of the thematic maps. Data collected in the field was computerized and detailed inventories were prepared. The basic data, pertaining to the study has been derived from the toposheet, geocoded images and collateral data. The digital data was rectified with the help of geocoded toposheet.

Various thematic maps, viz.l, Drainage, Drainage Density, Density Frequency, Contour, Slope, DEM, Aspect, Landuse/Landcover, Lineament, Lineament Density, Lineament Frequency, Lineament Buffer, Geology, Geomorphology, etc., were prepared/derived, checked in the field and updated. Subsequently, using GIS technique these layers were integrated by assigning weighted rank based on their intensive causative factors for landslide. The study area has finally been classified into hazardous zones, using Multicriteria Modeling, using Satty's method. Landslide Inventory Map has also been prepared based on the field investigations and ground truthing.

PROJECT

Public awareness-cum-training Programme on Earthquake Preparedness and Mitigation Strategies in Arunachal Pradesh

(DST-Seismicity Programme)

(Trilochan Singh)

Frequent occurrences of earthquakes in northeastern region, particularly in Arunachal Pradesh, have cautioned the people. Since most of the people do not have basic knowledge about the earthquake they get panic. The general concept amongst the common man, particularly those in remote areas, is that the earthquake kills people and, thus, they live under psycho-fear. So if they are given the basic knowledge, such as what is earthquake, how and where it occurs, damage caused by earthquake, mitigation measures to reduce the impact, etc., the people may get out of psycho-fear to lead comparatively peaceful life. Thus, this project was initiated to create earthquake awareness amongst the people.

The project has been completed on 15th November, 2003. Under the project, seven districts were covered during the year and a total number of 12 lectures were delivered. The districts covered are : West Siang, East Siang, Upper Siang, Lohit, Dibang Valley, Lower Subansiri and Upper Subansiri. Lectures were mainly arranged though district administration and at some places through Border Roads, and Army which were arranged either at the Town Club, DC Office, School/College or Border Road/Army Camps. These lectures were highly appreciated by the administration as well as by the public. Five districts, viz. Tawang, East Kameng, Kurung Krume, Changland and Tirap, could not be covered. However, in two of these five districts viz., Tawang and Tirap, similar public awareness programs were conducted earlier in Feburary and March 2000 respectively.

PROJECT

Paleobiology and Biosedimentology of the Buxa Dolomite, NE Lesser Himalaya

(DST-Seismicity Programme)

(V.C. Tewari and Ambika Sharma)

The Mesopoterozoic to Terminal Proterozoic (1000-570 Ma) microbialite diversity has been reported from the Buxa Dolomite for the first time in a single section in Ranjit window, Sikkim Lesser Himalaya. The organic walled microfossils such as *Siphonophycus, Eomycetopsis, Obruchevella* and *Myxococooides* has been recorded, The microfacies of the dolomite are oodolomicrite, oodolosparite, micrite. The ooids are concentric, concentric cum radial, radial, and composite types showing various stages of diagenesis. The biosedimentological studies have suggested that the Buxa Dolomite was deposited in intertidal to subtidal environment.

A very thick sequence of the Buxa Dolomite (800 m) is exposed between Reshi and Tatapani in the Ranjit Valley, West Sikkim, NE Lesser Himalaya. Microbial (stromatolitic) buildups are well developed in the Buxa Dolomite and show a variety of morphological diversity from bottom to top of the sequence.

The important buildups recognized are Grey dolomite with *Colonnella columnaris, Kussiella kussiensis* and *Conophyton garganicus*. The cross bedded intraformational with this buildup. This buildup was formed in the high energy subtidal and intertidal environment. Dark grey cherty intraclastic-oolitc dolomite with microbial mats and stratified buildups (*Stratifera*) and *Nucleilla* structures. The buildup was formed subtidal environment. A thick microbial buildup with diversified assemblage (*Jurusania, Colleniella, Minjaria, Gymnosolen, Tungussia, Jacutophyton, Baicalia, Aldania, domal, Nucleiila* and linked conical-stratified and columnar stratified forms). This buildup represents peritidal depositional environment. A cyclic buildup of digitate microbialites, intraformational pebbles, crenulated microbialites and columnar and domal forms is developed. There is a cyclicity in the intraformational pebbles and microbialites. This buildup is a product of high energy intertidal depositional environment. Shaly dolomite buildup is characterized with large domal columnar and *Nucleiila* forms and intraformational pebbles are found associated with shaly dolomite. Five cycles of columnar and domal buildups have been recorded.

All these microbial buildups of the Buxa Dolomite recorded between Reshi and Tatapani in Ranjit river section suggest a shallow marine (high energy tidal flat) depositional environment. The microbialite (stromatolite) assemblage of Buxa Dolomite suggest a Lower Riphean to Upper Riphean- Vendian (Meso-Neoproterozoic) age.

PROJECT

Establishment of Geotechnical Laboratory for Landslide investigations and training of manpower

(DST-Geohazards)

(Director, M.P.Sah, Vikram Gupta and Surya Parkash)

A Geotechnical Laboratory has been established in the Institute for undertaking geotechnical investigations on landslides and for generating data base on geotechnical parameters of rocks and soils. The laboratory is presently equipped with some of the conventional instruments for soils and rock sample analysis.

The laboratory facility has been utilized for generating geotechnical data for R & D as well as Consultancy projects. In-house studies for exploring the additional applications the laboratory has been used for testing the construction materials of Guest House-cum-Hostel building in the institute to judge their quality and suitability for building. The tests done on the construction materials included sand grading, compressive strength of bricks and concrete blocks, water absorption of bricks, slumps tests. Besides testing of construction materials, the suitability of the foundation soils of the Guest House has been assessed through geotechnical testing in the laboratory as well as in the field. The grain size analysis, limit tests, permeability, consolidation properties and bearing capacity of the soils have been determined.

The laboratory has also undertaken a study on geotechnical characterization of slope materials from Sataun landslide, Giri Valley in Himachal Pradesh. The tests conducted on these samples included field moisture contents, water absorption, dry density, saturated bulk density, porosity, void ratio, specific gravity, point load strength index and uniaxial compressive strength.

Besides, the Geotechnical laboratory has an Automated Target Recognition System (Leica Model - TDA 5005). The instrument has been utilized to prepare a contour map of the Sataun Landslide in the Giri valley, H.P. and is presently being used for monitoring slopes in the Uttarkashi region. On the slopes of Varunavat Parvat 140 markers have been placed at different locations. The study would provide the necessary information on slope displacements, their directions and magnitudes. The data thus would give an idea about the actual stability condition of the slopes on this hill and may also lead to development of a warning system for the landslide. Till date two sets of observations have been recorded and analyzed. The results indicated that there were no slope movements during the period of measurements. An attempt has also been made to record automated real time monitoring data of slopes using ATR and APS win software facility during the field work from one of these stations. The work was done successfully using seven prisms up to a distance of about 800 m from observation stations at Joshiyara in Uttarkashi.

The samples collected from the Varunavat slide were analysed for grain size (sieve analysis and hydrometer analysis), liquid limit analysis, moisture contents and point load strength test. The monitoring of slopes and the further resting of the strength of material is in progress. The laboratory facility has also been utilized for a Consultancy project of Uttarkashi area.

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SEMINARS / WORKSHOPS ORGANIZED

a) Expert Group Meeting for 'Mission Mode Project in Seismology'

On recommendation of the Expert Group for "Mission Mode Project in Seismology" a meeting of the sub-group under the chairmanship of Prof. V.K. Gaur was held at Wadia Institute of Himalayan Geology (WIHG), Dehra Dun, on November 3-4, 2003 to finalize the site selection for Broad-Band Seismometers and Strong Motion Array.

Some 40 sites aligned along four NNE-SSW profiles were selected to provide adequate coverage to various tectonic and geological blocks of Uttaranchal. It was agreed that NGRI, Hyderabad will play a lead role in coordinating the project. However, operational base and the data center would be located at WIHG.

During deliberation it was also planned to install 300 strong ground motion equipments in the seismic zones IV and V encompassing the Himalayan region. Committee also felt that co-lateral studies using GPS and MT data would be important to constrain and refine the sub-surface structures and geodynamic models resulting from the BBS studies. The key locations for GPS deployments were identified that can be undertaken jointly by WIHG and NGRI.

b) Workshop on "Methodology for Seismic Microzonation and its Application for Society''

A workshop on "Methodology for Seismic Microzonation and its Application for Society" was organized by the Institute on November 10-11, 2003 in collaboration with Indian Institute of Remote Sensing (IIRS), Dehradun and International Institute of Geo-information Science and Earth Observation (ITC) Enschede, The Netherlands.

The workshop was aimed to focus on the Methodology and Principles of Seismic Microzonation and Risk Assessment. It was attended by over 60 participants from India, Nepal, USA and The Netherlands. The two day long workshop was inaugurated by Dr. P. Nag, Surveyor General of India. The co-ordination of seminar was organized in four technical sessions, assessment of seismic microzonation methods and principle, data requirement for suitable methodology, assessment of existing and available data with different organizations, and seismic loss estimations and risk assessment methods. A total of 22 papers were presented on various theme. The workshop was concluded by a Panel Discussion under the chairmanship of Dr. Amod Mani Dixit. On behalf of the Institute, Dr. A.K. Mahajan and Dr. Vikram Gupta took leading role in the organization of workshop.

c) National Conference on "Natural Hazards (Earthquakes and Landslides): Challenges, Perspectives and Societal Dimensions with focus on the State of Uttaranchal and the 13th IGC Convention

The National Conference on Natural Hazards and 13th IGC Convention was hosted by Wadia Institute of Himalayan Geology, Dehradun from December 26-28, 2003. The conference was inaugurated by Hon' able Minister of State for Science and Technology, Shri Bachi Singh Rawat. A souvenir of IGC Directory and a book on "Bukamp Ek Prakartik Apda" authored by Dr. H.K. Gupta, Secretary, Department of Ocean Development, Government of India, were released by the Hon' able Chief Guest. Around 60 delegates from outside and 30 delegates from WIHG attended the conference. A total of 74 abstracts were contributed to this seminar. Scientists of Wadia Institute have contributed 22 abstracts, which were presented in Oral/Poster sessions. On behalf of the Institute, Dr. A.K. Mahajan and Dr. Vikram Gupta took leading role in the organization of workshop.

D) National Seminar on Role of Fluids in the Crustal Evolution: Special emphasis on the Himalayan Magmatism, Tectonism and Metallogeny

The Wadia Institute of Himalayan Geology organized '*National Seminar on Role of Fluids in the Crustal Evolution: Special Emphasis on the Himalayan Magmatism, Tectonism and Metallogeny*" on February 4 - 6, 2004 in the Institute premises at Dehra Dun. The chief guest of the seminar was Prof. R.S. Sharma, F.N.A., INSA Senior Scientist, Rajasthan University, Jaipur. The Guest of Honour was Dr. K.R. Gupta, Advisor, Earth System Sciences, Department of Science

and Technology, New Delhi. The seminar started with the welcome address by Prof. B.R. Arora, Director, Wadia Institute of Himalayan Geology, Dehradun. Dr. Rajesh Sharma was the Convener of the Seminar and Dr. H.K. Sachan, co-Convener.

Chief Guest Prof. R.S. Sharma and Guest of Honour Dr. K.R. Gupta along with Dr. B.R. Arora and Dr. Rajesh Sharma sharing the dais during the inaugural function of seminar on the "Role of fluids ...." at WIHG.

The technical sessions were planned on February 4-5, 2004. The seminar received encouraging response, and the participants from various institutions and universities including NGRI, WIHG, IIT (Roorkee), IIT (Mumbai), Jammu University, Rajasthan University, Shivaji University, Banaras Hindu University, Kumaun University, etc attended the seminar. The proceedings of the seminar were conducted in five technical sessions, each session began with review presentation from distinguished experts. In total thirty-eight research papers were presented.

The Plenary session was organized after the last technical session; wherein the need of fundamental and applied research on fluid related processes in the earth crust is emphasized. One of major recommendation was related to the organization of contact programme on 'Fluid-Rock Interaction". A field excursion was also organized following the seminar to the Krol-Tal succession of Mussoorie syncline.

VISITS ABROAD

- Dr. Talat Ahmed, Dr. N. Siva Siddaiah and Dr. Barun K. Kukherjee participated in the 18th HKT Workshop held at Ascona, Switzerland, April 2-4, 2003. Dr. Talat Ahmed was one of the Indian representatives nominated by DST.

- Dr. Talat Ahmad attended the EGS-AGU-EUG joint assembly at Nice, France, April 6-11, 2003.

- Dr. Vikram Gupta visited University of Geneva, Switzerland to attend a two months Post-graduate training course on "Study and Management of Geological Risks" under the supervision of Prof. J.J.Wagner, Scientific Director of the CERG, April 28-June 19, 2003.

- Dr. G. Philip participated in trench excavation survey across Ushikubi Active Fault with Geological Survey of Japan, Tsukuba, Japan, June 6-21, 2003.

- Dr. H.K. Sachan attended the West Norway Eclogite Field Symposium 2003, held at Selje, Norway, June 20-29, 2003.

- Dr. V.C. Tewari visited the International Centre for Theoretical Physics, Trieste, Italy, as Regular Associate, for three months from August – October, 2003.

- Dr. P. K. Mukherjee went on a 9 days tour to Edinburgh, U.K. from September 6, 2003 to present a paper in the 6th International Symposium on Environmental Geochemistry and attended a meeting on "Global baseline mapping" organized by IUGS & I.A.G.

- Dr. Talat Ahmad visited Kurashiki, Japan from September 5-26, 2003, to present a paper at 13th Goldschmidt Conference. He also visited Nagoya University and Tokyo University to deliver invited talks, and for interaction.

AWARDS AND HONOURS

- Prof. B.R. Arora has been awarded National Mineral Award for the year 2002 for his contribution to Geophysics.
- Dr. T. Ahmad has been elected as a Fellow of National Science Academy, Bangalore.
- Prof. B.R. Arora has been nominated as a Member of Executive Council of Association of Exploration Geophysist.
- Wadia Institute Best Research Paper Award for the Year 2002 were awarded to:

  i) Dr. S.K. Ghosh, Dr. R. Islam and Dr. H.K. Sachan for their paper "Geochemical characterization of the Neoproterozoic Nagthat Silciclastics, NW Kumaon Lesser Himalaya: Implications for Source Rock Assessment".

  ii) Dr. Rohtash Kumar, Dr. S.K. Ghosh, Dr. S.J. Sangode and Dr. V.C. Thakur for their paper "Manifestations of Intra – Forland thrusting in the Neogene Himalayan Foreland Basin Fill".

- The following papers presented in the poster session of the 13th Convention of Indian Geological Congress, 2003 were adjudged as best papers:

  i) Barun K Mukherjee and H.K. Sachan, entitled "Signatures of continuous subduction process in the Himalaya".

  ii) A.K. Pandey and Prabha Pandey, entitled "Active deformation along the Hinna Fault in Uttarkashi region of Garhwal Himalaya".

  iii) S.K. Bartarya, R.K. Mazari and N.S. Virdi, entitled "Bhimgoda slide of August 24, 1994 in the Siwalik rocks near Haridwar: a success story of landslide control measures".

  iv) Nilesh Kumar, A.K. Mundepi and Kamal, entitled "Site response studies in Dehradun city – A step towards Seismic Microzation in Uttaranchal.

  v) Vikram Gupta, entitled "Geomorphic evaluation of Landslides in the Satluj valley, Northwestern Higher Himalaya".

  vi) P.S. Negi, entitled "Geophytological investigation on landslide precursors in Himalaya-An interdisciplinary and eco-friendly approach for identification of area of potential hill slope movements.

Ph. D THESES

Name	Supervisor/s	Title of the Thesis	University	Awarded/ Submitted
Barun K. Mukherjee	Dr. H.K. Sachan	Metamorphism and fluid evolution of ultra-high pressure rocks from Tso-Morari, Crystalline Complex, Indus Suture Zone, Ladakh, India	HNB Garhwal University, Srinagar, Garhwal	Awarded
Syed Ihsan-ul-Andrabi	Dr. A.K. Dubey Prof. G.M. Bhat	Evaluation of sediments attributes and structural geometry of tectono-stratigraphic units along the National Highway between Batote and Banihal, Jammu & Kashmir (India)	Jammu University, Jammu	Awarded
S.K. Chabak	Dr. P.K. Sharma Dr. A. K. Dubey	Numerical solution of seismic wave propagation	HNB Garhwal University, Srinagar, Garhwal	Awarded
Kalpana Negi	Dr. R.S. Rawat	Structural State (Triclinicity) of Alkali Feldspar in selected granitoids from the Northwestern Himalaya	HNB Garhwal University, Srinagar, Garhwal	Submitted
Reenu Joshi	Dr. A.K. Dubey Dr. A.K. Biyani	Tectonic evolution of the Doon valley with special reference to Neotectonics	HNB Garhwal University, Srinagar, Garhwal	Submitted
Priti Verma	Dr. Rajesh Sharma Dr. M.N. Joshi	Genesis of Barite Mineralization and the environmental impact of its exploitation in the Tons valley, Lesser Himalaya	HNB Garhwal University, Srinagar, Garhwal	Submitted
Shashipal Singh	Dr. H.K. Sachan Dr. B.P. Singh	Comparative study of Precambrian Evaporites from Himachal Pradesh and Jammu region.	Jammu University, Jammu	Submitted
P.S. Negi	Dr. P.K. Hajra Dr. B.K. Gupta	Investigation on ligneous flora of Doon valley	HNB Garhwal University, Srinagar, Garhwal	Submitted
Nyo Nand	Dr. Devendra Pal Dr. M.P.S. Bisht	Geomorphological, environmental and economic aspects of the Aravali Hills of Haryana	HNB Garhwal University, Srinagar, Garhwal	Submitted

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOP / TRAINING COURSES

Seminar / Symposia / Workshop

- Pointers of Electrical Anisotropy in Magnetotellurics, MT Interpretation Workshop, NGRI, Hyderabad, May 13-17, 2003.

  Participant: B.R. Arora

- National workshop on "Urban management Information System using Remote Sensing and GIS for urban renewal of Itanagar Capital Complex", Remote Sensing Application Centre, Itanagar, July 16, 2003.

  Participant: A.K. Singh

- Workshop on Formulation of water policy in Uttaranchal organized by Directorate of Watershed Management, Uttaranchal at F.R.I. Dehradun, September 6, 2003.

  Participant: S.K. Bartarya

- Indo-US Workshop on 'Seismicity and Geodynamics, Sponsored by Indo-US Science and Technology Forum, NGRI, Hyderabad, October 6-10, 2003.

  Participants: B.R. Arora and Sushil Kumar

- Chief Guest at the Geo-Hazard Seminar, organized by Geological Society, Jammu University, Jammu, October 9-11, 2003.

  Participant: B.R. Arora

- XIX Indian Colloquium on Micropaleontology and Stratigraphy & Symposium on Recent Development in Indian Ocean Paleoceanography and Paleoclimate, B.H.U., Varanasi,October 9-11, 2003.

  Participants: R.J. Azmi, B.N. Tiwari and Kapesa Lokho

  The following papers were contributed/presented and abstracts published:

  Kumar, K., Rana, R.S. & Paliwal, B.S. Lepisosteid and osteoglossid fish remains from the Paleocene Palana Formation, Rajasthan, India, pp. 29-30.

  Parcha, S.K. Agnostid fauna from the Cambrian succession of Zanskar region: their implication for correlation, pp. 122-123.

  Shukla, M., Tewari, V.C. & Babu, R. Diversified Neoproterozoic organic walled microfossils from the Buxa domolite, west Siang district, Arunachal Pradesh, Lesser Himalaya, India, pp. 133.

  Azmi, R.J., Joshi, D., Srivasatava, S.S., Tiwari, B.N. & Joshi, M.N. Age of the Vindhyan Supergroup of Central India: an exposition of biochronology vs radiochronology, pp.141-143 (s*pecial talk*).

  Bhandari, A & Tiwari, B.N. A note on the discovery of middle Siwalik ostracode fauna from Mohand, Saharanpur district, Uttar Pradesh, pp. 55.

  Venkatachalapathy, R., Kapesa Lokho, Raju, D.S.N. & Ramesh, P. Preliminary study of foraminifera of the Disang Group, Nagaland State, NE, India, pp. 36.

- Workshop on "Dev Boomi Elephants Under Threat", Parmarth Niketan, Rishikesh.organized by Friends of Doon Society, October 11, 2003.

  Participants: A.C. Nanda and R.K. Sehgal

- Workshop on "International Conference on Ecorestroration", FRI, Dehradun. Chaired a Session of the Workshop, October 14-19, 2003.

  Participant: A.C. Nanda

- Workshop on "Global geochemical baselines for environment management in India", NGRI, Hyderabad , October 16, 2003.

  Participants : P.P. Khanna and P.K. Mukherjee

- HIMPROBE Workshop, IIT Roorkee, 16-17 October, 2003.

  Participants: B.R. Arora, T. Ahmad, Kamal, Sushil Kumar, P. Banerjee, H.K. Sachan, S.K. Parcha and V.Sriram

  The following papers were contributed/presented and abstracts published:

  Arora, B.R., Patil, S.K., Venkateshwarlu, M. & Singh, S. Magnetic mineralogy and low field AMS investigations in North-West Himalaya: implications for regional tectonics, pp. 65

  Arora, B.R., Rawat, G., Nagar, V. & Tyagi, A. Long period magnetotelluric measurements in the NW Himalaya: implications on Upper Mantle Electrical Conductivity, pp. 53-57.

  Ahmad, T., Harris, N.B.W., Tanaka, T., Bickle, M.J., Chapman, H., Khanna, P.P. & Bunbury, J. Nd-, Sr-isotopic and geochemical constraints on the source characteristics and petrogenesis of arc volcanics from the Shyok Suture Zone, Ladakh, India, pp. 11-13

  Banerjee, P. Crustal deformation studies in NW Himalaya using Global Positioning System, pp. 85.

  Hakim Rai. Geological and tectonic evolution of the Shyok Ophiolitic Melange Belt, pp. 8-9.

  Parcha, S.K. Biostratigraphy of the Cambrian sequence of Zanskar and associated regions, pp. 40-41.

  Sachan, H.K. & Mukherjee, B.K. Ultra-deep subduction of Indian continental crust, pp. 21.

- National Seminar on Disaster Management with special reference Landslides and Avalanches, Vigyan Bhawan, New Delhi, October 29, 2003.

  Participants: R.K. Mazari, M.P. Sah and S.K. Bartarya

- Workshop on "Methodology for seismic microzonation and its application for Society", WIHG, Dehradun, November 10-11, 2003

  Participants: B.R. Arora, D.R. Rao, Kamal, Sushil Kumar, A.K. Mahajan, Vikram Gupta and A.K. Mundepi

- International Conference on Luminisence and its application. Bhabha Atomic Research Centre, Mumbai, Feb. 9-12, 2004.

  Participants: N. Suresh and T.N. Bagati

  The following paper was contributed/presented and abstract published:

  Suresh, N. & Bagati, T.N. Determination of slip rate by optically stimulated luminescene dating of uplifted fluvial terraces along Himalayan Frontal fault, India. pp. 309, 2004.

- Workshop on National Geochemical Baseline Mapping in India, NGRI, Hyderabad, November 19-20, 2003.

  Participant: P.K. Mukherjee

- National workshop on Water Policy of Uttaranchal, organized by Uttaranchal Government, Hotel Aketa, Dedradun, November 22-24, 2003.

  Participant: P.S. Negi

- 16th Conference Indian Institute of Geomorphologistson Mountain Geomorphology: Multi-dimensional Approach, jointly organized by IIRS and Survey of India, Dehradun, November 24-26, 2003.

  Participants: D. Pal, R.K. Mazari, M.P. Sah and S.K.Bartarya

- 20th Indian Association of Sedimentology Convention, Garhwal University, Srinagar, November 28-30, 2003.

  Participants: N.S. Virdi, T.N. Bagati, V.C. Tewari, R. Kumar, S.K. Ghosh, K. Kumar, N. Sivasiddaiah, R. Islam, D.P. Dobhal, P.S. Negi, B.Sharma and A.K.L. Asthana

  The following papers were contributed/presented and abstracts published:

  Nyonand, M.P.S. Bist & Devendra Pal. Eco-system restoration and sustainable production in degraded soils of southwest Haryana, pp. 24.

  Sivasiddaiah, N., Kumar, K., Juyal, K.P. & Mathur, N.S. Importance of Kakara-Subathu sediments, foothills of NW Himalaya as tracers of Palaeocene-Eocene climate, pp. 40.

  Joshi, M.N. & Prithi Verma, A comparative analysis of the sedimentological evolution of Rautgara and Nagthat siliciclastics of Uttaranchal Lesser Himalaya, pp. 48.

  Bagati, T.N. Evolutio of the Carbonate Plateforms through time and space in the Spiti Basin pp. 59. *(Keynote),*

  Prithi Verma, Fluid inclusions characterization of Neoproterozoic Nagthat siliciclastics, Tons valley, Lesser Himalaya, p. 62.

  Bagati, T.N. and Suresh, N. Paleoseismicity in the form of soft sediment deformation structures and Neo-tectonic activity along active fault zones in the Northwestern sub-Himalaya, pp. 82.

  Dobhal, D.P. and Thayyen, R.J. Climatic influence on rapid recession of glaciers in Himalaya and its impact on environment. pp. 84.

  Ghosh, S.K. and Kumar, R. Records of thrusting event in the Himalayan Foreland sediments. pp. 81.

  Islam, R., Ghosh, S.K. and Khanna, P.P. Geochemistry of Proterozoic clastic sedimentary rocks of Lesser Himalaya: implication for the source rock and weathering. pp. 66.

  Kumar, R. and Ghosh, S.K. Distinct characteristics of Plio-Pleistocene stream low dominated alluvial fan deposits: Kangra re-entrant of Himalayan Foreland Basin. pp. 7.

  Kummaravel, V., Sangode, S.J. and Sivasiddaiah, N. Rock magnetic characterization of Paleosols in high energy sediment depositional regime: a case study from the Mio-Pliocene Siwalik sequence near Dehradun, NW Himalaya. pp. 22.

  Negi, P.S. Ecological signature of slope instability and its implication in Landslide Hazard Mitigation (LHM) – a case study along MCT zone in Himalayan Mountains. pp. 91

  Parcha, S.K. Cambrian sequence of the Zankar region of Ladakh Himalaya: its boundary problems. pp. 37.

  Sharma, B. and Asthana, A.K.L. Quaternary, sedimentation, geomorphology and Neotectonic in Alkananda valley from Pipalkoti to Rudraprayag, Garhwal Himalaya, Uttaranchal. pp. 31.

  Tewari, V.C. Glacial palaeoclimatic events in the Arunachal Lesser Himalaya. pp. 6.

  Bagri, D.S. and Devendra Pal. A study of slope failures, mass movements and related natural hazards with mitigation measures in Bhagirathi and Jalkur rive valleys, district Uttarkashi, Uttaranchal, pp. 93.

  Mukherjee, B.K. and Sachan, H.K. Continuous subduction process in the Himalaya: some possible evidence, pp. 63.

- Workshop on "Public interaction for natural resources conservation and hazard management in Uttaranchal", organized by Nehru Yuva Sangathan, Dehradun, December 16, 2003.

  Participant: K.S. Bist

- National Conference of IGC on "Natural Hazards (Earthquake and Landslides) challenges perspective and societal dimension with focus on the state of Uttaranchal and the 13th Convention, December 26-28, 2003, WIHG, Dehradun.

Participants: R.K. Mazari, M.S. Rathi, K.S. Bist, V.M. Choubey, P.P. Khanna, R. Kumar, S.K. Ghosh, M.P. Sah, N.K. Saini, K.K. Purohit, R. Sharma, R. Islam, D. Rameshwar Rao, S.K. Bartarya, Kamal, P.K. Mukherjee, S.J. Sangode, Sushil Kumar, H.K. Sachan, P. Banerjee, A.K. Mahajan, V. Gutpa, A.K. Mundepi, B. Sharma, P.S. Negi, A.K.L. Asthana, Surya Prakesh, N. Suresh, B.K. Mukherjee, A.K. Pandey and P. Pandey

The following papers were contributed/presented and abstracts published:

Banerjeee, P. Stable Indian shield is not stable. pp. 11.

Bartarya, S.K., Choubey, V.M. & Ramola, R.C. Radon variation in active landslide zone along Pinder river, in Chamoli district, Uttaranchal Himalaya; preliminary results. pp. 61.

Bartarya, S.K., Mazari, R.K. & Virdi, N.S. Bhimgoda slide of August 24, 1994 in the Siwalik rocks near Haridwar: a success story of Landslide control measures. pp. 60.

Gupta, V.K. Geomorphic evaluation of landslides in the Satluj valley, north-western Higher Himalaya. pp. 66.

Gupta, V.K., Bist, K.S., Sharma, B. & Asthana, A.K.L. Varunavat landslide hazard in the Bhagirathi valley, Uttaranchal Himalaya: its causes and risk assessment. pp. 41-42.

Islam, R. Cambro-Ordovician granite magmatism in the NW Himalaya. pp. 92.

Kamal. Need for developing methodology for systematic site response studies in India. pp. 16.

Kumar, R., Ghosh, S.K. & Sangode, S.J. Mio-Pliocene coarse clastic Kangra re-entrant of Himalayan Foreland Basin: implication to tectonic. pp. 80.

Kumar, N., Mundepi, A.K. & Kamal. Site response studies in Dehradun city – a step towards seismic microzonation in Uttaranchal. pp. 28.

Kumar, Sushil. Need to identify and characterise active blind thrust faults for the assessment of seismic hazards in the Himalaya and continental region. pp. 35.

Mahajan, A.K. Macroseismic study of shallow earthquakes. pp. 17.

Mahajan, A.K., Ghosh, G.K. & Thakur, V.C. Statistical analysis of completeness of earthquake data of northwest Himalayan region and its implication for seismicity evaluation. pp. 5.

Mukherjee, B.K. & Sachan, H.K. Signature of continuous subduction process in Himalaya. pp. 84-85.

Negi, P.S. Geo-phytological investigation on landslide precursor in Himalaya – an interdisciplinary and ecofriendly approach for the identification of area of potential hills slope movement. pp. 65.

Pandey, A.K. & Pandey, P. Active deformation along the Hinna fault in Uttarkashi region of Garhwal Himalaya. pp. 20.

Pandey, A.K., Thakur, V.C. & Suresh, N. Late Quaternary-Holocene deformation in Dehradun and piedimont zone to the south with respect of seismotectonic. pp.18.

Pandey, P. & Pandey, A.K. Liquefaction and its significance in Paleoseismic studies: examples from documented earthquakes in India. pp. 29.

Purohit, K.K., Mukherjee, P.K., Saini, N.K., Rathi, M.S. & Khanna, P.P. Geochemical landscape of some heavy metals in upper Alaknanda catchment: implication environmental hazard. pp. 89.

Rameshwar Rao, D., Rai, H. & Senthil, J. Oceanic plagiogranite in the Nidar ophiolitic sequence of eastern Ladakh: a petrological and geochemical approach. pp. 86-87.

Shah, M.P. & Mazari, R.K. Status of natural hazard in the Kullu valley, Himachal Pradesh. pp. 49.Sharma, R. Sulphide mineralization in the Lesser Himalaya carbonates. pp. 93.

Sharma, R. Sulphide mineralization in the Lesser Himalaya-carbonates. pp.93.

Surya Parkash. Landslide precursors and potential for monitoring studies on Varunawat hills at Uttarkashi. pp. 46.

Surya Parkash. A case study from Garhwal Himalaya. pp. 64.

- National workshop on "Science & Technlogy for regional development: case for NE India", IIT, Guwahati, February 3-6, 2004.

  Participant: T. Singh

  The following paper was contributed/presented and abstracts published:

  Singh, Trilochan. Landslide Hazards in NE India: Prespective, Hazards Quantification and Knowledge Products for Mitigation Strategies.

- National Seminar on "Role of fluids in the crustal evolution: special emphasis on the Himalayan Magamtism, tectonism and metallogeny, W.I.H.G, Dehradun, February 4-6, 2004.

  Participants: B.R. Arora, N.S. Virdi, A.K. Dubey, H. Rai, R.S. Rawat, N.S. Gururajan, M.S. Rathi, Talat Ahmed, P.P. Khanna, Rohtash Kumar, N.K. Saini, K.K. Purohit, T.N. Jowhar, N. S. Siddaiah, Rajesh Shrarma, R. Islam, D. Rameshwar Rao, B.N. Tiwari, P.K. Mukherjee, S.J. Sangode, Sushil Kumar, H.K. Sachan, P. Banerjee, A.K. Singh, R. Jayangondaperumal, A.K. Pandey, B.K. Mukherjee and Priti Verma

  The following papers were contributed/presented and abstracts published:

  Arora, B.R. Evidences of crustal fluids from electrical conductivity distribution and their geodynamic consequences. pp. 5. (*keynote address*)

  Rawat, R.S. Role of synthetic fluid inclusions in Ore Petrology: a case study of Badrinath Leucogranite, Higher Himalaya, India. pp. 7-9. (*keynote address*)

  Rajesh Sharma. Some ore forming Fluids of Himalayan Sulphides. pp. 21-22.

  Jowhar, T.N. & Rawat, R.S. Geothermobarometry of the Dudatoli-Almora Crystallines and tin-tungsten mineralization in Garhwal-Kumaun Lesser Himalaya. pp. 31-33.

  Kumar, Sushil, Negishi, Hiroaki, Mori, Jim & Sato, Tamao. Presence of fluid in the upper and lower crust: evidence from Tomographic inversion of aftershocks data of 2001 Gujarat Earthquake (M 7.9), India and 1995 Kobe earthquake (M 7.2), Japan. pp. 47-48.

  Sachan, H.K. & Bodnar, Robert J. Methane (CH_4) in upper mantle rocks from the Indus Suture Zone, Ladakh (India): evidence from Fluid Inclusions and Raman Spectroscopy. pp. 52.

  Rameshwar Rao, D. & Rajesh Sharma. Petrogenesis of granitoid rocks from the central part of Askot Crystallines, Kumaun Himalaya: inferences from the geochemical and fluid inclusion studies. pp. 53-54.

  Pandey A. K, Sachan, H.K. & Virdi, N.S. Microstructural and Fluid Inclusion constrains on the exhumation history of the out-of-sequence Jakhri Thrust in the Satluj valley of NW Himalaya. pp. 55.

  Sachan, H.K., Mukherjee. Barun K., Ahmad, T. Metamorphic and fluid evolution of Ultra-High metamorphosed (UHP) crust of Tso-Morari region, Ladakh, Himalaya, (India): constraints from mineral chemistry and Fluid Inclusions. pp. 56-57

  Singh, S.P., Sachan, H.K. & Singh, B.P.. Fluid inclusions in the Precambrian-Cambrian evaporites of the Lesser Himalaya: a note on dehydartion and rehydration effects. pp. 58.

Verma, Priti & Sharma, Rajesh. Fluid inclusion evidences for the deposition and recrystallisation of Barite Mineralization, Tons valley, Lesser Himalaya. pp. 59.

Jayangondaperumal, R., Dubey, A.K. & N.S.Gururajan. An interaction of sedimentary and tectonic fabric: evidence from microstructure and Anisotropy of Magnetic Susceptibility (AMS) in weakly deformed rocks, Mussoorrie Syncline, Lesser Himalaya. p. 65-66.

Islam, R., Ahmad, T. & Khanna, P.P. Ladakh Plutonic Complex, Trans Himalayan Magmatic Arc, North Western Himalaya: its geochemistry and geodynamic evolution. pp. 69.

Srivastava, H. B., Tripathy, Nihar Ranjan & Sachan, H.K. Mesoscopic ductile shear zones and their tectonic significance in the MCT zone of Alakhnanda valley. pp. 70.

Rai, Hakim. Origin of andesitic magma in the Shyok tectonic zone, Ladakh, pp. 71.

Tiwari, B. N. Conceptualization of uneven uranium uptake in vertebrate fossils, examples from studies on the Siwalik vertebrates, pp. 72.

Kumaravel, V., Sangode S.J., Siddaiah, N.S. & Kumar, Rohtash. Effect of dewatering and burial on the soils from Dehradun Basin: A Rock Magnetic Approach. pp. 74.

Banerjee, P. Low velocity zone in Southern Tibet as evidenced from Gravity and Geoid undulation measurements. pp. 76.

Jowhar, T. N. Calculation of thermodynamic properties of minerals at higher temperatures and pressures: application for formulation and calibration of geothermobarometers. pp. 77.

Singh, A. K., Bikramaditya Singh, R.K. & Vallinayagam, G. Geochemistry and Petrogenesis of Neoproterozoic bimodal volcanic rocks of the Kundal area, Malani Igneous Suite, Northwestern Peninsular India. pp. 78-79.

Khanna, P.P., Saini, N.K., Mukherjee, P.K., Purohit, K.K. & Rathi, M.S. Stream sediment geochemical survey across MCT zones in Garhwal Himalaya: prospects for Uranium an Thorium Mineralization. pp. 80.

- All India Science Conference, jointed organized by DST and NPL, New Delhi, February 19-21, 2004.

  Participant: P.S. Negi

- Brain storming session on "Hydrology of Glacierized Basins", National Institute of Hydrology, Roorkee, March 4-5, 2004.

  Participants: J.T. Gergan, D.P. Dobhal and R.J. Thayyen

- National Conference on "Human Origin, Genome and People of India", Anthropological Survey of India, New Delhi, March 22-24, 2004.

  Participant: A.C. Nanda

National Meetings

- Project Implementation and Monitoring Committee and Discussion Meet of Geochronology/Isotope Geology, IIT, Roorkee, May 19-20, 2003.

  Participants: D.R. Rao, P.K. Mukherjee and H.K. Sachan

- 2nd Meet of Subject Expert Committee (SEC) for Earth and Atmospheric Sciences, Pune, May 30-31, 2003.

  Participant: Meera Tiwari

- 5th Meeting of PAMC-DCS, RRL, Bhubaneswar, June 5-6, 2003.

  Participant: T. Ahmad

- National Working Group IGCP-434 meeting , GSI, Lucknow, July 14-18, 2003.

  Participant: Kishor Kumar

- Meeting of the 'Mineral Working Group' of the Govt. of Uttaranchal, organized by Directorate of Geology and Mining, Department of Industries, Dehra Dun, July 30, 2003.

  Participant: Rajesh Sharma

- Meeting on 'Interlinking of Rivers' and a thrust area meeting of 'Shallow Subsurface studies', organized by DST, Indian Institute of Sciences, Bangalore, August 29-30, 2003.

  Participants: B.R. Arora and S.J. Sangode

- Working Group on Seismic Microzonation, DST, New Delhi, August 27, 2003.

  Participant: Kamal

- Discussion meeting with the Officers of Institute of Technology Management ITM, Mussoorie, September 6, 2003.

  Participants: R.J.Thayyen and Rambir Singh

- Meeting on Landslide Hazard Zoning mapping along Silk Route, NRSA, Hyderabad, September 10, 2003.

  Participant: G. Philip

- Meeting of National Workshop on "National Children Science Congress (NCSC), DST, Haridwar, September 26-27, 2003.

  Participant: D. Pal

- Mission Mode on Seismology (first meeting on Programme Implementation Committee), DST, New Delhi, October 13-14, 2003.

  Participant: B.R. Arora

- PAMC meeting of the Deep Continental Study Programme, attened its meeting held at Bangalore University, Bangalore, October 2021, 2003.

  Participants: B.R. Arora and T. Ahmad

- Annual General Body Meeting of the Geological Society of India, NIO, Goa, November 3-5, 2003.

  Participants: J.T. Gergan and T.N. Jowhar

- Meeting of Executive Council, Indian Geological Congress, New Delhi, November 15, 2003.

  Participants: A.K. Mahajan and Vikram Gupta

- INSA-IGBP (International Global Biosphere Programme) meeting, held in New Delhi, November 17, 2003.

  Participant: N.R. Phadtare

- Seminar and exhibition meeting on Human Genome and evolution, Haridwar, December 3, 2003.

  Participant: A.C. Nanda

- Meeting of Central Composite Team (Constituted by Ministry of Home Affairs) Regarding action plan about Varunawat Parvat Landslide, in North Block, New Delhi during 5th Dec. 2003.

  Participant: V. Gupta

- Meeting on "Shallow subsurface studies", University of Delhi, December 8, 2003.

  Participants: B.R. Arora, S. J. Sangode, R. Kumar, S.K. Ghosh

- Indian National Committee (INC) for I.G.C.P., Geological Survey of India, Kolkata, December 9, 2003.

  Participant: V.C. Tewari

- Meeting on finalization of "Landslide Hazard Zonation Atlas" in CBRI, Roorkee during 22 Dec. 2003.

  Participants: M.P. Sah and V.Gupta

- Indo-Russian delegation meeting held at Delhi, December 23, 2003.

  Participant: B.R. Arora

- Meeting of School Earthquake Monitoring Programme on Seismology, New Delhi, January 6, 2004.

  Participant: A.K. Mahajan

- Programming Advisory and Monitory Committee on Himalayan Glaciology Meeting, Indian Institute of Tropical Meteorology, Pune, January 28, 2004.

  Participants: B.R. Arora and J.T. Gergan

- 7th PAMC-DCS meeting, Arunachal Unit of WIHG, Itanagar, February 18-19, 2004.

  Participant: B.R. Arora

- National Meeting of IUGS and IUGG, INSA, New Delhi, February 29, 2004.

  Participant: B.R. Arora

- Meeting of National Special Data Information (NSDI) Task Force, New Delhi, March 5, 2004.

  Participant: M.P. Sah

- Reconnatory visit to comprehend the operational requirement of the Pilot Project on "Broad band Seisometer and long period Magnetotelluric Survey over Lakshdeep", Lakshdeep.March 18-24, 2003.

  Participant: B.R. Arora

Training Courses

- Co-convenor, DST Contact Program on Palaeomagnetism and rock magnetism, Centre of Earth Science Studies, Trivandrum, June 16-30, 2003.

  Participant : S.J. Sangode

- Participating in Short term Course on Engineering Seismology, IIT, Kharagpur, August 1-12, 2003.

  Participant : S.K. Chabak

- Training course on 'Engineering Seismograph', WIHG, Dehradun, January 19- February 3, 2004.

  Participants : Kamal, Sushil Kumar, A.K. Mahajan, V. Gupta, A.K. Mundepi, Ravinder Singh, H.C. Pandey, S.K. Chabak and L. Vashishtha

LECTURES BY VISITING SCIENTISTS

Name and Address	Date	Topic
Dr. Prithvish Nag Survey of General, Survey of India, Dehradun	29-6-2003	Contribution of Survey of India in Geoscientific Studies
Dr. M.R. Saklani Asst. Director (Rajbhasi), Income Tax Dept., Dehradun	18-9-2003	The Government Policy regarding usage of HINDI
Dr. Rajpal Singh Central Ground Water Board, Dehradun	30-9-2003	Jal hi Jeevan hai (in Hindi)
Prof. B.N. Upreti Head, Department of Geology, Tribhuvan University, Kathmandu, Nepal	6-10-2003	An outline of the stratigraphy and tectonics of the Nepal Himalaya
Dr. S.M. Naqvi Emeritus Scientist, N.G.R.I., Hyderabad	17-10-2003	Efficiency of the Mantle Convection Currents
Dr. S.M. Naqvi Emeritus Scientist, N.G.R.I., Hyderabad	22-10-2003	Palaeo Oceans
Prof. S.K. Joshi, Vikram Sarabhai Professor, NPL, New Delhi.	23-10-2003	D.N. Wadia Honour Lecture on "A Strange Story of the Electron"
Prof. R.V. Karanth, M.S. University, Baroda	14-1-2004	Break Thrust and Blind Thrust of Kutch, Gujarat
Dr. Conrad Lindholm Department Geohazards, Norsar, Norway	9-2-2004	The 26th December, 2003 Bam, Iran Earthquake. Report from a field survey after the earthquake
Dr. V.C. Thakur Emeritus Scientist. W.I.H.G., Dehradun	13-2-2004	Active tectonics of the Himalayan frontal thrust system and associated earthquake hazard
Prof. Glenn W. Berger, University and Community College, Nevada, U.S.A.	16-2-2004	Recent examples of Luminescence dating of Quaternary Sediments at the Reno, U.S.A.
Prof. Syed Hamidullah, Director, National Centre of Excellence in Geology, Peshwar University, NWFP, Pakistan	17-3-2004	Science for Environment and Peace cross-border continents with India and Afghanistan

LECTURES DELIVERED BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
N. Siva Siddaiah	Departmento di Scienze, Universita degli Studi dell` Insubria, Como, Italy	1-4-2003	REE Geochemistry of Bengal Fan Sediments
Trilochan Singh	Refresher Course in 'Geology', Nagaland University, Kohima	1-4-2003	Earthquake disaster: awareness and personal protection
Trilochan Singh	Refresher Course in 'Geology', Nagaland University, Kohima	2-4-2003	Geodynamic evolution of the Himalaya
Trilochan Singh	Refresher Course in 'Geology', Nagaland University, Kohima	3-4-2003	Landslides in the Himalaya: causes and mitigation measures
Trilochan Singh	Refresher Course in 'Geology', Nagaland University, Kohima	3-4-2003	Geographic Information System : A tool for micro-level planning with example of spatial database in Arunachal Pradesh
Trilochan Singh	Refresher Course in 'Geology', Nagaland University, Kohima	4-4-2003	Tectonic setting of North-Eastern region.
Kamal	ITBP, Disaster Mitigation and Management Centre, Academy of Administration, Nainital	23-5-2003	Earthquake Disaster: Implications on society and mitigative measures
Trilochan Singh	Dept. of Geography, Symbiosis Institute of Arts & Commerce, Pune	16-8-2003	Landslides: causes and mitigation measures with a case study from Arunachal
Trilochan Singh	Geology Department, Pune	16-8-2003	Geodynamic evolution of the Himalaya with emphasis on tectonics of north eastern region.
Trilochan Singh	"Abacus-the Technology Fest 2003" Dept. of Computer & Engineering Sciences, NERIST	31-8-2003	Evolution of the Himalaya
S.K. Bartarya	F.R.I. Deemed University Dehradun	9-9-2003 to 25-9-2003	15 Lecture Series on "Chemistry of Hydrosphere"
Kamal	Wadia Institute of Himalayan Geology, Dehradun	22-9-2003	Earthquake: causes and remedial measures (in Hindi)
Sushil Kumar	Wadia Institute of Himalayan Geology, Dehradun	26-9-2003	Seismic wave velocities structure in the Himalayan and shield region.
Surya Parkash	Wadia Institute of Himalayan Geology, Dehradun	26-9-2003	Landslide : problems and mitigation (in Hindi)

Name of Scientist	Venue	Date	Topic
B.R. Arora	Departmental of Geology, Jammu University, Jammu	9-10-2003	Importance on Multi-parameter observations in seismotectonics and seismic hazard, studies
A.K. Mahajan	UEVP Workshop by MDDA Dehradun	29-10-2003	Key note address on Seismic hazards and Microzonation of Dehradun city
V.C. Tewari	Center for Space Physics, Kolkata	10-2-2004	The Quest for the Search of Life in the Space
Trilochan Singh	Education Program, "Application of RS & GIS in the Management of Malaria", Defence Research Lab (DRL), Tezpur	16-2-2004	Concepts and basics of Geographic Information System
Trilochan Singh	Education Program, "Application of RS & GIS in the Management of Malaria", Defence Research Lab (DRL), Tezpur	16-2-2004	Application of GIS: a case study of Landslide Hazards in Itanagar Capital Complex
Rajesh Sharma	Wadia Institute of Himalayan Geology, Dehradun	27-2-2004	Earth Science and Society: Mineral Wealth of Uttaranchal
S.K. Bartarya	Project Management Unit, Swajal Project, Dehradun	15-3-2004	Augmentation of water sources and catchment area treatment for sustainability of water supply schemes in Uttaranchal
Sushil Kumar	DFO Office Staff Chamba Himachal Pradesh	16-3-2004	Scenario of Local earthquake activities around Kangra-Chamba region
Sushil Kumar	Baira suil hydroelectric power project Surgani, district Chamba, Himachal Pradesh	18-3-2004	Seismological view of great earthquakes occurred in India in the past

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEE

Name of the Scientist		Status	Prestigious Committee/s outside WIHG
Dr. B.R. Arora	i)	Member	Executive Council, IGC.
	ii)	Member	Executive Council, Association of Exploration Geophysicists, 2003-05.
	iii)	Convener	17th International Workshop on Electromagnetic Induction in the Earth", October 18-23, 2003.
	iv)	Member	Program Advisory and Monitoring Committee for Deep Continental Studies (DCS), in India, Department of Science & Technology, New Delhi, 2002-2004.
	v)	Coordinator	DCS Newsletter, DST.
Dr. A.C. Nanda		Vice President	Indian Geological Congress.
Dr. V.C. Tewari	i)	Member	International Meteorite Working Group, USA.
	ii)	Founding Member	Indian Networking Group, USA.
	iii)	Member	FROMAGE (SEPM Research Group on Marine authigenesis), Ha waii, USA.
Dr. Kamal	i)	Member	Working Group on Seismic Microzonation of Delhi region.
	ii)	Council Member	Seismological Society of India.
Dr. Vikram Gupta		Member	Central Composite Team (constituted by Ministry of Home Affairs), New Delhi

FOUNDATION DAY CELEBRATIONS

The Institute celebrated its 35th Foundation Day on 29th June, 2003. The Chief Guest on the occasion was Dr. Prithvish Nag, Surveyor General, Survey of India. A brief report on Institute's activities was presented by the Director. The Chief Guest delivered the Foundation Day Lecture on "*Contribution of Survey of India in Geoscientific Studies*".

On the occasion of foundation day, awards were presented for the best two research papers for the year 2002, the first paper was co-authored by Dr. S.K. Ghosh, Dr. R. Islam, Dr. H.K. Sachan, whereas Dr. Rohtash Kumar, Dr. S.K. Ghosh, Dr. S.J. Sangode and Dr. V.C. Thakur were joint authors for the second paper. The awards were also received by Sh. Sanjeev Dabral, Sh. N.K. Juyal, Sh. Rakesh Kumar, Sh. C.B. Sharma, Sh. S.S. Bisht, Sh. Shiv Singh Negi, Sh. Santoo Das, Sh. M.M.S. Rawat, Sh. Deewan Singh, Sh. Jeewan Lal, Sh. Puran Singh, Sh. Pritam Singh, Sh. A.K. Pandit and Sh. Shyam Lal for good work done during the year 2002-2003.

Dr. Prithvish Nag, Surveyor General, Survey of India delivering Foundation Day Lecture.

FOUNDER'S DAY

The Institute celebrated its Founder's Day on 23rd October 2003. The Chief Guest, Prof. S.K. Joshi, Vikram Sarabhai Professor, NPL, New Delhi, delivered the "*D.N. Wadia Honour Lecture*" on "*A Strange Story of the Electron*". On the occasion of Founder's Day celebration, the Institute's Museum was named as "*S.P. Nautiyal Museum*" in the Honour of Prof. Sateshwar Prasad Nautiyal, former President of the Governing Body of the Wadia Institute of Himalayan Geology. The Chief Guest, Prof. S.K. Joshi, did the honours. The other dignitaries present on the occasion included Prof. K.S. Valdiya Chairman Governing Body, WIHG and Prof. Prem Vrat, Director- IIT Roorkee.

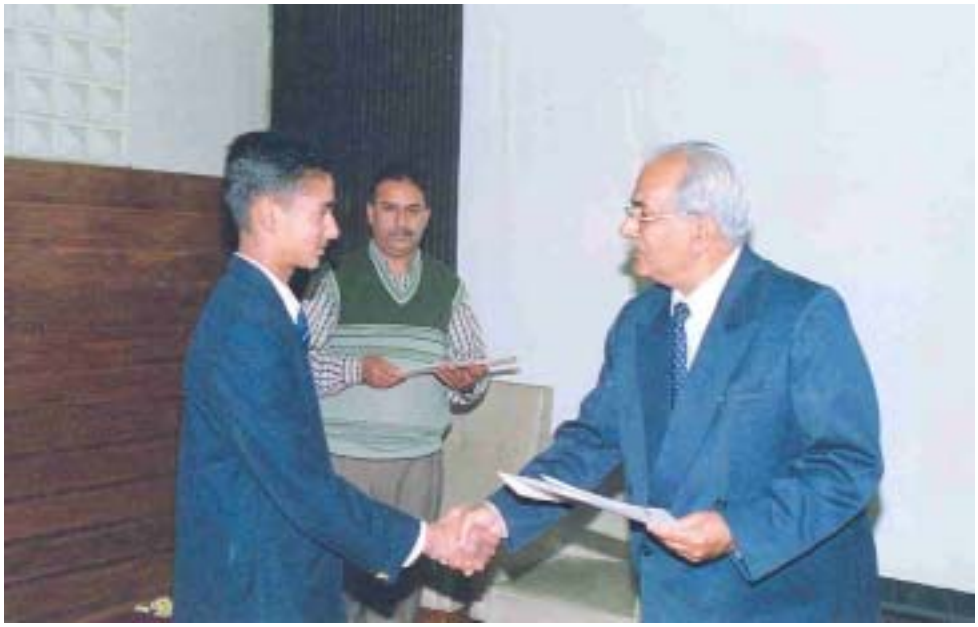
Prof. S.K. Joshi, Vikram Sarabhai Professor and Ex-Director General, CSIR dedicating the Institute Museum in the memory of noted Geologist "Prof. S.P. Nautiyal".

Prof. Prem Vrat, Director, IIT, Roorkee viewing the personal diary and medals received by Prof. D.N. Wadia preserved in Institute Museum.

NATIONAL SCIENCE DAY

As a part of National Science week celebrations, the Institute organized Science Quiz and Hindi Essay Competition for school children on February 25. Department of Science & Technology, Govt. of India has designated 2004 as a year for "*Encouraging Scientific Awareness in the Country*". So, keeping in view the theme of the year, Science Quiz and Hindi Essay competitions were organized focusing the main theme. The title of the Hindi essay was, "*Bharat varsh Ko San 2020 tak Viksit Desh Bananay may Vagyanik chetna ka yoagdan*" *in* which students from 28 schools participated. Winning students were given certificates and awards.

A popular science lecture on "Earth Science and Society: Mineral Wealth of Uttaranchal" was delivered by Dr. Rajesh Sharma, Scientist, Wadia Institute of Himalayan Geology, on 27th February. On February 28th the Institute observed 'Open Day' for School Children and public of Doon valley for the visit Museum and various other Laboratories. A special exhibition was arranged in the Museum on the theme, "*Natural Resources and Tourism potential of Uttaranchal*". The exhibition was visited by a large number of people and received wide attention of media persons.



Prof. B.R. Arora, Director presenting awards to the winners of Quiz and Assay organized on the eve of National Science Week celebration.

NATIONAL TECHNOLOGY DAY

The fifth, "National Technology Day" was celebrated by the Wadia Institute of Himalayan Geology on 11th May 2003, with great zeal. The Institute observed an 'Open Day' by keeping the Museum open for the students and for the general public. The main exhibits of interest in the Museum shown were Natural Hazards, Himalayan Glaciers, Origin and Evolution of Life, Volcanoes, Rocks, Minerals and different vertebrate and invertebrate fossils from the different regions of Himalaya.

TECHNICAL SERVICES

Analytical Services

A total number of 2621 samples were analyzed using different techniques available in the laboratories, which includes 779 samples on XRF, 752 samples by ICP and ASS instruments, 931 samples on SEM, and 159 samples on XRD. Services were provided to more than 45 users, which includes outside users from Research Organizations, Universities and Industries. The services of analytical facilities to outside organization also generated more than Rs. 2.00 lacs revenue to the Institute.

A major analytical instrument i.e. ICP-MS (Perkin-Elmer ELAN-DRCe) was added to the Wet Chemical Laboratory during this year. It was installed and standardized during the reporting year. The instrument enhanced the analytical capability for a large number of elements, which may be present in the samples down to ppt level. Around 500 samples have been already analyzed using this instrument. Further, the existing SEM (Philips PSEM-515) was upgraded by adding a Digital Image Scanning System (DISS-5 from Point Electronic, Germany), which can store images in digital form on a computer.

New ICP-MS set-up in the Central Facility of the Institute.

Practical training was also provided to the users (specially to research scholars) on various analytical instruments. Nine M.Sc. dissertations from Gurukul Kangri University, Hardwar were supervised. Efforts have been made towards development of analytical techniques for the analysis of non-geological matrices like bones, plants and food products.

Photography section

During year 45 black and white film rolls were processed and printed over 3200 black and white prints of assorted sizes. The institute maintains a photographic section that extents support to scientists in processing films exposed on SEM, light microscopes, from hand-specimens, and those exposed during the field-work. Besides this at least 10 colour slide film rolls and 25 colour negative film rolls were exposed by the section. In all about 30 colour slide film rolls and 55 colour negative film rolls were got processed, and over 1500 colour enlargements of various sizes got made from the market.

The photography section records various academic events and functions held in the Institute during 2003-2004. These include Republic Day, National Science Day, National Technology Day, Foundation Day, Independence Day, Hindi Week, Founder's Day, Warming *Puja* of Institute's Guest House Building, and Superannuating-parties arranged for Dr. N.S. Virdi, ex-Director, WIHG and others. Two seminars held in the Institute (Indian Geological Congress and Fluid Inclusion) were also covered. Besides this visits of academicians, dignitaries and VIP's were also recorded. These include visits of Parliamentary Standing Committee on Science and Technology and Environment and Forests, Hon'ble Minister for Science & Technology Shri Bachchi Singh Rawat.

Drawing Section

The Drawing Section catered to the cartographic needs of the Institute Scientists and the works pertaining to sponsored research projects. A total number of 150 geological/ geomorphological/cross sections etc. were prepared. Besides these, 21 label writings, 25 poster/charts and 130 ammonia prints were made for museum, and for various seminars/symposia organized in the Institute. Preparations were also made for 45-photo plate writing, and 35 diagrams by reduction and enlargement.

Sample Preparation Lab

The sample preparation lab provided a total of 2,364 thin sections of rocks samples of different kind. It has also provided with crushing/grinding of 654 rock specimens for different fineness during this year.

MUSEUM

Museum remained the main center of attraction for the national and international visitors. It 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 universities, colleges, schools and from other Institutions visited the museum, and were given expert guiding by scientists and research scholars. In the concluding year, the visitors from England, Canada, Holland, USA, U.K, Germany, Australia, Japan, Nepal, France, Hungary, Sri Lanka, Poland, Chez Republic, Switzerland, Canada, Italy, Israel, Austria, Pakistan and Nepal visited the Museum. Besides, different dignitaries also visited the museum. The brochure "Personal Protection in Earthquakes" both in Hindi and English popularly attracted the visitors, which were distributed to general public for their general awareness and precautions. Like in previous years, the museum observed Open Days on National Technology Day, Foundation Day, Founders Day, and on National Science Day.

School Children visiting Museum on "National Science Day".

LIBRARY

The Library of the Wadia Institute of Himalayan Geology is a specialized Library consisting of books, monographs, journals and seminar/conference proceedings on Earth Sciences with special reference to Himalayan Geology. It not only serves to the scientific, technical and administrative staff of the Institute, but also provides services to outside scientists, academicians and researches from the universities, scientific organization and NGO's.

A large number of National and International scientific core journals in the field of earth sciences are subscribed in the Library. It includes subscription to 146 journals, out of which 85 are from international publications. Library receives 12 titles of journals as gratis. It acquired a total of 278 books, including 106 books in Hindi. The Library has a good collection of Hindi books to promote Hindi Language among the staff members of the Institute.

Four issues of quarterly Current Awareness Service (CAS) were compiled and distributed to the scientific staff of Institute and sent to various individuals as well as Geology/Earth science departments of Universities. The HIMGEO ABSTRACTS volume 6 has been compiled, which consists of 261 records of bibliographic references along with abstracts on various aspects of Himalayan Geology published during the year 2003. It is the printed version of the HIMGEO database, which is compiled and maintained by the Library. Adding 261 bibliographic records have updated the 'HIMGEO'. Library has provided 15 annotated bibliographies on various aspects of H Himalaya to the scientists and

researchers of the institute as well as other organizations. The Library has also been upgraded by three IBM Pentium-IV personal computers to facilitate the users of the Library using intranet services. This is in addition to internal networking.

The Library incorporates a reprographic cell that serves as a central facility for photocopying and cyclostyling. During the period of this report the Library provided a large number of photocopies of articles from journals, books and monographs to the scientists of the Institute. The photocopying and cyclostyling facility was also provided to the administrative and technical sections of the Institute. This facility was also extended to the other organizations on payment basis.

PUBLICATION & DOCUMENTATION

The Publication and Documentation section of the Institute is mainly involved in bringing out the "Journal on Himalayan Geology" and publishing Hindi magazine, annual report yearly, etc. The 'Himalayan Geology' vols. 24 (2) and 25 (1) were brought out during this year. The section also published the annual report of the Institute for the year 2002-2003 both in Hindi and English, and Hindi Magazine 'Ashimika' vol. 9. Abstract volume was also brought out for the seminar 'Role of fluids in the crustal evolution: special emphasis on Himalayan magmatism, tectonism and metallogeny', organized by the Wadia Institute of Himalayan Geology. Besides, it has printed the D.N. Wadia Honour Lecture entitled 'A Strange Story of the Electron', delivered by Prof. S.K. Joshi. Invitation cards, New Year cards, certificates for celebrations of Foundation Day and National Science Day, vouchers, letter pads etc. were also brought out.

DISTINGUISHED VISITORS TO THE INSTITUTE

An eleven member Parliamentary Standing Committee on Science & Technology, Environment & Forest visited the institute on 27th June, 2003, under the chairmanship of Sh. Manoj Bhattacharya. The other members of team included: Sh. M.V. Rajasekhran, Sh. Dwijendra Nath Sharmah, Sh. B.P. Singhal, Prof. (Smt.) Alka Balram Kshatriya, Sh. Gordhanbhai Javia, Sh. S. Muregesan, Sh. A. Venkatesh Naik, Sh. Suresh Pasi, Sh. S. P. Patil, Kunwar Akhilesh Singh, and Sh. Ashok Patel. Dr. B. Hari Gopal, Scientific Advisor to autonomous institutions under DST, and other Rajya Sabha Secretarial staff accompanied the team.

Some other dignitaries who visited the Institute include, Hon'ble Minister for Science & Technology, Shri Bachchi Singh Rawat, Prof. V.S. Ramamurthy, Secretary, Department of Science and Technology, Government of India, New Delhi, Dr. H.K. Gupta, Secretary, DOD, Govt. of India, Prof. S. K. Joshi, Vikram Sarabhai Professor, National Physical Laboratory, New Delhi, Dr. P. Nag, Survey General, Survey of India, Dehradun, Prof. V.K. Gaur, IIA, Banglore, Padamshri Prof. A.S. Arya, Professor Emeritus, IIT, Roorkee, Dr. V.P. Dimri, Director, NGRI, Hyderabad, Dr. S.M. Naqvi, Emeritus Scientist, N.G.R.I., Hyderabad, Dr. B. D. Acharya Advisor, Department of Science and Technology, Government of India, New Delhi, Dr. S.S. Prasad Director DTRL, (DRDO), Metcalfe House, Delhi, Mr. V.K. Raina Ex. Dy. D.G, Geological Survey of India, Brig. (Dr.) B. K. Khanna, HCG Course, BSF Academy Tekanpur.

Some of the foreign dignitaries who visited our Institute included, Prof. Alexander Gliko, Dr. S. Arefiev, and Dr. A. Ponomarev from Russian Academy of Sciences, Moscow, Russia, Prof. S.G. Wesnousky, Centre for Neotectonic Studies, University of Nevada, USA, Dr. Carlos A. Villacis, UNESCO/ISDR Consultant, USA, Dr. Coes J. van Western, International Institute for Geo-Information Science and Earth Observation (ITC), Enschede, The Netherlands, Amod Mani Dixit, National Society for Earthquake Technology, Nepal (NSET), Kathmandu, Nepal, Prof. Takashi Nakata, Department of Geography, Hiroshima University, Higashi-Hiroshima, Japan, Prof. B.N. Upreti, Head, Department of Geology, Tribhuvan University, Kathmandu, Nepal, Prof. Syed Hamidullah, Director of National Centre of Excellence in Geology, Peshwar University, NWFP, Pakistan, Dr. Conrad Lindholm from Department of Geohazards, Norsar, Norway, Prof. Glenn W. Berger, University and Community College, Nevada, U.S.A.

Honourable Members of the Parliamentary Standing Committee on Science & Technology, Environment & Forest during their visit to Institute on June 27, 2003.

A warm send- off to Dr. N.S. Virdi, Director on his superannuation on June 30, 2003.

STATUS OF IMPLEMENTATION OF HINDI

Programmes of the Hindi Fortnight were celebrated from September 15-30, 2003. The following programmes were organized during this period :

- On September 15, Poem recitation and Hindi Quiz Competitions for the Institute employees.
- On September 17, Hindi Essay Competition and Hindi Letter Writing Competitions for the Institute employees.
- On September 18, Invited Hindi Lecture on *"The Government Policy regarding usage of HINDI as an official language" by* Dr. M.R. Saklani, Asst. Director (Rajbhashi), Income Tax Department, Dehradun.
- On September 19, debate competitions in Hindi for inter school students.
- On September 22, Hindi Essay competitions for inter school students. A talk in Hindi on *"Earthquakes: causes and remedial measures"* by Institute Scientist Dr. Kamal. The lecture was well attended many school children.
- On September 26, a lecture in Hindi *"Landslides: problems and mitigation*" by Dr. Surya Parkash.
- The Hindi fortnight programmes ended on September 30, with a concluding talk delivered by Dr. Rajpal Singh of Central Ground Water Board, Dehradun. He gave a talk on *"Jal Hi Jeevan Hai."*

The winners of various competitions were also given token prizes as a gesture of appreciation and encouragement.

The Institute purchased sixteen copies of the software "*Akshar for Windows 4.02*" for use by various groups and sections of the Institute, Training for use of this software in Hindi was also arranged for the offices and employees of the Institute.

Dr. Prithvish Nag, Surveyor General of India, releasing the in-house Hindi magazine "Ashmika" on the eve of the "Foundation Day" function of the Institute.

As in the previous years, the Hindi Magazine of the Institute, *"Ashmika"* vol. 9 which contain general and scientific articles was published.

The scientists and staff of the Institute were encouraged to do office work in Hindi, and awards were given for this. Prize for contribution and promotion in Hindi was given to Sh. V.P. Singh. The scientists were also encouraged to participate in scientific programmes and also write and publish articles and scientific papers in Hindi. On such article was published by Sh. P.S. Negi in *"Janyatra*" on the "*Impact of natural resources on environmental scenario of hills, with special reference to Uttaranchal"*. Some articles were published in "Ashmika" volume.

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 Committees 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 society 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**

6. Approved budget grant for the year 2003-2004.

Plan : Rs. 5.75 crores
Non-Plan : Rs. 1.43 crores
Total : Rs. 7.18 crores.

7. Xth Plan approved outlay

Plan : Rs. 30.00 crores
Released : Rs. 5.75 crores (during 2003-2004).

STAFF OF THE INSTITUTE

(A) Scientific Staff

1.	Dr. N.S. Virdi	Director (upto 30.6.2003)
2.	Dr. B.R. Arora	Director (w.e.f. 1.10.2003)
3.	Dr. A.C.Nanda	Scientist 'G' (Director Incharge 1.7.2003 to 30.9.2003)
4.	Dr. Surender Kumar	Scientist 'F' (Retired on 31.8.2003)
5.	Dr. A.K. Dubey	Scientist 'F'
6.	Dr. T.N. Bagati	Scientist 'F'
7.	Dr. Trilochan Singh	Scientist 'F'
8.	Dr. Devendra Pal	Scientist 'E'
9.	Dr. R.J. Azmi	Scientist 'E'
10.	Dr. R.S. Rawat	Scientist 'E'
11.	Dr. J.T.Gergan	Scientist 'E'
12.	Dr. V.C. Tewari	Scientist 'E'
13.	Dr. N.S. Gururajan	Scientist 'E'
14.	Dr. R.K.Mazari	Scientist 'E'
15.	Dr. M.S. Rathi	Scientist 'E'
16.	Dr. K.S. Bist	Scientist 'E'
17.	Dr. R.A.K. Srivastava	Scientist 'E'
18.	Dr. D.K. Misra	Scientist 'E'
19.	Dr. B.K. Choudhuri	Scientist 'E'
20.	Dr. R.K.Chaujar	Scientist 'E'
21.	Dr. V.M. Choubey	Scientist 'E'
22.	Dr. N.R. Phadtare	Scientist 'E'
23.	Dr. Talat Ahmad	Scientist 'E'
24.	Dr. P.P. Khanna	Scientist 'E'
25.	Dr. Rohtash Kumar	Scientist 'E'
26.	Dr. Keser Singh	Scientist 'E'
27.	Dr. (Mrs.) Meera Tiwari	Scientist 'E'
28.	Dr. S.K. Ghosh	Scientist 'E'
29.	Dr. M.P. Sah	Scientist 'E'
30.	Dr. N.K. Saini	Scientist 'E'
31.	Dr. K.K. Purohit	Scientist 'E'
32.	Dr. S.K. Paul	Scientist 'E'
33.	Dr. T.N. Jowhar	Scientist 'E'
34.	Dr. Kishor Kumar	Scientist 'E'
35.	Dr. N.Siva Siddaiah	Scientist 'E'
36.	Dr. Rajesh Sharma	Scientist 'E'
37.	Dr. George Philip	Scientist 'E'
38.	Dr. Rafikul Islam	Scientist 'E'
39.	Dr. D. Rameshwar Rao	Scientist 'E'
40.	Dr. B.N. Tiwari	Scientist 'D'
41.	Dr. S.K.Bartarya	Scientist 'D'
42.	Dr. Kamal	Scientist 'D'
43.	Dr. P.K.Mukherjee	Scientist 'D'
44.	Dr. S.J.Sangode	Scientist 'D'
45.	Dr. Sushil Kumar	Scientist 'D'
46.	Dr. H.K.Sachan	Scientist 'D'
47.	Dr. S.K.Parcha	Scientist 'D'
48.	Sh. B.S.Rawat	Scientist 'C'
49.	Dr. P. Banerjee	Scientist 'C'
50.	Dr. A.K. Mahajan	Scientist 'C'
51.	Dr. D.P. Dobhal	Scientist 'C'
52.	Dr. Vikram Gupta	Scientist 'C'
53.	Dr. S.S. Bhakuni	Scientist 'C'
54.	Dr. A.K. Mundepi	Scientist 'B'
55.	Sh. V. Sriram	Scientist 'B'
56.	Dr. Bhagwat Sharma	Scientist 'B'
57.	Sh. P.S. Negi	Scientist 'B'
58.	Dr. A.K.L.Asthana	Scientist 'B'
59.	Dr. Jayangondaperumal	Scientist 'B'
60.	Dr. A.Krihsnakanta Singh	Scientist 'B'
61.	Miss Kapesa Lokho	Scientist 'B'
62.	Dr. Khayingshing Luirei	Scientist 'B'

(B) Technical Staff

1.	Sh.V.P. Singh	Sr. Pub. Doc.Officer Gr.III(5)
2.	Sh.Saeed Ahmad	Sr. Librarian Gr.III(5)
3.	Smt. Abha Kumar	Sr. Pub. Doc.Officer Gr.III(5) (Retired on 31.8.2003)
4.	Sh.J.J. Sharma	Sr. Technical Officer Gr.III(5)
5.	Sh.M.M.S. Rawat	Tech. Officer Gr.III(4)
6.	Sh.B.B. Sharma	Tech. Officer Gr.III(4)
7.	Sh.A.K.Pandit	Artist-cum-Modellor Gr.III(3)
8.	Sh.Sanjeev Dabral	Jr. Technical Officer Gr.III(3)
9.	Dr. R.K.Sehgal	Jr.Technical Officer Gr.III(3)
10.	Sh.Chandra Shekhar	Jr.Technical Officer Gr.III(3)
11.	Sh.V.P. Gupta	Jr. Technical Officer Gr.III(3)
12.	Sh.Samay Singh	Sr. Technical Asstt. Gr.III(2)
13.	Sh.Ravindra Singh	Sr. Tech. Asstt.
14.	Sh.H.C. Pandey	Sr. Tech. Asstt.
15.	Sh.Satish Chandra Kothiyal	Lab. Asstt. Gr.II(5)
16.	Sh.Vishnu Shrestha	Lab. Asstt.Gr.II(5)
17.	Sh.Rakesh Kumar	Sr. Technicaì Asstt. Gr.III(2)
18.	Sh.N.K.Juyal	Technicaì Asstt. Gr.III(1)
19.	Sh.Chandra Bhan Sharma	Junior Engineer
20.	Sh.S.S.Bhandari	Technical Asstt. (2.7.2003)
21.	Sh.Rambir Kaushik	Technical Asstt. (1.9.2003)
22.	Sh.D.N. Dutta	Mech. Tech.
23.	Sh.V.K. Kala	Draughtsman Gr.II(5)
24.	Sh.G.S. Khatri	Draughtsman Gr.II(5)
25.	Sh.Navneet Kumar	Draughtsman Gr.II(5)
26.	Sh.B.B. Saran	Draughtsman Gr.II(2)
27.	Sh.Chandra Pal	Section Cutter Gr.II(5)
28.	Sh.Shekhara Nandan	Section Cutter Gr.II(4)
29.	Sh.Pushkar Singh	Section Cutter Gr.II(4)
30.	Sh.Satya Prakash	Section Cutter Gr.II(4)
31.	Sh.Santu Das	Section Cutter Gr.II(1)
32.	Sh.Nand Ram	Elec.-cum-Pump Operator Gr.II(4)
33.	Dr. S.K. Chabak	Sr. Lab. Tech.
34.	Sh. Lokeshwar Vashistha	Sr. Lab. Tech.
35.	Sh.R.M. Sharma	Sr. Lab. Tech.
36.	Sh.C.P. Dabral	Sr. Lab. Tech.
37.	Sh.Subodh Kumar	Lab. Asstt.
38.	Sh.Nain Dass	Lab. Asstt.
39.	Sh.S.K. Thapliyal	Field-cum-Lab.Attendant Gr.I(4)
40.	Sh. S.P. Bahuguna	Field-cum-Lab-Attendant Gr.I (4)
41.	Sh.Shiv Prasad Bahuguna	Field-cum-Lab. Attendant Gr.I(4)
42.	Sh.Sashidhar Balodi	Field-cum-Lab. Attendant Gr.I(4)
43.	Sh.Rajendra Prakash	Field-cum-Lab. Attendant Gr.I(4)
44.	Sh.Tirth Raj Ram	Field-cum-Lab. Attendant Gr.I(4)
45.	Sh.A.K. Gupta	Field-cum-Lab. Attendant Gr.I(4)
46.	Sh.Balram Singh	Field-cum-Lab. Attendant Gr.I(4)
47.	Sh.Ram Kishore	Field-cum-Lab. Attendant Gr.I(4)
48.	Sh.Anop Singh	Field-cum-Lab. Attendant Gr.I(4)
49.	Sh.Pratap Singh	Field-cum-Lab. Attendant Gr.I(3)
50.	Sh.Jaya Nand Khanduri	Field-cum-Lab. Attendant Gr.I(3)
51.	Sh.Ansuya Prasad	Field-cum-Lab. Attendant Gr.I(3)
52.	Sh.Puran Singh	Field-cum-Lab. Attendant Gr.I(2)
53.	Sh.Ram Khilawan	Field-cum-Lab. Attendant Gr.I(2)
54.	Sh.Madhusudan	Field-cum-Lab. Attendant Gr.I(2)

55.	Sh.Hari Singh	Field-cum-Lab. Attendant Gr.I(2)
56.	Sh. Ravi Lal	Field-cum-Lab. Attendant Gr.I(2)
57.	Sh. Preetam Singh	Field-cum-Lab. Attendant Gr.I(2)
58.	Mrs. Rama Pant	F.C.L.A.
59.	Sh. R.S. Negi	F.C.L.A.
60.	Sh. Ramesh Chandra	F.C.L.A.
61.	Sh. Khusi Ram	F.C.L.A.
62.	Sh. Tikam Singh	F.C.L.A.
63.	Sh. Bharosa Nand	F.C.L.A.
64.	Sh. B.B. Panthri	F.C.L.A.
65.	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 (28.5.03)
6.	Sh. Tapan Banerjee	Sr. Personal Assistant
7.	Sh. U.S. Tikha	Accountant
8.	Mrs. Manju Pant	Assistant
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 lien w.e.f. 30.9.2001 to R.L.I., Chennai)*
14.	Sh. P.P. Dhasmana	Stenographer Gr.(II)
15.	Sh. D.P. Chowdhury	Stenographer Gr.(II)
16.	Mrs. Rajvinder Kaur Nagpal	Stenographer Gr.(II)
17.	Sh. B.K. Juyal	Asstt.
18.	Sh. Hukam Singh	U.D.C.
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. Anand Singh Negi	U.D.C.
26.	Sh. S.K. Chhetri	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 Adhoc)
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. Jitendra Bhatt	L.D.C. (Adhoc)
39.	Sh. Puran Singh	Driver
40.	Sh. Khem Singh	Driver
41.	Sh. Diwan Singh	Driver
42.	Sh. Sohan Singh	Driver
43.	Sh. Ganga Ram	Driver
44.	Sh. Chander Pal Singh	Driver
45.	Sh. Naresh Kumar	Driver
46.	Sh. Shyam Singh	Driver
47.	Sh. Alok Narayan Sharma	Driver (Retired on 31.12.2003)
48.	Sh. Mani Kumar Tamang	Driver
49.	Sh. R.S.Yadav	Driver
50.	Sh. K.B. Rai	Driver (Adhoc)
51.	Sh. G.C.Singh	Guest House Attdt. Cum Cook
52.	Sh. D.P. Saklani	Guest House Attdt. Cum Cook (19.3.04)
53.	Sh. Bhagat Singh	Bearer
54.	Mrs. Kamla Devi	Bearer
55.	Sh. Shyam Lal	Bearer
56.	Mrs. Deveshwari Rawat	Bearer
57.	Sh. S.K. Gupta	Bearer
58.	Sh. Chait Ram	Bearer
59.	Smt. Omwati	Bearer
60.	Sh. Jeevan Lal	Bearer
61.	Sh. Surendra Singh	Bearer
62.	Sh. Rahul Sharma	Bearer
63.	Sh. Lal Bahadur	Chowkidar
64.	Sh. Har Prasad	Chowkidar
65.	Sh. Mahendra Singh	Chowkidar
66.	Sh. Minu Ram	Chowkidar
67.	Sh. Rahlu Ram	Chowkidar
68.	Sh. H.S. Manral	Chowkidar
69.	Sh. G.D. Sharma	Chowkidar
70.	Sh. Swaroop Singh	Mali
71.	Sh. Ashok Kumar	Mali
72.	Sh. Satya Narayan	Mali
73.	Smt. Dukni Devi	Mali
74.	Sh. Ram Singh	Safaiwala
75.	Sh. Ramesh	Safaiwala
76.	Sh. Hari Kishan	Safaiwala

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

Governing Body

(upto 31.10.2003)

Sl. No.	Name	Address	Status
1.	Prof. K.S. Valdiya	JVE-5, Vigyanpura Opp. New B.E.L. Road BANGALORE- 560 094	Chairman
2.	Dr. H. K.Gupta	Secretary Dept. of Ocean Development Mahasagar Bhawan, CGO Complex Lodi Road, NEW DELHI - 110 003	Member
3.	Shri P.C. Mandal	Director General Geological Survey of India 27, Jawaharlal Nehru Road KOLKATA - 760 016	"
4.	Dr. P. Nag	Surveyor General of India Sureveyor General's Office Post Box No. 37 Hathibarkala Estate DEHRA DUN - 248 001	"
5.	Shri Y.B. Sinha	Director (Exploration) Oil & Natural Gas Corporation Ltd. Tel Bhawan DEHRA DUN - 248 001	"
6.	Prof. Ashok Sahni	Centre for Advanced Studies in Geology Panjab University CHANDIGARH - 160 014	"
7.	Dr. D.K. Paul	BF/217, Sector - I, Salt Lake KOLKATA - 700 064	"
8.	Prof. K.R. Subrahmanya	Dept. of Marine Geology Mangalore University Mangalagangotri KARNATAKA - 574 199	"
9.	Prof. S.K. Tandon	Geology Department Delhi University DELHI - 110 007	"
10.	Dr. S.K. Acharyya	Emeritus Scientist Dept. of Geological Sciences Jadavpur University KOLKATA - 700 032	"
11.	Prof. A.K. Awasthi	Department of Earth Sciences IIT, Roorkee ROORKEE - 247 667	"

12.	Shri R.C. Chakraborty	Director D.T.R.L., R & D Organization Ministry of Defence Metcalf House NEW DELHI - 110 054	Member
13.	Shri Arun Sharma	Joint Secretary & Financial Adviser Dept. of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110016	"
14.	Dr. G.D. Gupta	Advisor Deptt. of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110016	"
15.	Dr. N.S. Virdi	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary
16.	Shri G.R.K. Nair	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Non-Member Asstt. Secretary (Upto 30-11-2002)
17.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Non-Member Asstt. Secretary (w.e.f.1-12-2002)

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	"
4.	Prof. Alok Gupta	Director National Centre for Experimental Mineralogy and Petrology, 14, Chattam Lines ALLAHABAD - 211 002	"
5.	Prof. D.C. Goswami	Deptt. of Environmental Science Gauhati University, GUWAHATI - 781 014	"
6.	Dr. R.N. Singh	Emeritus Scientist National Geophysical Research Institute Uppal Road HYDERABAD	"

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	"
9.	The Scientific Advisor	To the Defence Minister Ministry of Defence South Block NEW DELHI - 110 002	"
10.	Shri Arun Sharma	Joint Secretary (F&A) Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	"
11.	Shri P. C. Mandal	Director General Geological Survey of India 27, Jawaharlal Nehru Road, KOLKATA - 760 016	"
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	"
13.	Dr. P. Nag	Surveyor General of India Surveyor General's Office Hathibarkala DEHRA DUN - 248 001	"
14.	Dr. G.D. Gupta	Adviser & Head Seismology Division Department of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	"
15.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248001	Member Secretary
16.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN – 248001	Non-Member Asstt. Secretary

Research Advisory Committee

(upto 31.10.2003)

Sl. No.	Name	Address	Status
1.	Prof. S. B. Bhatia	House No. 441 Sector - 6 PANCHKULA - 134 109 (Haryana)	Chairman
2.	Dr. L.M.S Palni	Senior Scientific Advisor Biotechnology and Project Director State Biotechnology Programme GB Pant University of Agriculture & Technology TDC Building, PO, Haldi, U.S. Nagar – 263 146 (Uttaranchal)	Member

3.	Dr. J.R. Trivedi	Solar System and Geochronology Area Physical Research Laboratory Navrangpura AHMEDABAD – 380 009	Member
4.	Dr. R.K. Bhandari	C-II / 61, Satya Marg Chanakyapuri NEW DELHI - 110 001	"
5.	Dr. M. Ramakrishnan	Editor Journal Geological Society of India 63, 12th Cross Basappa Layout Gavipuram, P.O. BANGALORE - 560 019	"
6.	Shri V.D. Mamgain	(Ex.Dy.Director General,GSI) B-9, Indira Nagar Faizabad Road LUCKNOW - 226 016	"
7.	Dr. A.K. Chaudhury	Geological Studies Unit Indian Statistical Institute 203, B.T. Road KOLKATA - 700 035	"
8.	Shri C.P. Vohra	Ex. Director General, GSI House No. 1879, Sector-34-D CHANDIGARH-160 022	"
9.	Prof. P.K. Saraswati	Department of Earth Sciences I.I.T., Powai MUMBAI - 400 076	"
10	Dr. G.D. Gupta	Advisor Deptt. of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110016	"
11.	Shri N.K. Lal	G.M. (Geology) KDMIPE, ONGC Ltd. 9, Kaulagarh Road DEHRA DUN - 248 195	"
12.	Brig. (Dr.) B. Nagarajan	Director Geodetic & Research Branch, Survey of India. P.B. No. 77 DEHRA DUN - 248 001	"
13.	Prof. K.N. Khattri	100, New Rajender Nagar DEHRA DUN – 248 001	"
14.	Dr. Sumit K. Ray	Director GSI Eastern Region, MSO Building CGO Complex, DF Block, Salt Lake, Sector - I KOLKATA - 700 064	"
15.	Dr. P.S. Roy	Dean Indian Institute of Remote Sensing 4, Kalidas Road DEHRA DUN - 248 001	"

16.	Dr. A.C. Nanda	Scientist 'G' Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member
17.	Dr. N.S. Virdi	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member & Convenor

Research Advisory Committee

(w.e.f. 1.1.2003)

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	"
4.	Prof. P.K. Saraswati	Dept. of Earth Sciences Indian Institute of Technology Powai MUMBAI - 400 076	"
5.	Dr. S.K. Biswas	201, C-Wing, ISM House 818-A, Thakur Village Kandivilli (E) MUMBAI - 400 101	"
6.	Prof. R.S. Sharma	Dept. of Geology Rajasthan University JAIPUR - 302 004	"
7.	Dr. R. Dhanaraju	House No.1-10-284/1 Lane - 5, Brahmanwadi Begumpet, HYDERABAD - 500 016	"
8.	Kanchan Pande	Dept. of Earth Sciences Indian Institute of Technology Powai MUMBAI - 400 076	"
9.	Dr. S.K. Gupta,	Physical Research Laboratory Navranpura AHMEDABAD - 380 009	"
10.	Dr. V.P. Dimri	Director National Geophysical Research Institute Uppal Road, HYDERABAD - 500 007	"
11.	Dr. Ramesh Chander	290, Sector – 4 Mansa Devi Complex PANCHKULA - 134109	"

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	"
14.	Dr. K. R. Gupta	Scientist 'G' /Adviser Deptt. of Science & Technology Technology Bhawan, New Mehrauli Road, NEW DELHI - 110 016	"
15.	Shri N.K. Lal	G.M.(Geology) KDMIPE, ONGC Ltd. 9, Kaulagarh Road, DEHRA DUN - 248 001	"
16.	Dr. C.P. Rajendran	Scientist Centre of Earth Sciences Studies, Akkulam, THIRUVANTHAPURAM – 695031	"
17.	Dr. V.K. Raina	(Ex. Dy. Director General,GSI) House No.258,Sector - 17, PANCHKULA - 134 109	"
18.	Dr. B.R. Arora	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member & Convenor

Finance Committee
(upto 31.10.2003)

Sl. No.	Name	Address	Status
1.	Dr. D. K. Paul	BF/217, Sector-I Salt Lake KOLKATA- 700 064	Chairman
2.	Shri Arun Sharma	Joint Secretary & Financial Adviser Dept. of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member
3.	Dr. K. R. Gupta	Adviser Dept. of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI - 110 016	"
4.	Mrs. Alka Sharma	Surveyor General's Office Survey of India P.B. No. 37, Hathibarkala Estate DEHRA DUN - 248001	"
5.	Shri K.C. Misra	Additional Secretary to the Govt. of Uttaranchal Dept. of Finance Secretariat, Subhash Road DEHRA DUN - 248 001	"

6.	Shri A.D. Chawla	Dy. Finance Adviser (Nominee, JS & FA, CSIR) CSIR, Rafi Marg NEW DELHI - 110 001	Member
7.	Dr. N.S. Virdi	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	"
8.	Shri G.R.K. Nair	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	" (upto 30-11-2002)
9.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	" (w.e.f. 1-12-2002)

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, Department of Science & Technology, NEW DELHI	"
4.	Shri Arun Sharma	Joint Secretary (F&A), Department of Science & Technology,Technology Bhawan, New Mehrauli Road, NEW DELHI - 110 016	"
5.	Shri M.K. Jain	Deputy Financial Adviser Indian Institute of Petroleum, DEHRA DUN - 248 001	"
6.	Mrs. Alka Sharma	Jt. Controller of Defence Accounts (R & D), 107, Rajpur Road, DEHRA DUN - 248 001	"
7.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	"
8.	Shri Harish Chandra	F & AO, Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	"

Building Committee
(upto 31.10.2003)

Sl. No.	Name	Address	Status
1.	Dr. N.S. Virdi	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	Suptdg. Engineer Dehradun Central Circle CPWD, Nirman Bhawan 20, Subhash Road DEHRA DUN - 248001	"
4.	Shri H.M. Vyas	Chief Engineer (Civil) O.N.G.C. Ltd. Tel Bhawan DEHRA DUN - 248 003	"
5.	Shri Avinash Dikshit	Director Deptt. of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI-110016	"
6.	Shri G.R.K.Nair	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary (upto 30-11-2002)
7.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary (w.e.f. 1-12-2002)

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	"
4.	Shri Rajesh Agrawal	Chief Engineer (Civil) Deptt. of Civil Engineer, Shed No.32, Oil & Natural Gas Corporation, DEHRA DUN - 248 001	"
5.	Shri A. J. Kurian	Director, Department of Science & Technology, Technology Bhawan, New Mehrauli Road, NEW DELHI - 110 016	"
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**, Dehra Dun, as at 31st March 2004 and the annexed Income & Expenditure Account and Receipt & Payment Account for the year ended on that date. These financial statements are the responsibility of the Insitute'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 includeds 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 Balance Sheet of the state of affairs as at 31st March 2004.
2. In the case of Income & Expenditure Account of the surplus for the year ended on 31st March 2004.
3. In the case of Receipt & Payment Account of the receipts and payments for the year ended on 31st March 2004.

For A.K. Kashyap & Co.
Chartered Accontants

Sd/-

(Ashok Kashyap)
F.C.A. Partner

Date : 29th June, 2004
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 ON 31.03.2004

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 accured 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 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 Receipts & Payments Account as on 31.03.04.

ii) Balance of Debtors and Creditors as on 31.03.04 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 Stationary 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 2004

Amount in Rupees

Particulars	Current Year	Previous Year
Liabilities		
Corpus / Capital Fund	297,051,440	261,371,398
Reserves and Surplus	--	--
Earmaked/Endowment Fund	447,748	232,078
Secured Loans & Borrowings	--	--
Unsecured Loans & Borrowings	--	--
Deferred Credit Liabilities	--	--
Current Liabilities & Provisions	1,746,287	567,398
Pension Fund	27,581,513	22,491,827
CPF/GPF Fund	28,388,885	24,771,950
Total	**355,215,873**	**309,434,651**
ASSETS		
Fixed Assets	242,865,288	208,100,216
Investment from Earmaked/Endowment Fund	17,773	16,356
Investment others	15,783,000	6,785,000
Current Assets Loans & Advances	40,579,414	47,269,303
Pension Fund	27,581,513	22,491,827
CPF/GPF Fund	28,388,885	24,771,950
Total	**355,215,873**	**309,434,651**

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 : 29.06.2004
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 2004

Amount in Rupees

S.No.	Particulars	Current Year	Previous Year
A.	**INCOME**		
	Income from sales/services	-	-
	Grants/Subsidies	58,300,000	64,300,000
	Fees/Subscription	9,000	10,750
	Income from Investments	43,100	72,000
	(Income on Invest from Earmarked/ Endowment - Fund)		
	Income from Royalty. Publication etc.	62,160	94,643
	Interest earned	1,334,257	906,172
	Other Income	1,445,308	2,408,375
	Increase/Decrease in stock of Finished goods & WIP	–	–
	TOTAL (A)	**61,193,825**	**67,791,940**
B.	**EXPENDITURE**		
	Establishment Expenses	43,564,683	42,514,102
	Other Research & Administrative Expenses	9,923,113	7,225,854
	Expenditure on Grant/Subsidies etc.	-	-
	Interest/Bank Charges	7,426	8,703
	TOTAL (B)	**53,495,222**	**49,748,659**
	Surplus (Deficit) being excess of Income over Expenditure (A - B)	7,698,603	18,043,281
	Transfer to Special Reserve (Specify each) -	-	-
	Transfer to / from General Reserve	-	-
	GRAND TOTAL	**61,193,825**	**67,791,940**

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 : 29.06.2004
Place : Dehradun

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

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
Receipts & Payments Account for the year ended 31st March 2004

Amount in Rupees

Particulars	Current Year	Previous Year
RECEIPTS		
Opening Balance	16,016,961	7,003,212
Grants - in Aids	77,300,000	75,300,000
Grants - in - Aids (Ear Marked)	705,000	-
Loan & Advances	12,243,845	297,211
Fees/Subscription	9,000	10,750
Income from Investments	43,100	72,000
Income from Royalty, Publication etc.	62,160	94,643
Interest earned on Loan to Staff	1,334,257	906,172
Other Income	1,445,308	2,408,375
Investment	6,786,426	14,000,728
Decrease in Stock (Publications)	17,655	149,435
	115,963,712	**100,242,526**
PAYMENTS		
Establishment Expenses	43,564,683	42,514,102
Other Administrative Expenses	9,923,113	7,225,854
Interest/Bank Charges	7,426	8,703
Loans & Advances	10,453,608	3,134,605
Investments	15,784,426	9,323,696
Fixed Assets	27,953,380	10,719,071
Ear Marked Fund Expenses	459,055	82,714
Grant-in-Aid (Ear Marked) Refunded	31,692	11,216,820
Closing Balance	7,786,329	16,016,961
Increase in value of closing Stock (Publication)	-	-
	115,963,712	**100,242,526**

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 : 29.06.2004
Place : Dehradun

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