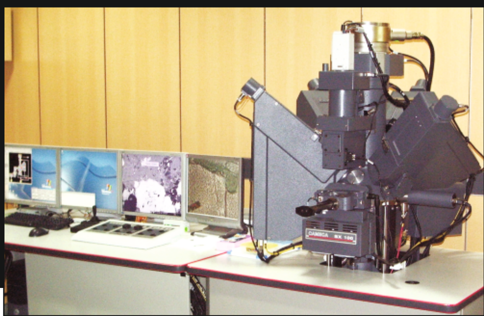

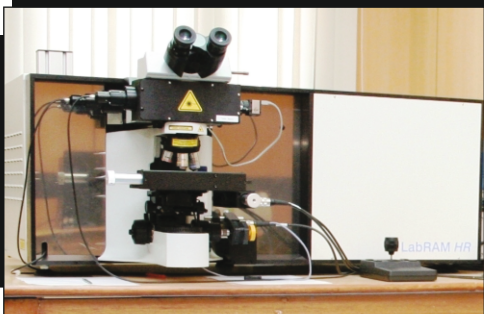

Annual Report

2008-2009

WIHG

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

ANNUAL REPORT
2008-09

WADIA INSTITUTE OF HIMALAYAN GEOLOGY

(An Autonomous Institute under Department of Science & Technology, Government of India)

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VISION

Application of emerging knowledge about the earth processes for fostering sustainable development and secured living in the Himalayan region.

Hon'ble Minister Shri Prithviraj Chavan, Ministry of Science & Technology and Earth Sciences, Govt. of India in the institute during inauguration of the Centre for Himalayan Glaciology at WIHG.

PARTING WITH 2008-09

Dreams come true

Marching forward on the well illuminated path marked by continuous growth in high impact publications, new laboratory practices, intensification in field monitoring networks and furling flags on unexplored terrains of the Himalaya, a glance into the spectrum of activities reassures that 2008-09 has been a year of fulfillment. The journey has been specially rewarding as number of mega programs have been realized. The distinctive examples are:

- The Government of India approved the creation of the Centre for Himalayan Glaciology at WIHG. The primary mission of the Centre is to "Mount a coordinated research initiative on Himalayan glaciology to understand the factors controlling the effects of climate on glaciers in order to develop strategies for climate change adaptability for sustained growth of society". In addition, the Centre shall take up program of capacity building in this very specialized field, which eventually nurture the independent Institute of Glaciology.

- The Centre for Himalayan Glaciology was inaugurated by the Hon'ble Minister for Science and Technology and Earth Sciences, Shri Prithviraj Chavan on July 4, 2009 in the benign presence of the Secretary, DST, Dr. T. Ramasami and Joint Secretary, Shri Sanjiv Nair.

- The Centre also had the proud privilege of visits by the Deputy Chairman, Planning Commission, Shri Montek Singh Ahluwalia and Hon'ble Minister for Environment and Forests, Shri Jairam Ramesh. These visits have served as stimulant in furthering the pace of glaciology research by opening gates of collaboration with sister institutions.

- Another milestone achievement of the year has been the inauguration of Multi-Parametric Geophysical Observatory (MPGO) for Earthquake Precursory Research by the Secretary, Ministry of Earth Sciences, Government of India, Dr Shailesh Nayak. The observatory established at Ghuttu, Tehri Garhwal is the first major initiative to study the earthquake precursors in an integrated manner.

- Continued efforts over the last 4-5 years have helped in developing a band of dedicated research scholars. Reviewing the progress of research scholars, the Chairman, RAC Dr. M. Ramakrishnan expressed that research themes pursued by most of them relate to emerging areas of geosciences and the opportunities provided to work on state-of-the-art equipments have enabled them to learn and contribute to the development of new laboratory practices. He emphasized that such programs of capacity building need to be continued recognizing the unique character of the Institute and required manpower.

MISSION

Continuously strive to unravel the geological truths related to mountain building, particularly Himalaya, for improving understanding of geodynamic processes, climate variability, natural resources, evolution of life, assessment and mitigation of natural hazards.

Hon'ble Shri Montek Singh Ahluwalia, Deputy Chairman, Planning Commission, and Hon'ble Minister Shri Jairam Ramesh, Ministry of Environment & Forests, Govt. of India in the institute during one of their visit to institute.

Important Highlights of Mission Mode Research Projects

The Mission Mode Projects initiated under the 11th Five Year Plan have begun to show signs of maturity and moving in the right direction to achieve broad long-term objectives. The quality of research output is reflected in the trend of emerging results. Some of the significant accomplishments in 5 major mission mode projects are summarized below.

Himtransects

Impact of the induction of geophysical imaging techniques as an aid to on-going geological and geochemical studies has begun to constrain or evolve new conceptual models for evolution of the Himalaya. Applications of modern numerical tools like local earthquake tomography, receiver functions and magnetotellurics have enabled to image the basement thrust fault (BTF) separating down-going Indian plate from the SW riding Himalayan wedge as a low velocity/ low resistivity interface. This is able to explain the sharp cut-off depth of crustal seismicity and focusing of large Himalayan earthquakes on a linear plane seen as a rheological transition. Passive seismology experiment conducted along the Lohit valley, Arunachal Himalaya lend support to the intender hypothesis wherein due to intense crust-mantle interaction the character of Moho is lost beneath the Eastern Himalayan Syntaxis.

Climate-Tectonics Interactions

The results of maiden investigations on the Spiti, Yamuna, Bhagirathi, Alaknanda, Mandakini, Nayar, Kameng and the Brahmaputra rivers in Himalaya have indicated that these valleys in terms of aggradations and incisions oscillated in phase with the changing climate during the last 40 ka. It is emerging that in tectonically active settings, river valleys although show different incision rates their timings of incision group around known periods of wetter climatic conditions, suggesting climate change to be the major forcing factor responsible for periodic river aggradations and incisions.

Biodiversity-Environment Linkage

Worldwide Neoproterozoic carbonates have shown the promise of rich reserves of hydrocarbons. In addition to recognizing the wide occurrences of Neoproterozoic carbonates in the Himalaya, the scientists have confirmed the presence of dark organic matter in the cellular and filamentous microfossils in the Buxa Dolomite in Sikkim Lesser Himalaya. This suggests that micro-activity giving rise to stromolitic structure in shallow warm waters of the sea was thriving in the Neoproterozoic. Raman Spectrometry has further re-affirmed that Kerogen present has intermediate grade of organic maturation.

Sustainable Natural Resources: Glacier as Repository of Fresh Water

The institute since 1991 has been engaged in the study of the Dokriani Bamak Glacier in Bhagirathi Basin, Uttarakhand for snout progression, mass balance, melt water runoff as well as sediment transfer, making it the longest continuously monitored glaciers in India. Comparison of snout positions in 1962, 1991 and 2008 has revealed that like many global glaciers, the Dokriani Glacier has been receding at an average rate of 17m/y but strikingly the rate of recession has been constant, contrary to hitherto claims of rapid accentuation in recent years due to global warming. These results are also corroborated by mass balance studies. Year-to-year rate of recession brings strong evidence that in addition to temperature, the pattern of winter precipitation controls the recession rate. Mass balance-ELA relationship indicates that compared to many global valley glaciers, melt water equivalents are minimum for the Himalaya. Such results are clear testimony to the fact that quantification of meteorological parameters on the health of the Himalayan glaciers is the right choice for priority research at the newly established Centre for Himalayan Glaciology.

Real Time Geology for Society: Coping with Natural Hazards

In real time geology program to cope up with natural hazards, a major accomplishment has been the up-gradation of seismological network in phased manner to provide uniform coverage in the NW Himalaya, especially to study the seismically active zones of Kangra, Kinnaur and Uttarakhand Himalaya. This upgradation has brought down the detection threshold of earthquakes from magnitude M=4 to 2 and has greatly improved the locations of hypocenters allowing tracking of tectonic-seismicity linkage. The space time pattern is regularly being examined to demarcate space time patterns of enhanced/

MISSION

MPGO aims at generating high quality geophysical database for Earthquake Precursory Research.

Inauguration of the Multi-Parametric Geophysical Observatory at Ghuttu by Dr. Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India quiescence that invariably precede the large earthquakes in this region. While this program will continue, a new major initiative on earthquake precursors will take the centre stage as earthquake precursors hold the promise for earthquake predictions in future. The present focus of the Multi-Parametric Geophysical Observatory is to rationalize the front line numerical methods for isolating the precursory signals from background variations of terrestrial, inter-terrestrial and environmental origin.

Awards and Honours

The above initiatives hold promise and have begun to enhance the visibility of WIHG in areas of basic and societal geosciences. One immediate example is that one of our scientists has been bestowed with the prestigious National Mineral Award by the Ministry of Mines, Govt. of India for his significant contribution in the field of Geo-Environmental studies. This is the 6th award in the last five years the Institute has bagged in fostering research in environmental study of the Himalaya. On the turn of year, yet another coveted 'Hari Narain' Award has come to the ambit of the Institute.

Academic Pursuits

The path breaking initiative by the Secretary, DST, Dr T. Ramasami bringing head of all autonomous Institutions of the DST on a single platform has provided a glimpse of the multi-disciplinary strengths of the extended family of the DST and in promoting spirit of togetherness.

To disseminate and share knowledge emerging from more recent efforts, the Institute organized a three day International Symposium on "Mountain Building and Climate-Tectonic Interaction MBCT-2008" during October 23-25, 2008. The event co-sponsored by the Indo-US Forum was a great success as more than 114 delegates participated, including 10 from abroad. Young scientists were awarded for their excellent contributions.

The platform of the Founder, Foundation Day, West Memorial Lecture, Technology Day, Hindi Fortnight was used to arrange series of invited lectures on multi-facetted themes. One significant accomplishment enhancing academic environment at the Institute has been the in-house weekly seminars, which have now become a regular feature. Like previous years, Science Week 'celebrated as open day' attracted large number of students and public.

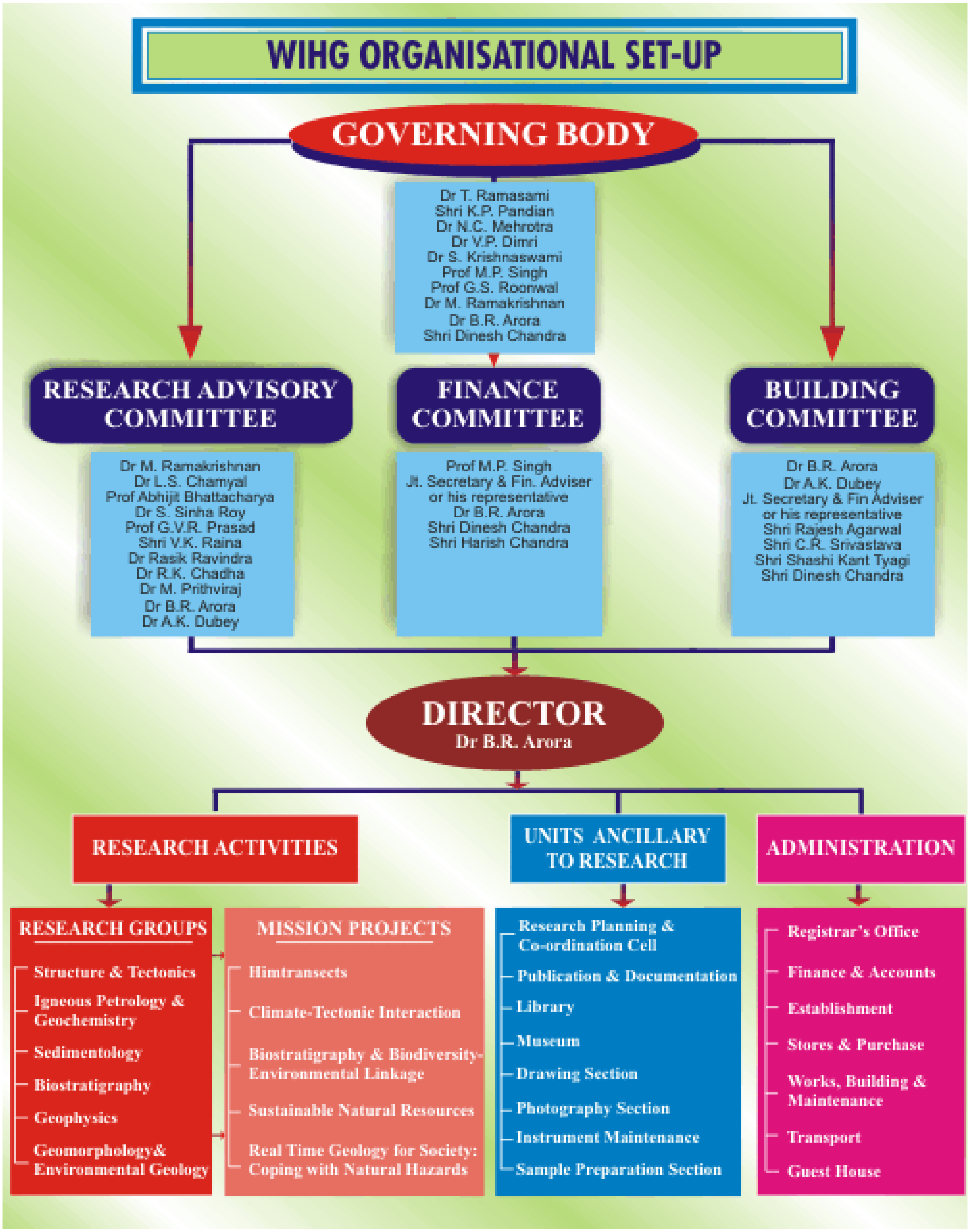
Republic and Independence days were celebrated with great enthusiasm and fervour. Yet another positive side-effect of increasing number of young research scholars was organization of colourful and patriotic cultural events on the Republic day. The visionary combination of ideas, technology backed up by powerful performances touched the heart of one and all.

Development vis-à-vis Finance

The Institute continued its strive to upgrade in-house analytical facilities. Particle Size Analyser, Raman Probe, Laser Ablation attachment to ICP-MS, Automatic Sample Fusion Machine and 5 units of Data Acquisition System for Broad Band Seismometers were added to promote research in the fields of sedimentology, geochemistry and geophysics. To sustain a respectable ratio between fixed cost and development investments, two way strategies proved productive; a section of grant-in-aid from the DST were used to upgrade in-house laboratories while creation of field observational networks were largely achieved from sponsored projects. Judicious planning helped to touch development costs attain peak value of about 45 per cent during 2007-08. However, a critical appraisal showed that during the years when annual budget did not increase at least by 15 per cent, developmental activities suffered the most. A more enterprising lead by DST to introduce a transparent formula in distribution of funds to autonomous institutions will not only resolve the imbalances but will serve as stimulant to perform better to have a big bite in the central pool.

Gratitude

The Institutional upward climb during the past couple of years has become possible by the vision, guidance and encouragement, received in abundance, from the present and past Governing Councils, Research Advisory Committees and above all unconditional support and faith reposed by the parent ministry, the Department of Science and Technology, Government of India. We express our gratitude to Chairpersons, distinguished members and decision makers for their continued motivation to aspire higher and higher. Special thanks to 'Guru' Ramasami who introduced us personally to 'Gobinds' of Science and Technology, the Hon'able Ministers of Science and Technology, Shri Kapil Sibal and Shri Prithviraj Chavan. Their personal patronage, interactions and advises have helped to accept more challenging missions of national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Himtransects
Climate-Tectonic Interaction
Biostratigraphy & Biodiversity-Environmental Linkage
Sustainable Natural Resources
Real Time Geology for Society: Coping with Natural Hazards
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Publication & Documentation
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Museum
Drawing Section
Photography Section
Instrument Maintenance
Sample Preparation Section
Registrar's Office
Finance & Accounts
Establishment
Stores & Purchase
Works, Building & Maintenance
Transport
Guest House

significance. We record our deep appreciation to chairpersons and members of Vision HimGeo, Graduate Program, Laboratory Up-gradation, Administrative Reform, Building Committees who have extended co-operation in introducing new academic pursuits and environment. The Screening and Selection committees in implementing objective procedure in screening enabling creation of broad based human resource to take up research in emerging areas of geosciences. The collaboration with numbers of national and international institutions has helped to give multi-disciplinary character to the research themes. Old saying goes well that no war is won by General alone. The Scientists and Technical staff of the Institute have always remained at the centre stage in implementing new vision and setting new standards for the Institute. The administrative and support staff have risen above their own standards to accommodate expanding activities and new ventures, like Centre for Glaciology. We wish that new gateways are opened soon for them to climb with the ascent of the Institute, similar to colleagues in scientific and technical streams. I wish, true to the unique character of the Institute, the dynamism of the Himalaya keeps deriving us to sustain forward and upward march.

Baldev Raj Arora
Director

PROGRESS IN RESEARCH PROJECTS

MMP 1 : Himtransects

1.1 Tracking Collision Tectonics in Himalaya through Magnetotellurics

(B.R. Arora and Gautam Rawat)

MT data is collected at thirty three sites along Bijnaur-Mallari Profile crossing major litho tectonic units of Himalaya starting from Indo Ganges plain, Siwalik, Lesser Himalaya, Higher Himalaya to Tethys Himalaya. Five component time series of electric and magnetic field is analyzed at each site for estimating MT transfer functions and GDS transfer function as well. At few sites, measurements are dominated by near source effect due to cultural noise and signal to noise ratio is low for periods greater than 1 sec. MT signals are weakest during this course of time as solar activity is in minimum phase. Weaker signals at longer period restricted depth penetration and resolution of deeper structure. Skewness and other dimensionality parameters indicate validity of regional 2-D model. Decomposition of thirteen station transfer functions considering 3D/2D model gives strike within good agreement of geological fabric of the area. The most conspicuous feature of the inverted resistivity section is the low resistivity zone at a shallow depth of 10 km beneath the Indo-Gangetic Plains that dips down at a low-angle and extends as a continuous plane right up to the northern limit of the profile.

This year two LMT sites with newly procured LMT units are covered. One unit is installed at Mallari and another at Garurganga which is just south of MCT zone. At each place, time variation of orthogonal electric field and magnetic field are measured for a period of 25 days. Long period time series is being analyzed for MT and GDS transfer function as well.

1.2 Lithospheric Structure and Dynamics of the Eastern Himalayan Syntaxis - Mishmi Hills

(V. Sriram, D. Hazarika and B.R. Arora)

Receiver Function (RF) Analysis

The P-wave RF computation have been completed for all the 12 Broadband (BB) seismic stations of Lohit Valley, Arunachal Pradesh, using time domain iterative deconvolution method of Ligorria and Ammon (1999). The stacked RF within a narrow bin (5˚x 5˚) of back azimuth and epicentral distance show an azimuthally varying lithosphere structure. The majority of RF for NE back azimuths (30˚- 85˚) do not show clear Moho converted phase (Ps) depicting a very complex structure, may be due to complex deformational style in the syntaxial bend.

Strong mid-crustal layers are observed clearly in WDNL, WLPR and WSGM stations. The multiple layering of the crust in the suture zone is clearly perceptible in the RF of WSGM station. The RFs of WMDP station show delayed first P arrival indicating a very low velocity top layer, may be due to thick sedimentary layer of Brahmaputra river beneath the station. From the RF of Walong (WWLG) station, it is observed that further east of Walong thrust the subsurface structure is different from that of west of the along thrust.

Forward and inverse modelling of stacked RF have been done for all the stations to obtain shear wave velocity structure and Moho depth underneath the BB seismic stations. The result obtained from modelling suggests a dipping Moho from west to east, which is in conformity with gravity data. The presence of Moho is observed to be at a depth of 46$\pm$2 km beneath Brahmaputra valley that gradually increases towards east and attains a depth of 60$\pm$2 km east of Walong thrust. The WSDL station, which is in the south of the profile, shows Moho depth of about 50 km.

It would be also tried to analyse the tangential component of the RFs which carries significant energy, may be because of various factors like scattering, crustal anisotropy etc. This will further improve the result obtained from the radial receiver function modelling.

Shear Wave Anisotropy study

Measurement of the strength and orientation of azimuthal anisotropy using the SKS splitting technique have been carried out for some events recorded by 6 - 7 stations in the seismic station profile mentioned above. The standard grid search method of Silver and Chan (1991) was used.

The fast axis orientation in these stations is observed to be ENE-WSW oriented with delay time 0.8 - 2.5. About 50 teleseismic events of magnitude >5.5 in the epicentral distance of 80 - 120 have been selected for mantle anisotropy study. The analyses for the other station data are under process.

1.3 Structural vis-à-vis a Crustal Evolution in the Trans-Himalayan regions of Tso-Morari, Indus and Shyok Suture Zones

(S.K. Paul and H.K. Sachan)

The Indus Suture Zone (ISZ), a major crustal lineament, defines the collision boundary between the Indian and Eurasian plates. It represents a complete set of subduction and collision related rocks in which the ophiolitic mélange is the most characteristic unit. In the present study area of Indus Suture Zone (northwestern Himalaya), the ophiolitic mélange accreted after the Cretaceous as indicated by the presence of Cretaceous olistoliths observed in the Shergol Ophiolitic Melange (SOM-S & SOM-N) and Zildat Ophiolite Melange (ZOM) while oceanic pelagic sedimentation existed up to early Eocene time (Mathur & Juyal 2000). These ophiolitic mélange bodies exposed in western and eastern Ladakh respectively are genetically same, but differ considerably in development of their penetrative foliation and also in emplacement time. The Shergol Ophiolitic Mélange is divided into two separate linear mélange bodies in western Ladakh; the southern mélange body (SOM-S) passes along the southern boundary of the ISZ and the northern mélange body (SOM-N) located to the north of the Nindam Formation well within the ISZ. The eastern extention of southern mélange (SOM-S) terminates near Lamayuru while northern mélange (SOM-N) profusely emplaced near Khalsi and its southeastern extension passes through Chilling to the north of the volcanoclastic Nindam Formation in the Zanskar valley and terminates near Nalbukar in eastern Ladakh. These emplaced ophiolitic mélange represent the principal evidence for collision between the two plates. Similarly in eastern Ladakh, the SOM-N to the west and Zildat Ophiolitic Melange (ZOM) to the east are not a continuous body as it is commonly believed. These ophiolitic mélange bodies have developed in phases in response to eastward progressing sequential collision between the two plates. The emplacement of SOM-S, SOM-N and Zildat Ophiolitic Mélange (ZOM) at different places and even different time reflects the kinematic deformational stages of the India-Asia collision in the NW Himalaya. All of these mélange bodies are almost similar in their physico-chemical character. Based on the present mapping, the northern belt of SOM-N was emplaced during post early Eocene to middle Eocene and has cross cut relationship with the Red Bed Formation of early Eocene rocks as seen in Zanskar valley, while ZOM emplaced within the Hemis Member of the Indus Formation, during terminal part of late Eocene to Oligocene time. The southeastern extention of the SOM-N terminates near Nalbukar to the north of Tso-Kar in eastern Ladakh as it can not be traced further eastward in its strike continuation across the Tso Morari Crystalline Complex. Since the on going north-south contraction is continuing, a new collisional boundary has been developed to the north of SOM-N. The SOM-N has an extensive thickness at Khalsi in western Ladakh while its thickness reduces eastwards beyond Markha. Further eastward, it is either very thin or occurs in patches between Markha and Nalbukar in eastern Ladakh.

On the basis of mineralogy, the metamorphic rocks of Pangong-Tso area of Karakoram metamorphic complex, have been classified into three groups of calc-pelite and one group of metapelite. The biotite containing calc-pelite is comprised of quartz, carbonate, muscovite, biotite, chlorite, plagioclase with minor tourmaline. The matrix is comprised of recrystallised quartz and carbonate with quartz exceeding carbonate in terms of modal abundance. Plagioclase is comprised of coarse anhedral grains with inclusions of quartz, carbonate and muscovite. The Staurolite grade metapelites are comprised of quartz, plagioclase, garnet, staurolite, biotite, muscovite, chlorite with minor amounts of tourmaline and opaque minerals. Porphyroblasts are comprised of staurolite and garnet. Garnet porphyroblasts have, in general, numerous quartz inclusions in them which do not have any preferred alignment. Skeletal garnet is also observed where the quartz grains almost intrude into garnet. There are several subhedral to anhedral staurolite porphyroblasts present along with fine staurolite grains whose grain size is comparable to that of quartz in the matrix. These finer staurolites are strewn within the matrix. Some garnet porphyroblast has lots of quartz inclusions in the core with no inclusion towards the rim. This suggests two stage growth of garnet. The Sillimanite bearing calc-pelites are comprised of quartz, carbonate, plagioclase, garnet, biotite, muscovite and fibrolite. Biotite has two modes of occurrence – first as randomly oriented flakes just like muscovite and second as fine threads intergrown with fibrolite. Some of the fibrolite have also recrystallised into needles of sillimanite. The metabasic rocks are comprised of plagioclase, carbonate, hornblende, biotite, quartz, garnet, chlorite, opaque and epidote. Discrete grains of hornblende (with elongation parallel to alignment of biotite) occur enclosing quartz grains within it. A few subhedral garnet porphyroblasts are present with biotite along fractures. Some garnet grains contain hornblende poikiloblastically included in it.

The Thermobarometric results for Staurolite grade metapelites indicate a temperature range of 574˚C to 691˚C and pressure of 4.7 kbar to 6.9 kbar. Sillimanite bearing metapelite has been metamorphosed at the peak temperature 670˚C and peak pressure 7.8 Kbar. Whereas, the metabasite metamorphosed at the temperature of 514˚C to 770˚C and a pressure of 14 to 6 kbars.

1.4 Comparative study of Himalayan Gneissic Domes

(Barun K. Mukherjee, R. Islam and H. K. Sachan)

The study of Gneiss domes that are exposed along the axis of the North Himalayan antiform and 50 km south of the Indus-Tsangpo Suture Zone, the core part of the antiform are characterized by Cambro-Ordovician gneiss. Among the several gneiss domes in the Himalaya, the first positive feedback is received from Leo Pargil and Tso Morari gneiss. Which is showing some similarity in regards to the metamorphism achieved by the core part of the both the gneiss domes. This shows the high-grade metasediments, pelitic and orthogneiss. Metamorphism of the pelitic rock displays staurolite–kyanite grade along the margin part of the gneiss. With more distal zones, showing up to garnet and chloritoid grade of metamorphism. The cursory knowledge of metamorphism for both the gneissic domes (Leo Pargil and Tso Morari), could be more accurately studied through systematic grain scale approach. In this regards efforts have been made to see the zircon and monazite. This reveals the studied zircons having complex internal structure with large rectangular igneous core. The zircon contains abundant inclusion mineralogy but no xenotime development on the zircon has been noticed. The monazites are comparatively smaller in size and relatively heterogeneous in nature. However, the proper chemical zonation of grains is yet to be achieved successfully. The complimentary fluid inclusion study reveals the fluid recycling pattern in Tso Morari rock is matched with enlarge P-T range linked to deep subduction processes. Study shows, initiation of subduction process has been dominated by brines followed by enriched with gaseous phases. Nevertheless, the coherency of retrograde fluid system between two gneiss domes is being observed in Leo Pargil and Tso Morari region. This has been enriched with carbonic as well as aqueous saline condition. Hence the studied fluid pattern and mineralogy for both the gneiss bodies suggests the exhumation path for both the gneiss domes are following similar pattern.

1.5 Magmatic and Metamorphic Studies of Kumaun Region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao)

The Chiplakot Crystalline Belt is considered as klippen of the Munsiari Formation. The geochemical studies suggest that the rocks under study from the Chiplakot crystallines are dominated by granite gneisses. These rocks are characterized by their high-K calc alkaline nature and low Na contents. They plot in granite fields on P-Q classification diagram. They are peraluminous granites showing normative corundum and mol. A/CNK ratios >1.6. The major and trace elements show much scatter on the Harker's variation diagram. The rocks show ΣREE >180 ppm, and their normalized REE pattern show fractionated trends with distinctive negative Eu anomalies. They show 120-170 times enrichment of LREE and 5-10 times enrichment of HREE than chondrite values. The sample plot at triple point junction on the Pearce Y+Nb vs Rb log-log plot, and plot along to syn-to pre-collision fields on the R1-R2 tectonic discrimination diagram.

Metamorphic studies have also been carried out to the north of Mangti beyond MCT, in the MCT zone along the Tawaghat-Malpa section of northeast Kumaun region. The section covered includes from low structural levels of Gathiabaghad-Garbhadhar-Jipti to higher structural levels of Shantivan and further-up towards Malpa. The region is dominated by garnet-biotite-muscovite gneisses with inter-bedded pelitic rocks and quartzites. The grade of metamorphism increases along the traverse from garnet-biotite grade in the lower structural levels to garnet-kyanite grade at higher structural levels. Along the traverse we find compositional variation of garnet and plagioclase. However, it has been observed that the composition of the minerals in general do not show any zoning. At lower structural levels in the Gar-Bi grade the rocks shows X_{Alm} ~0.500, X_{Py} ~0.015, X_{Gr} ~0.360, X_{An} ~ 0.340 and X_{Ab} ~0.640, while at higher structural levels in the Kyanite grade the rocks show X_{Alm} ~0.800, X_{Py} ~0.150, X_{Gr} ~0.080, X_{An} ~ 0.105 and X_{Ab} ~0.890. The P-T calculations using garnet-biotite thermometry and gar-bi-mus-plag-ky-q geobarometers reveals that the region is subjected to low temperatures, with temperatures increasing from 500˚C to 600˚C, and pressures increasing from 5 kbar to 7 kbar from gar-bi grade to kyanite-grade. The garnet amphibolites near MCT thrust contact have also been studied. The garnet has X^{51}_{Alm}, X^{4}_{Py}, X^{34}_{Gr}, X^{11}_{Sp}, and plagioclase has X^{77}_{Ab}, X^{23}_{An}, while the amphibole in these rocks is Ferro-Tschermark Hornblende. The P-T calculations show that the garnet amphibolite records 520˚C and 5.7 kbar of temperature and pressure respectively.

The fluid inclusion study has also been carried out in granite gneisses and in the quartz veins from the North Chiplakot Thrust zone. This helps to understand the fluid front in the thrust zone rocks of the detached klippen system of Lower Himalaya. Raman spectrometry of some fluid inclusions in the gneisses in the Chiplakot Crystalline Belt has been carried out in the Institute Raman Probe Lab. An early fluid record is noticed in the discrete fluid inclusions present as isolated ones and in the restricted trails. Such inclusion trails terminate within the quartz grains wherein fine granulation has not occurred and therefore they survived the last stage of recrystallization. Within these earliest inclusions an aqueous fluid and a carbonic-aqueous fluid is entrapped wherein the low homogenization of CO_2 at +1.6°C indicates density of 0.92g/cm^3. Large inclusions show increased internal pressure because of the uplift along the thrust plane as indicated by the incipient cracks developed on the host grain. The coexisting carbonic-hydrosaline fluid represents deep seated fluid migrated along the thrust. Subsequent fluid inclusions with immiscible carbonic-aqueous composition are present in the north-south trending FIP developed along the oblique fractures.

1.6 Exhumation history of the Higher Himalayan Crystallines, Western Uttarakhand Himalaya

(T. N. Jowhar)

Field work in Uttarkashi-Gangotri area (Bhagirathi valley) was carried out with reference to mineral chemistry and petrogenesis of Gangotri granite and P-T estimates of Higher Himalayan crystallines. Representative samples were collected for detailed laboratory investigations. Petrographic and mineralogical studies were carried out on Bhaironghati granite, Gangotri granite and Higher Himalayan crystallines. The EPMA data were obtained by utilizing Cameca SX 100 microprobe at WIHG. Whole Rock analysis (Major and trace elements) of the Gangotri granite and Bhaironghati granite was done by XRF technique. Temperature estimates have been done on Bhaironghati biotite granite by utilizing biotite-muscovite, plagioclase-muscovite and two feldspar geothermometers. These geothermobarometer gives temperature of subsolidus equilibration in the range of 358 to 489˚C (for two feldspar), 424 to 507˚C (for plagioclase-muscovite). Biotite-muscovite geothermomter gives T in the range of 570 to 766˚C which reflects both subsolidus and temperature of crystallization of granite. Mineralogical differences in Bhaironghati biotite granite (500 Ma) and Gangotri granite (23±0.2 Ma) is found and documented. Plagioclases from Bhaironghati granite show a distinct higher content of X_{AN} (10 to 32%) as compared to plagioclases from Gangotri granite (X_{An} = 1 to 6%). Mineralogical differences in muscovites in these two granites with respect to amount of Al^{iv} and Al^{vi} is also found. P-T estimates were done for Higher Himalayan Crystallines from Bhatwari-Gangotri region. A review of tourmaline and its petrological applications was also done.

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

(Keser Singh)

The field work was carried out along the Zanskar Valley and surrounding areas for about a month during August-September, 2008. The crystalline rocks of the Himalaya, in general, (Higher Himalayan Crystallines, Central Crystallines etc.) are bounded above by the Zanskar Shear Zone (ZSZ)/Trans Himadri Fault System and below by the Main Central Thrust (MCT). South and tectonically below the MCT lies the Lesser Himalaya, comprises the low grade meta-sedimentary succession and the crystallines klippen. North and tectonically over the Zanskar Shear Zone lies the sedimentary succession of the Tethys Himalaya. Defying this normal set-up, however, a different geological setup to the northwest of Beas valley, where the Tethyan rocks are either in contact with the Lesser Himalayan thrust sheets or surrounding the Higher Himalayan Crystallines (HHC) to a large extent. This is documented around areas comprising Chamba and Lahaul regions in the northwest Himalaya. With this scenario the question that how the Tethyan rocks occur south of the HHC and the ZSZ is still remains unresolved in the northwest Himalaya. Although folding of the MCT were described long before in the Himalaya and a simultaneous translation along with the ZSZ, with no inference that ZSZ could also be folded in geometric concordance with the MCT for the southward occurrence of Tethyan rocks. An alternative explanation that how the Tethyan rocks, now correspond to as Chamba succession, has translated south of the HHC was studied. This study also confirms two major phases of deformations related to the ZSZ. The D_1 microstructures like asymmetry of fold style, the sense of movement provided by asymmetric shape of the feldspar's porphyroclasts within the foliation etc. indicate an early top to southwest sense of shear. These microstructures indicate that the ZSZ probably acted initially as a synmetamorphic thrust. The microstructures superposed on the D_1 fabrics are top to northeast and S-C mylonites. The main foliation is superposed by a steeper anastomosing shear band (C′) foliation (D_2). The extension along this S-C foliation is toward NE at moderate angles. The late stage of D_2 deformation is expressed by pseudotachylites and cataclasites associated with exposure scale northeast dipping normal faults that cut the pervasive foliation at moderate to high angle.

The Tethyan rocks occurring, south of ZSZ and the HHC, are folded into opposite vergent regional scale folds generally known as Chamba and Tandi synclines and were explained by two different tectonic events. On the basis of new field data and structural analysis these synclines are interpreted as flanks of a large asymmetric box fold ~35 km wide and ~80 km long produced under a single deformation phase (D_1). Nearly similar orientation of the superposed crenulation cleavage (S_2) and related folds (F_2) indicate progressive, co-axial nature of deformation.

1.8 Thrust zone geochemistry and mineralogy: Implications for Tectonic evolution, fluid-rock interaction and associated mineralization along Uttarakhand Himalaya Geotransect

(P.K. Mukherjee and K.K. Purohit)

The Ramgarh Thrust (RT) is considered as part of Lower Himalayan crystalline. The scale of deformation is also comparable to that of MCT. With the aim to compare the nature of elemental mobility under the influence of the thrust of comparable dimension of MCT and RT, sets of samples were collected across the thrust zone. Like MCT in Garhwal, here also several pairs of deformed and relatively less deformed samples were collected from two major lithologies, i.e. quartzite-phyllonite and granite gneiss -> mylonite -> phyllonite. As noted in case of Munsiari thrust, the mylonites and phyllonites after Ramgarh gneiss on the hanging wall side and Nagthat quartzite on the footwall side of Ramgarh thrust also show very high volume loss and most of it is accounted for by the loss of silica. REEs are nearly conserved even under extreme deformation to phyllonite and with respect to REEs as reference frame, the volume loss is estimated at about 60% for Quartzite-> phyllonite and that of Granitic gneiss-> phyllonite is about 70%. The Phyllonitization process accompanied by high volume loss in presence of plentiful fluid. Whereas breakdown of feldspars are dominant reaction softening operative in case of granitic rocks, dissolution of Quartz and residual enrichment dominates the quartzite – phyllonite alteration. In both cases, chalcophile elements are extensively partitioned into the fluid phase (the sulphide mineralizations may be related to this alteration process. This work is in progress in collaboration with Prof. D.C. Srivastava (IIT, Roorkee) who had also accompanied in the field to help in working out the structural control of the Ramgarh Thrust.

In another attempt to study the deformation induced geochemical alteration in a shear zone cutting across Badrinath leuco-granite associated with South Tibetan detachment (STD) system of normal faults (Jointly with Dr. H.K. Sachan). In this case it was found that the deformed granites show alteration of K-Feldspar to Muscovite and further muscovite to chlorite. To characterize this reaction, the geochemical mass-balance approach was applied. The results of mass-balance study and geochemical signature of the bulk rock confirm that HREEs and some HFSEs were immobile. Taking these as immobile reference frame, it was found that that a volume strain of about -31% explains the geochemical mass-transfer mostly in terms of loss of SiO_2, Al_2O_3 and Na_2O. This is also consistent with observed mineralogical reactions above.

1.9 Kinematic history of the thrust sheets and metamorphic evolution of the crystallines of Subansiri and Siyom valleys, Arunachal Pradesh

(B.K. Choudhuri)

During this year geology and structural evolution of the eastern Himalayan syntaxial bend in eastern Arunachal Pradesh, has been worked out. Except Subansiri Valley all the major valleys viz., Lohit, Dibang, Siang, Siyom and Kameng Valleys are covered in this work. The eastern syntaxis, were a large scale antiform, known as the Siang Antiform. The crestal portion of the antiform exposed in the Namche Barwa peak area, is occupied by Higher Himalayan Crystallines. The litho-tectonic units from south to north are: the Sub-Himalayan sediments, Lesser Himalayan Sedimentary Sequence, Lesser Himalayan Crystallines, Higher Himalayan Crystallines (HHC), Trans-Himalayan tectonic units, namely the lower Tsangpo Suture Zone and the upper subduction related Lohit Plutonic Complex (LPC). Field investigations have been carried out along four major valleys viz, Siyom, Siang, Dibang and Lohit Valleys. The structural analysis indicates that the area has undergone four phases of deformation, out of which the first two phases are coaxial and the third phase of deformation has produced a regional scale NNW plunging Siang Antiform, which cross-folded the earlier structures. The variation in the pattern of foliation and lineation on both the limbs is interpreted as due to passive rotation during F3 folding and the western limb is more rotated than than the eastern limb. The last phase of deformation has affected the Trans-Himalayan units exposed in the eastern limb and reactivated the early thrusts, into dextral strike-slip faults. Both the Lesser and Higher Himalayan Crystallines exhibit inverted metamorphic character. The HHC exposed in the eastern limb of the Siang Antiform show an increase in both temperature and pressure towards higher structural levels and the inverted metamorphism is related to post metamorphic shearing. The high grade gneisses, exposed along the Walong Thrust that divide the LPC into western and eastern belts, forms the basement for the LPC and these crystalline rocks can be correlated with the Mogok Gneissic Belt of Central Burma in the south and the Nyainqentangiha Crystallines in the north that tectonically overlie the Tsangpo Suture Zone in eastern Tibet. Our field investigations in the syntaxial region suggest that the thrust bound litho-stratigraphic units have been translated towards south during the main phase of deformation (D2). Later, these tectonic units have been folded by the overall north trending Siang Antiform. The folding has tilted the early thrusts particularly in the eastern limb that were reactivated into dextral strike-slip faults. Subsequent indentation of the folded Indian plate rocks has folded the suture zone and the Gangdese belt and the northward migration have been accommodated by strike-slip faults on both sides of the antiformal syntaxis.

1.10 Geochemical and petrogenetic studies of basic and metabasic rocks of Lesser Himalayan sequence (LHS) in Siang and Subansiri valleys of Arunachal Himalaya

(A. Krishnakant Singh)

Direct derivation of acid volcanics from the magma appears to be precluded by their silica-rich nature. The implication of this observation is that these rocks are not direct mantle melts, rather they can be derived by fractionation from, or re-melting of mantle derived basic material, or by partial melts of the upper continental crust. Thus, the acid volcanics associated with the basic volcanics of Lesser Himalayan Sequence (LHS) in Siang, Arunachal Himalaya has been investigated to understand their geochemical characteristics, basic-acid magmatism relationship and their petrogenesis. These acidic rocks show flow banded with a conspicuous porphyritic texture in which coarse grained feldspar phenocrysts occur in a microgranular to vitrophyric groundmass. They show higher concentration of SiO_2 (66.93-74.69 wt. %), Na_2O+K_2O (3.00-8.55 wt.%), Rb (53-166 ppm), Zr (373-575 ppm), Y (40-71 ppm), Nb (19-46 ppm) and low Al_2O_3 (11.60-15.37 ppm), MgO (0.41-1.25 ppm), CaO (1.14-5.55 ppm) and Sr (113-613 ppm). These rocks possess negative anomalies for Sr, P, Ti, Nb. Such anomalies may be attributed to fractionation of feldspars (for Sr depletion), apatite (for P depletion) and Fe-Ti oxides (for Ti depletion). Slightly wide variation of Rb/Zr and La/Sm in the felsic volcanics may indicate random crustal contamination during the time of their evolution. They are characterised by less fractionated patterns [(Ce/Yb)N = 6.53-9.34] which show steeply sloping of LREE [(La/Sm)N = 3.08-3.52] and gently sloping of HREE [(Gd/Yb)N = 1.59-2.74] with pronounced negative Eu-anomaly (Eu/Eu* = 0.56-0.71). Major and trace elements signature suggest that these rocks were generated by partial melting of continental crustal rocks and heat from the solidified underplating basaltic magmas and the presence of mantle-derived volatiles could have initiated the partial melting process.

The coal seams in the Garu-Gensi-Dali section of west Siang area of Arunachal Himalaya have been also investigated to understand their nature of trace elements concentrations. These coal seams are associated with carbonaceous shales and siltstones belonging to the Lower Gondwana Sequence (Figs. 1a & b). Mineral matters

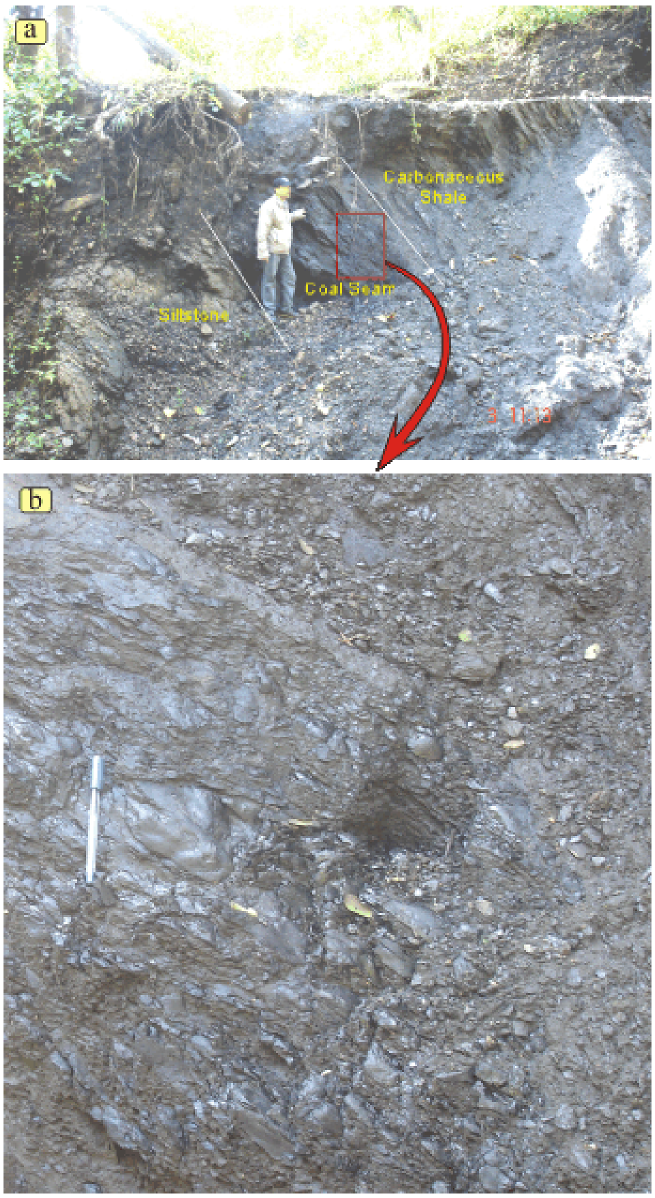


Fig.1. **(a)** Field photograph showing the disposition of coal seam associated with Garu-shales. The thickness of the seam is about 3 m. Note the high inclination of the seam. **(b)** Close view of coal.

such as clay, siderite (iron carbonate) and fine crystals of pyrite were recorded in the coal under the microscope. Proximate analytical results reveal that these coals are high volatile coals with relatively low ash content and their sulfur contents are also low. The observations indicate that these coals are low-rank bituminous type (V_0 = 0.64), their vitrinite content is about 60% and likely to be non-coking. However, the effects of stress on the macerals are well evident. In contrast to the high-sulfur Tertiary coals of northeast India, the total inorganic sulfur (i.e., sulfide and sulfate) is more in the present Lower Gondwana Coals. Element concentrations of Mn, Co, Ni, Cu, Ba and Pb are considerably higher in the present case than those of the coal of Barakars. Ga, Ge, Nb, Sn and REEs are also higher in the Himalayan coals while elements such as Sr, Y and Zr are lower.

1.11 Structural evolution of the Uttarakhand Lesser Himalaya: A study based on field, model deformation, petrofabric and magnetic strains

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

The magnetic susceptibility axes in the Garhwal Synform reveal large variation in their orientation and the important observation is that a pattern changes over very short distances (tens of meters) because of superposed deformation. The study reveals that the available patterns are characteristic of all the three types of faults, i.e. normal, thrust and strike-slip. An example of recent normal fault from western termination of the Garhwal Synform at the junction of frontal and oblique fault ramps of the Main Boundary Thrust (MBT) is shown in figure 2. The K_{min} magnetic susceptibility axis at the location is vertical whereas K_{max} is horizontal. The orientation is characteristic of formation of normal faults. An excellent correlation between the tectonic structure and the orientations confirms that orientation of the magnetic susceptibility axes can be employed to infer neotectonics stress pattern in a region. Similar study in other parts of the area suggests that normal faults are likely to be activated in the central and western region whereas strike-slip faults can become active in the eastern and northern regions (close to the Nayar Fault). Thrust faulting is an important component of deformation in the area but the orientation required for thrust faulting is not very well marked in the orientation patterns. This is mainly because the present study deals with study of surface stress patterns and there is no

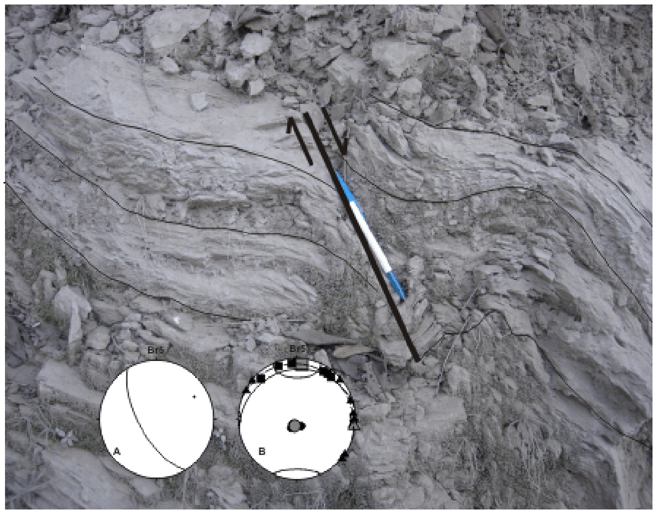


Fig.2. A young normal fault showing curvature of bedding foliation at the fault surface. Inset A shows orientation of the fault in the lower hemisphere stereoplot. Inset B shows orientation of magnetic susceptibility axes near the fault in the lower hemisphere stereoplot.

consideration of possible variation with depth. The thrust faults in the region have listric geometry and it is possible that thrusting is still active at depth where the fault is not locked because of gentle dips. Hence the deeper patterns may be of thrust faults.

The study of neotectonics stress patterns is important because the Himalaya is seismically active and earthquakes have occurred along different types of faults. For example, thrust (Uttarkashi earthquake, 20 October 1991, Ms 7.0, Gupta & Gupta 1995; Kangra earthquake, 4 April 1905, Mw 7.0; Middlemiss, 1910; Molnar 1987), oblique-slip normal fault (Kinnaur earthquake, 19 January 1975, Ms 6.8, Khattri et al. 1978), strike-slip fault (a large number of low magnitude earthquakes, Khattri & Tyagi, 1983; Gaur et al. 1985), and a combination of thrust and strike-slip faults (Chamoli earthquake, 29 March 1999, Ms 6.6; Mandal et al. 2002). Out of these, two very recent earthquakes, Uttarkashi and Chamoli have occurred in the Garhwal Lesser Himalaya. Seismic predictions in the Himalaya are mainly based on northward drift of the Indian plate and consequent strain build-up (e.g. Bilham et al. 1997; Larson et al. 1999; Bilham et al. 2001). The recent technique of the GPS has also helped in these studies (Banerjee & Burgmann 2002). Since GPS and the AMS studies are based on measurements of surface deformations, the two should correspond with one another and can be used as counter checks. No time frame can be predicted with the available data but it is suggested that in the seismically active areas like the Himalaya, AMS studies should be tried as long time earthquake precursor.

1.12 Neotectonic study of eastern Himalaya, Arunachal Pradesh

(S.S. Bhakuni, Pradeep Srivastava and Khayingshing Luirei)

Slip and creep movements along thrust and fault planes have deformed the geomorphic surfaces in the form of development of fault propagation folds in bed rocks, uplifting, up-warping and tilting of Late Pleistocene to Holocene fan deposit, and truncation of toe of fan deposit. These altogether have generated tectonic landforms along the thrust and fault zones. The elevated Quaternary landforms have developed across the mountain front. The epicenters of recent seismicity fall along the Main Boundary Thrust (MBT) and south of it. The fault plane solutions suggest N-S trending seismogenic fault indicating transverse subsurface tectonics. This implies that the sub-surface region beneath the Sub-Himalaya that is bounded between the MBT and Himalayan Frontal (HFT) is seismically active. Therefore the structural and geomorphological investigations were carried out across the foothills of the northeastern Himalaya, Arunachal Pradesh. This study has an important implication towards the understanding of the neotectonics along the leading edge of the eastern Himalayan syntaxis (EHS). In northeast direction of study area the NW-SE trending Mishmi Thrust (MT) separates the Lesser Himalayan Sequence from the Brahmaputra alluvium. The MT forms the boundary condition for the recent development of the major NW-SE trending Siang Antiform. Here the MT, MBT and HFT have almost merged with one another along the northeastern corner of the Assam. A zone of the mylonitized, brecciated and pulverized rocks is recognized at base of the much southeastward traveled Lesser Himalayan Thrust Sheet along the HFT, MBT and MT.

New structural field data have been generated across mountain front. Oriented samples were collected for Anisotropy of Magnetic Susceptibility (AMS) study. Regionally it is found that along length of faults/thrusts the nature and style of deformation vary drastically. The Sub-Himalayan rocks are tectonically attenuated and truncated out or subsided towards northeast direction of the mountain front. Analysis of AMS data indicates very weak internal deformation in the rocks of the Sub-Himalaya. No magnetic strain is observed in the Siwalik sandstones, and only external deformation is noticeable. Thus it has resulted in to the passive block movement of rocks across thrust and faults within the Sub-Himalayan domain. The structural and geomorphological studies suggest that the region has been active since the latest Pleistocene times (Srivastava et al. 2009). The study of morphostratigraphic units (fan terrace T3 formed between 13 and 10.5 ka, terrace T2 deposited during 10–8 ka and terrace T1 aggraded during <7 and 3 ka) at the mountain front in Pasighat region suggests that the tectonic-climate interplay took place between 15 and 3 ka. The OSL chronology indicates that the fan terrace deposited between 15 and 10 ka, after which the river incised. Aggradation was driven by a semi-arid climate and incision was facilitated by increased discharge, and tectonic activity along the transverse Ranaghat Fault that is interpreted to be activated after 10.5 ka. The sedimentation style and incision of these geomorphic units responded to contemporary climatic changes and uplift in the Siwalik range along the HFT and along intraformational thrust.

1.13 Sedimentological and geochemical attributes of the Pre-Vendian (1600-600 Ma) clastic and associated volcanic succession of the northwestern Lesser Himalaya

(Sumit K Ghosh and R. Islam)

The work is mainly focused on the geochemical studies of Palaeoproterozoic basic volcanics and soft sedimentary deformational (SSD) features of the associated sedimentary succession of the Garhwal Lesser Himalaya.

The basic volcanic rocks are mainly associated with Nagthat formation of outer Lesser Himalaya and Rudraprayag / Rautgara formation of inner Lesser Himalaya. The basic volcanic rocks range in composition from sub-alkaline basalt through andesite to andesitic basalt. Compositionally the Nagthat volcanics are depleted in TiO_2 as compared to Rudraprayag / Rautgara volcanics. Presence of minor trace elements suggests that these volcanics are continental tholeiites in nature and can be classified as Fe- tholeiites of continental character. Chondrite normalized REE data of Nagthat and Rudraprayag volcanics exhibit remarkable similarities, having enriched LREE and relatively flat HREE pattern along with weak negative Eu anomalies. Primitive mantle normalized multi- element spider diagram exhibit an enriched incompatible trace elements pattern especially in large ion lithophile elements (LILE) and distinct negative anomalies for Sr and high field strength elements (HFSE) from all the basic suites. The basic volcanics show distinct similarities in trace and rare earth element characters with the similar rocks of Aravalli and Bundelkhand regions of Indian shield. Syn-sedimentary deposit (with SSD – as a proxy for seismites) along with rift related setting the basic volcanics in Lesser Himalayan region marks a major thermal event capable of mobilization of sub-continental lithosphere.

The detection of unmistakable proxy of seismic events in ancient succession, (if possible), is of paramount importance, as it would provide a valuable insight into basin evolution. In fulfilling the criteria for establishing the SSD features as seismites, four critical lithosections viz, Chakrata (CHK-western extreme), through Nainbag –Damtha (ND), Shivpuri (SH) and Satpuli (SP-eastern extreme) sections of the Damtha Group from west to east (lateral spread of nearly 175 km aerial distance) were investigated for their temporal and lateral attributes.

Chakrata (CHK) Section: The measured 22 m section represents possibly the upper part of the Palaeoproterozoic Damtha Group. The SSD features mostly noticed in the silt-shale interface of the laminated silty shale of the siliciclastic- argillite rhythmic facies. Abundant SSD features are ball and pillow (H/W: 2.5 to 3), pseudonodules and occasional convolute laminations in the upper part. The thickness of the SSD zone reaches nearly 0.50 m (max) to 0.12m (min), less than the ND section.

Nainbag – Damtha (ND) Section: The 87 m measured section situated nearly 15 km east of CHK and 65km west of SH sections. The most abundant SSD features are ball and pillow (H/W: 3 to 20), pseudonodules, deformed cross-stratifications, convolute lamination /bedding and flame. The maximum thickness of the SSD zone reaches nearly 3.3 m and minimum 0.33 m.

Shivpuri (SH) Section: Situated nearly 60 km from ND section and the upper 22 m part of the measured 43 m section may be correlatable with the ND and CHK section. The SSD features are mostly observed in the upper part of the section. The SSD features are nearly similar in terms of types and dimension with that of the CHK section. Small-scale ball and pillow (H/W: 1 to 2), pseudonodules features are common. The thickness of the SSD zone ranges from 0.72 m to as thin as 0.18 m, less than the ND section.

Satpuli (SP) Section: Located in the extreme eastern part of the area of investigation situated nearly 40 km from the SH section and 100 km from the ND section. The SSD features are relatively rare as compare to the other section. However, in terms of types and dimension of SSD nearly similar as that of the CHK and SH section. The thickness of the SSD zone ranges within 0.70 m to 0.15 m. Therefore, it can be summarized that the syn-sedimentary Palaeoproterozoic basic volcanics of Garhwal Lesser Himalaya are evolved in a rift related tectonic environment. The SSD features (seismites) in the associated sediments point towards a regional triggering agent like frequent earthquakes in the region during Paleoproterozoic time.

1.14 Cretaceous – Tertiary and Palaeocene – Eocene boundaries in Um Sohrynkew section, Meghalaya : interdisciplinary study and global correlation

(V.C. Tewari, K. Kumar, N.S. Siddaiah and Kapesa Lokho)

Field work was carried out in different sections of Meghalaya and Shillong Plateau - for sedimentological, paleobiological, stable isotopic radiogenic isotopic, PGE and REE geochemical studies. Systematic sampling for various interdisciplinary studies has been done from Um Sohryngkew River (West and East) sections, Kommarah Limestone Quarry, Old border road section in East Khasi Hills and Ranikor- Dirang sections in West Khasi districts of Meghalaya. In laboratory, lithocolumns were finalized for different sections. Samples were processed for petrographic, isotopic, sedimentological, palaeobiological and mineralogical -geochemical studies. Petrographic thin sections from the Meghalaya plateau K/T and P/ E boundary have been studied for the palaeoenvironmental and microfacies analysis. Lakadong Limestone, Lakadong Sandstone, Therria Limestone, Prang Limestone and Umlatdoh Limestone show good development of foraminiferal-algal microfacies assemblages. Microstromatolites have also been observed in some thin sections.

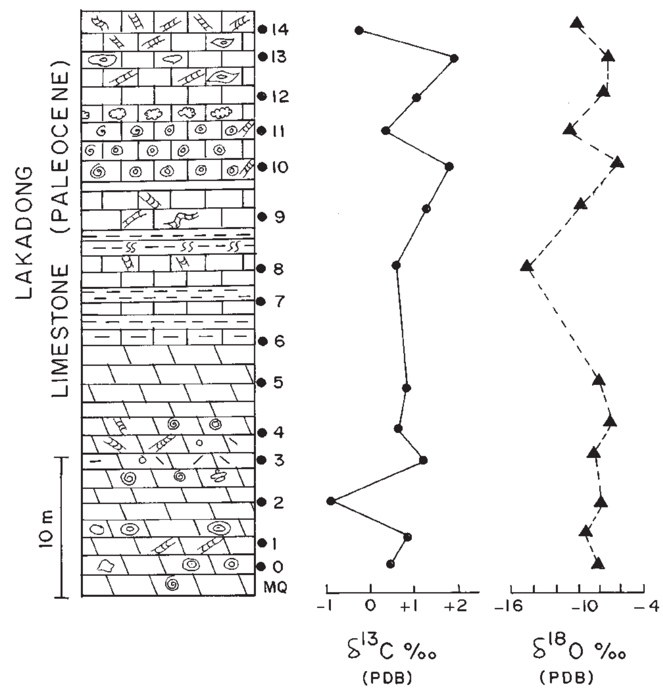
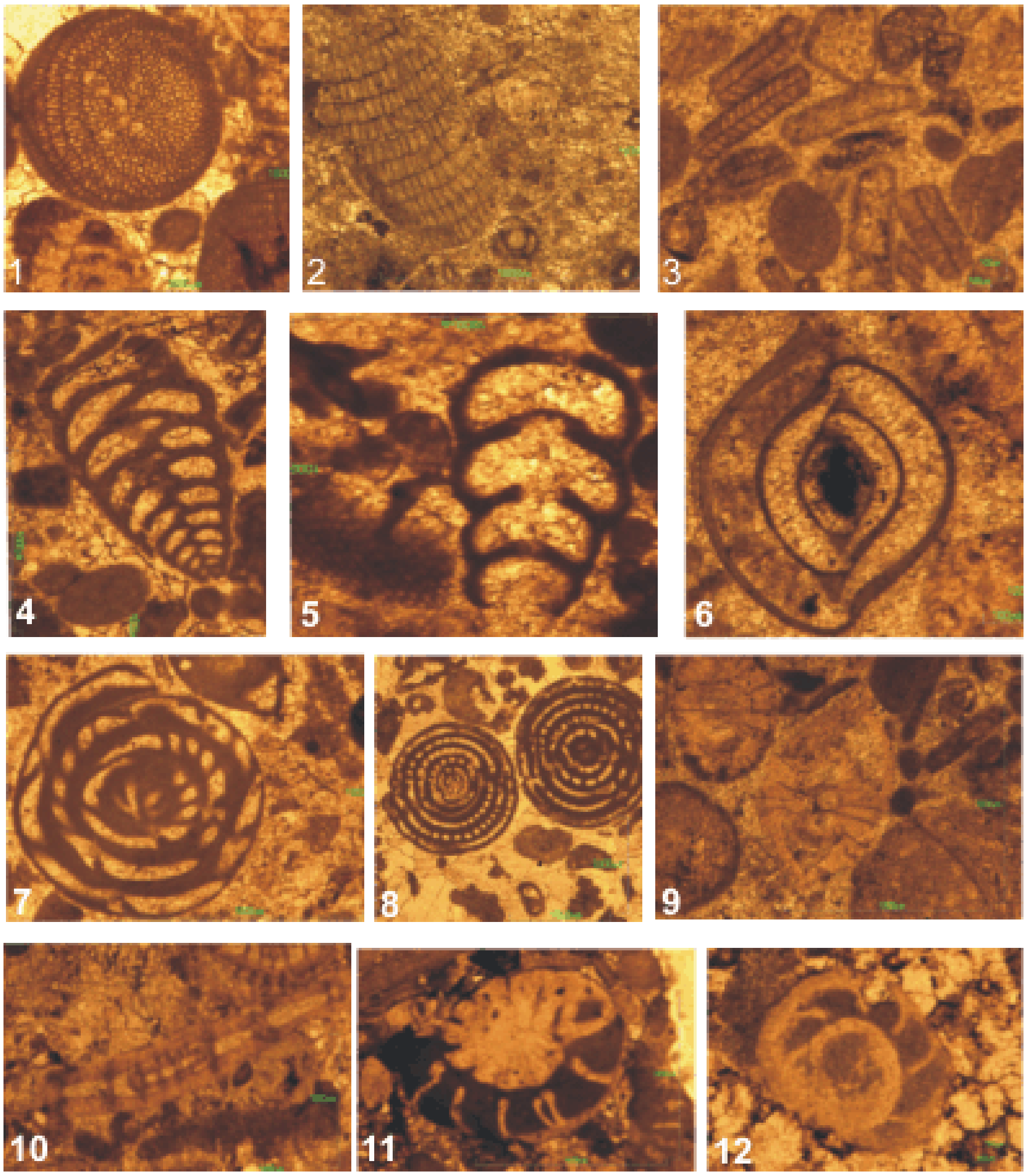


Fig.3. Paleocene algae and foraminifera in Lakadong Limestone, Mawmluh Quarry, Cherrajunji, Meghalaya.

A detailed closed sampling was carried at Mawmluh limestone quarry section for microfossil recovery. Processing and maceration of the rock samples are under process. Some of the recovered fossils are Miscellanea sp., Rotalia sp., Miliolids, Nummulites sp., Assilina sp., bi-serial forms like Textularia sp.?, Operculina sp., other smaller benthic forms and algae are shown in figure 3. Identification to the species level and interpretation for age and paleoenvironment is in progress.

Carbon and Oxygen isotopic data has been obtained for the Paleocene Lakadong Limestone from Mawmluh Quarry section for the first time. Figure 4 shows the $\delta^{13}C$ in the Lakadong Limestone which varies between – 0.13 ‰ (PDB) and +1.83 (PDB). The $\delta^{18}O$ ratio varies from 16.62 ‰ (SMOW) to 23.49 ‰ (SMOW). Carbon isotope data suggest shallow marine tidal flat conditions. Lakadong Limestone is deposited in Paleocene marine transgression. Tethys sea of Indian–Asian region is correlatable with western Tethys sea in Adriatic platform of North Italy and Slovenia based on comparison of similar foraminiferal–algal microfossil assemblage and stable isotopes.



1, 2, *Corallina algae*, MQ-2, MQ-3; 3. *Distichoplax* sp., MQ-12; 4, 5, *Textularia* sp.?, MQsp.?, MQ9,4; 6.*Spiroculina*? Sp., MQ-0; 7, 8, *Nummulites* sp., MQ-9,4; 9.*Miscellanea* sp., MQ-0; 10.*Assilina* sp., MQ-5; 11, *Rotalia* sp., MQ-14; 12.*Operculina* sp, MQ-12.

Fig.4. Carbon and oxygen isotope chemostratigraphy of the Paleocene Lakadong Limestone, Meghalaya.

Sedimentary facies, sedimentary structures and trace fossils (Thalassonides) indicate bioturbation in Lakadong Sandstone. Coal beds and black shales associated with Lakadong Sandstone indicate coastal, swampy and lagoonal conditions of deposition. Cretaceous oceanic anoxic event (represented by the black shales and pyritic lenses) and Paleocene–Eocene Thermal Maximum (PETM) are related to global carbon cycle perturbations.

1.15 Evaluating superposed fabric in granitoids of the Trans-Himalaya: Implications for tectonic evolution of the Indus-Suture Zone, and the Karakoram Fault Zone

(Koushik Sen and H.K. Sachan)

The Ladakh Batholith shows systematic variation in field and magnetic fabrics from N-S in the northern part to E-W in the central part and again NWN-SES in the southern part. The central part of the Batholith shows presence of 2 mica granites, while in the southern part, rhyolite is present. Apart from this, the whole Batholith is characterized by hornblende and magnetite bearing I type granites. The AMS fabric within the Batholith indicates a dextral transpression caused by the combined subduction and counter clockwise rotation of the Indian plate in respect to the Eurasian plate. U-Pb geochronology of one sample from the 2 mica granites gives an age of ~35 Ma. This indicates that due to continuous transpression the I-type granites have been remobilized and gave rise to two mica granites. Geochemical signature from XRF study also confirms this.

The Rhyolite of Ladakh batholith revealed the presence of three types of phenocrysts. These phenocrysts are of plagioclase, Chloritized amphibole and quartz. The first crystallizing phases are the mafic minerals (partially clhoritized amphibole and/or biotite), followed by the plagioclase and quartz. Detailed fluid inclusion study, occurring in quartz phenocrysts, allowed us to reconstruct the late stage evolution of the magma. All of the samples contain quartz phenocrysts which possess a large amount of randomly distributed primary fluid inclusion and minor silicate melt inclusions. Based on the petrographic features of the rock, the following crystallizing order can be constrained. The first crystallizing phases are the mafic minerals (partially chloritized amphibole and/or biotite), followed by the plagioclase and quartz. The groundmass is solidified as glass which went through late devitrification. Detailed fluid inclusion study, occurring in quartz phenocrysts, allowed us to reconstruct the late stage evolution of the magma. Prior to, or simultaneously with the crystallization of quartz, CO_2-H_2O-NaCl dominated fluids had been separated from the silicate melt via immiscibility. Further evolution of this separated fluid resulted in its second immiscibility, which resulted in entrapment of the CO_2 vapor and H_2O-CO_2-NaCl fluid inclusions, respectively. After the degassing of CO_2, the remaining fluids became relatively enriched in NaCl-H_2O components and can be recognized as three-phase (liquid-fluid-solid) fluid inclusions.

The fluid inclusion analysis and ^{40}Ar-^{39}Ar chronology combined with microstructural studies of mylonites of Tangtse Strand of the Karakoram Fault Zone (KFZ) reveals changes in deformation conditions and fluid composition with time. Microstructures indicate superposition of a high temperature ductile deformation followed by low temperature solid state deformation over primary igneous fabric. The fluids involved along the fault are carbonic-aqueous and aqueous in nature. The density of the inclusions changed as fault moved upward. Concomitantly, the salinity of fluid decreased drastically towards very low values (i.e. 2 wt. % NaCl at 3 km depth). The fluid inclusions and ^{40}Ar-^{39}Ar chronological data suggest that the Karakoram fault experienced exhumation under greenschist condition from ~10.5 to 9.5 Ma. The implosion type of texture as shown by secondary inclusions present in the mylonitic quartz grains, were formed due to the result of isothermal decompression at the late stage of exhumation. Field and microstructural investigation combined with available geochronological data indicates that migmatite and deformed granodiorite of this region were formed due to transpression tectonics long before the believed maximum age of initiation of the Karakoram Fault Zone.

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

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

The High Himalayan Crystallines (HHC) show discrepancy between field and magnetic fabrics. The magnetic fabric is steeper than the field fabric. Both have a NW-SE trend. The HHC show strongly oblate magnetic fabric. There is presence of boudins as late injections parallel to the foliation of the crystallines. All these suggest that there was dominance of simple shear in the initial part of and late stage compression in the structural evolution of this litho-unit is two staged. Petrographic study suggests that grade of metamorphism increases from MCT to STD in the study area. Presently detail geothermo-barometric and microstructural study is going on to decipher the P-T condition and shear regime within this litho unit. Mylonites from STD and MCT will be send in foreign lab for detail thermochronology to evaluate the timing of activation of the MCT and the STD.

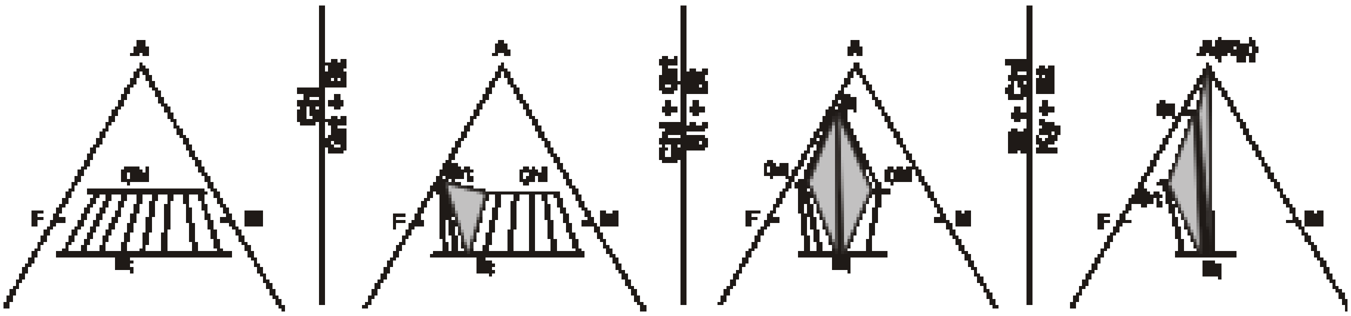


Fig.5. Schematic AFM diagrams projected from mu + qtz + H2O, showing mineral reactions and evolution of mineral assemblages. Mineral abbreviations are: Grt = garnet, St= staurolite, Ky = kyanite, Bt = biotite, Mu = muscovite, Chl = chlorite, and Qtz = quartz.

1.17 Study of Lower Palaeozoic Kinnaur Kailash granite and adjacent Higher Himalayan Crystallines (HHC) and Haimanta Group of the rocks in the Sutlej River valley, NW Himalaya: A metamorphic approach to understand the pre-Himalayan metamorphism

(S.S. Thakur)

Pelitic rocks of the Haimanta Group exposed in the Sutlej river valley, NW Himalaya have undergone kyanite-grade regional metamorphism. The rocks show evidences of two phases of deformation (D_1 and D_2) which have led to the development of S_1 and S_2 schistosities respectively. Numerous granite veins fed by the lower Palaeozoic Kinnaur Kailash granite pluton have intruded the area parallel to the S_1 schistosity of the host rocks. Many of the granite veins are folded by D_2 deformation, and have intruded either before or during the early part of D_2 deformation. Pelitic schists in the area contain porphyroblasts of garnet, staurolite and kyanite. Elongated grains of kyanite and staurolite aligned parallel to S_1 schistosity show microfolding related to D_2 deformation, and are interpreted to have grown during the early part of D_2 deformation. Petrographic study suggests that chlorite-biotite bearing pelite gave rise to garnet-staurolite-kyanite bearing mineral assemblages with increasing temperature. The progressive evolution of different mineral assemblages with increasing temperature in the K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O (KFMASH) system is schematically shown in a series of AFM diagrams (Fig. 5). Garnet porphyroblasts show reverse chemical zoning due to retrogression. Geothermobarometric calculations yield peak P-T conditions of 9.1 Kbar and 625˚C. Using the sequence of mineral reactions and P-T data clockwise P-T path is drawn for the development of observed mineral assemblages in pelitic schists (Fig. 6).

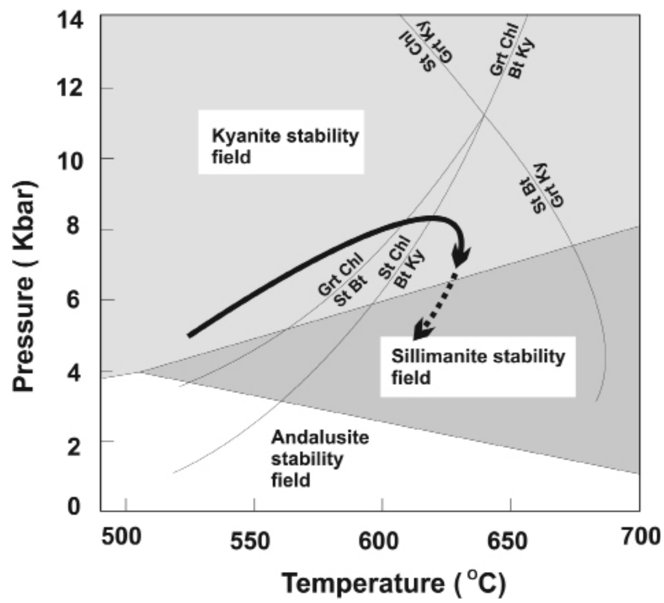


Fig.6. Petrogenetic grid in the KFMASH system for the phases kyanite-staurolite-garnet-biotite-chlorite (with excess muscovite, quartz and H2O. Stability field of alumino-silicates are from Holdaway12. Mineral abbreviations are same as in figure 5.

MMP 2 : Climate-Tectonic Interaction

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

(R.K. Mazari, M.P. Sah and A.K.L. Asthana)

During the year emphasis was given to synthesize the data on the development of the Quaternary basins in the Ladakh-Lahul-Spiti region that became the sites of short and prolonged periods of sedimentation. Apart from terrace development these basins also provided arenas of lacustrine deposition which act as proxy material for the reconstruction of the palaeoclimatic and palaeoenvironmental history of the region. Although detailed investigations at all the potential sites is a matter of time, nevertheless the scanty data generated so far through our previous studies as well as those reported by other workers does help to portray a sketch on the development and timing of the different Quaternary basins in the region and is summarized as below. Even though Tsokar basin in Ladakh is the single largest basin in which Quaternary sedimentation occurred, the Spiti basin has traces of one large basin which witnessed the lacustrine deposition during this period. The age of the Tsokar basin estimated from uniform sedimentation rate, available radiocarbon date and depth profile works out to be around 0.65 million years. In contrast, the age of the Quaternary lake in Spiti basin appears to be around 50,000 years BP or so although this seems to be at variance considering reported TL date at around 10,000 year BP for the Kioto lake sequence as against 45,000 years BP or so earlier based on varve count for the timing of the development of this lake. The development of lakes at a regional level from Lamayuru in Ladakh to Sumdo in Spiti and Kumaon around this time (~ 45,000 years BP) indicates mega tectonic event that disturbed the hill slopes which mobilized debris blocking the courses of the rivers and producing sites of lake sedimentation. The tectonic movement has taken place along the various faults developed in the compressional regime.

Climatically, there have been warm and wet and cold and dry phases during the late Quaternary throughout the region. However, variability has been recorded in space and time particularly between valley bottoms and ridge tops which is considered to be a function of the lapse rate. Evidences show that the relief controlled coeval climatic events show a difference of at least 500 years between the valley bottom and ridge top settings. This prompts for carefulness in correlation criteria while describing the regional climatic scenarios of the Quaternary times.

As regards the environmental change it is observed that the glaciers in the region receded fast as a result of less precipitation or blockade of monsoon currents due to rapid uplift of the Higher Himalaya. In other words, depleted moisture reached the Trans Himalaya which affected the snow accumulation regime in the region and thus led to rapid recession of the glaciers. Evidences however suggest that the study area had a vigorous fluvial system at some stage in time during the Quaternary which now lies in fossil state considering the progressive depletion in the atmospheric moisture on account of the tectonically elevated relief.

The late Quaternary tectonics has also been responsible for the migration of river courses in the Ladakh-Lahul-Spiti region. This includes Tsarap Chu in Ladakh and Spiti river in Spiti besides many other streams. In the Spiti valley development of various glacial, glacio-fluvial, fluvial and lacustrine deposits are observed. Fluvial deposits predominate the course of the Spiti river between Losar and Kaza, Sumra and Sumdo and Leo areas. Evolution of alluvial fans along the tributary streams of the Spiti river as also the overlooking hill slopes indicates a revealing environmental change during the Quaternary period in terms of recession of snow/glacial cover to pave way for the vigorous frost action and fluvial erosion and deposition. The presence of debris columns indicates that the past climate in the Spiti valley was relatively wet as compared to the present.

The main Spiti valley was carved by the advancement of the master glacier between Kaza to Sijling as indicated by its wide-open and straight outline in this section and the presence of till-like deposits upstream of Sijling. Once the glacial retreat reached its present position tectonic activities led to the impoundment of the valley bottom to eventually convert it into long time ranging lacustrine sedimentation. The fluvial and lacustarine sediments are in abundance upstream of Sijling without exposing the bedrock in the thalweg while downstream of this point Spiti has carved a deep gorge in the parent country rock following a transverse fault development.

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

2.2 Environmental magnetic study in selected higher Himalayan paleo- and present-day glacial lakes

(Narendra Kumar Meena)

The project is intending to reconstruct past (ca. 3 ka BP) climatic variation in vicinity of the Himalayan glaciers using environmental magnetism as prime proxy with geochemistry and grain size. We used fluvio glacial and lake sediments as geo-archival information. The present study focused on occurrence of aeolian sediments from Chorabari Tal (Chorabari glacier) imbedded with coarse sediment fraction of a relict outwash plain. The presence of aeolian deposits has been used as clue of glaciation as they deposits during cold and dry period. Hence presence of aeolian in Himalayan Glacier can be used as advancement of glaciers. The discrimination

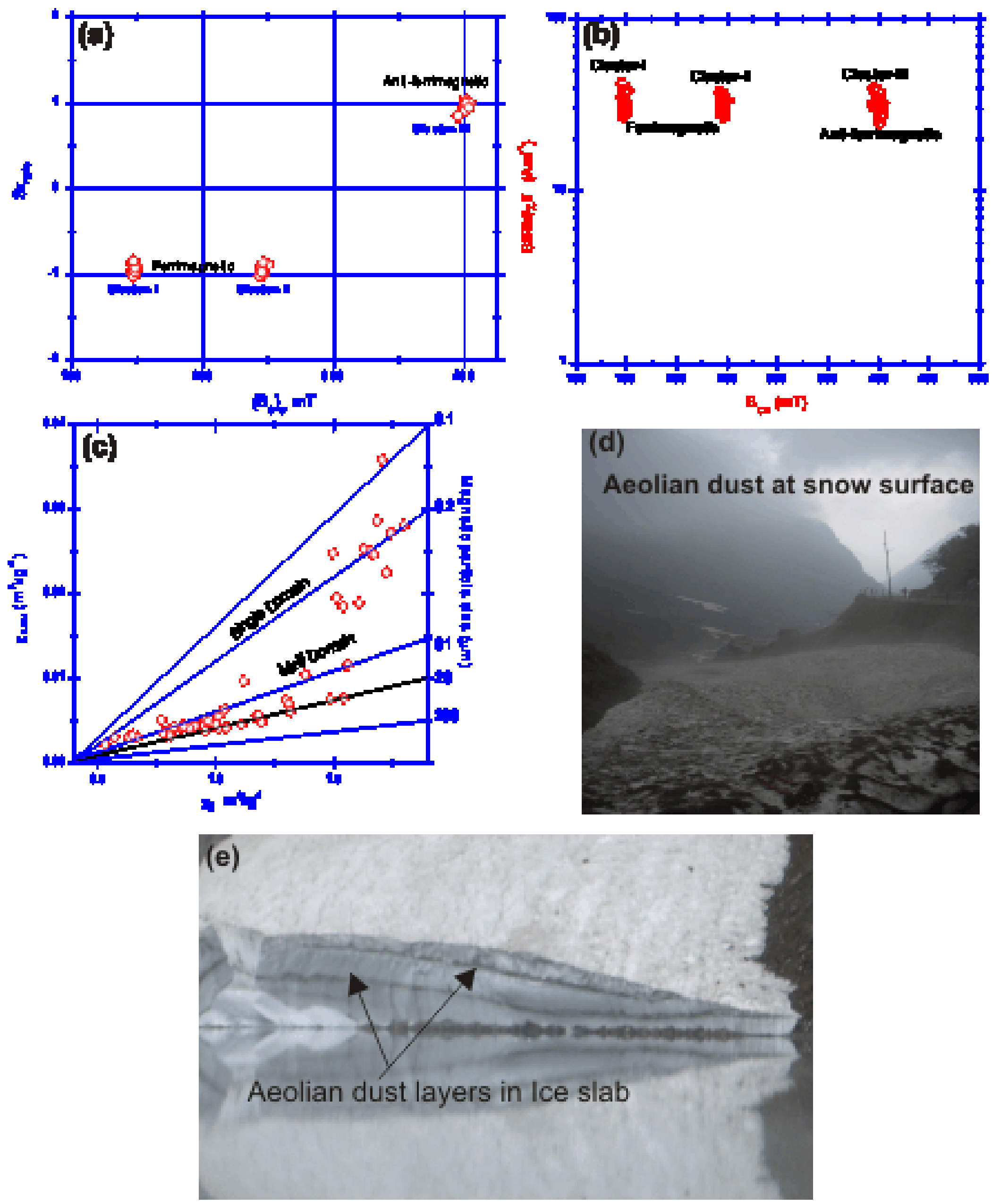


Fig.7. Shows evidence of aeolian sediments in Chorabari glacier, (**a&b**) discriminates ferrimagentic and anti-ferrimagentic magnetic mineralogy in Chorabari sediment profile, (**c**) dominant magnetic domain grain fraction (**d&e**) shows visual aeolian layer in Ice slab.

of the aeolian sediments from other sediments is not easy due to textural similarity and natural mixtures. The environmental magnetism has been used by previous researchers to discriminate aeolian sediments from others on the basis of the ferromagnetic and anti-ferrimagnetic mineralogy and magnetic domains grains. According to standard plot of SIRM/χlf Vs (BCR) Oldfield and Thomson (1986) (Fig. 7b) the magnetic mineralogy of the Chorabari profile falls in three clusters. Cluster-I and II indicates ferrimagnetic (Magnetite) with variable grain size with a lower value of (BCR) < 250 (mT) whereas cluster-III indicate anti-ferrimagnetic minerals (Hematite) with higher value of (BCR) > 300 mT. The plot between Sratio Vs (BCR) (Fig. 7a) that has been widely used to discriminate ferrimagnetic and anti-ferrimagnetic minerals based on the coercivity and granulomatry also strongly supports that the magnetic mineral fall in cluster-I and II shows ferrimagnetic nature whereas cluster-III is clearly dominated with anti-ferrimagnetic minerals. According to the King plot (King et al. 1982) (Fig. 7c) the magnetic granulomatry of the ferrimagnetic fraction is dominated toward Single Domain (SD) magnetic gains whereas anti-ferrimagnetic fraction is dominated with Multi Domain (MD) magnetic grains. On the basis of the magnetic and lithological data the preliminary source of the ferrimagnetic mineral in Chorabari profile is catchment rock, however a higher value of all concentration dependent parameters such as χlf and SIRM in the upper part of profile indicates magnetic enhancement during pedogenesis. If there is ferrimagnetic are dominated minerals from local source then from where the anti-ferromagnetic minerals has originated? The possible explanations are (i) Oxidation of Magnetite to Hematite (ii) aeolian influx, a mechanism in which the magnetic enhancement is taking place, the oxidation of Magnetite to Hematite is unfeasible. Thus the source of the anti-ferrimagnetic minerals remains through aeolian input. A aeolian layer (Figs. 7d & e) in Ice slab also support the aeolian influx in the glacier region. The occurrence of aeolian dust in Chorabari glacier is significant as aeolian dust in South Asian glaciers is reported as cooling event during which glacier reported in advance stage. There is a several episodes of aeolian influx can be detected in Chorabari lake.

2.3 Tectono-climatic evolution of Alaknanda-Bhagirathi River system in NW Himalaya

(Pradeep Srivasatava and R. Islam)

The drainage network of the Alaknanda river traverses through varied climatic gradient ranging from 1200 mm/ year at the foothills to ~3000 mm/year near the mountain front of Higher Himalaya. Thus the fluvial terraces preserved in the valley represent a composite record of 1) regional variations in climate, 2) local and regional tectonics. A morpho-tectonic navigation along Alaknanda valley between Rudraprayag and Karanprayag shows various levels of fluvial terraces, fossil valleys and epigenetic gorges that reflect the effect of past Tectono-climatic pulsations. In this segment the river runs parallel to the Alaknanda fault where the terrace configuration suggests that at least two major phases of rapid aggradation and bedrock incision/uplift are preserved. The terrace configuration at Gholtir show three levels of cut and fill fluvial terraces namely T1, T2 and T3 with bedrock being exposed at the base of T1. At Nagrasu two fossil valleys are observed at two different levels marking the two phases of rapid fluvial aggradation and bedrock incision and uplift. At Gaucher there are five levels of terraces, namely, T1 and T2, which are cut and fill type with bedrock at the base of T1. Further the older terraces T3-T5 are second set of cut and fill terrace sequence with bedrock at the base of T3 again suggesting two phases of valley aggradation and bedrock incision. Similarly at Bamoth two levels of cut and fill terraces are observed. The common observation at all location is northward shift of river channel probably linked with the activity of Alaknanda fault. Optically Stimulated Luminescence (OSL) chronology of the fluvial fill suggested that the aggradational phases were focused at Oxygen Isotope Stage-3 (OIS-3) and during the transition of OIS-2 and OIS-1. The latest phase of incision in Alaknanda River took place in response to enhanced precipitation after the Last Glacial Phase between 12-10 ka. Similar conclusion from the studies elsewhere that suggest that the phenomenon of Alaknanda aggradation responded to Global climatic changes where the activity along the local thrust and faults created accommodation space by laterally and vertically shifting the channel during the Late Pleistocene-Holocene.

2.4 Palaeoclimatic and Tectonic study of the Quaternary – Holocene speleothems from NW and NE Himalaya

(V.C. Tewari)

Field work was carried out in south Sikkim cave near Tatapani and systematic collection of stalactites and stalagmites samples were collected for laboratory work. Petrographic thin sections of stalagmites and stalactites from Sahastradhara caves in Dehradun, Brahma Khal and Pratapnagar areas in Bhagirathi valley and Mawsmai, Phyllut, Tatapani and Menga caves have been studied for microfacies, paleoclimate and sedimentary environment.

Petrograhic studies of speleothems shows finely laminated carbonate and microbial laminations. Carbonate minerals include aragonite, and fibrous calcite formed in fresh water. The Mawsmai and Menga speleothems have shown alternating white and dark laminated bands and voids. Various types of light (carbonate) and microbial (dark) morphology is related to the microclimatic decadal scale seasonal variations. Dark coloured clotted peloidal fabric may have been formed as calcified bacterial aggregates since such pattern has been observed in the microbialites, and travertines. Carbon and Oxygen isotopic variations in the Mawsmai speleothem has been recorded (Fig. 8). The carbon isotope values range from – 0.04 $^{o}/_{oo}$ (PDB) to +1.11 $^{o}/_{oo}$ (PDB). Oxygen isotope values range from –3.30 $^{o}/_{oo}$ (PDB) to –12.82 $^{o}/_{oo}$ (PDB). A number of dry and wet events have been identified based on oxygen isotope excursion (Fig. 8).

2.5 Late Quaternary climate changes and monsoon variability along the NW Himalaya

(N.R. Phadtare)

During the year fieldwork was carried out for detailed field survey and sampling for the Holocene climate studies at Chandra Tal (peat deposit), Patsio near Bara Lacha La (paleolake deposit), Hanley wet land (meadow), and Pangong Tso (exposed lake profile) in Ladakh and Karakoram area.

Chandra Tal: This Lake is situated along the northern base of Kunzum La, which is a major orographic barrier of the summer monsoon. About a meter thick profile of a lake deposit was cored and sampled at one-centimeter interval. A peat sequence (~ 55 cm thick) developed along the margin of a small pond was also trenched and sampled at a centimeter interval. The magnetic properties (susceptibility) data reveal that lake sediments as well as peat deposit are highly promising for the past few thousand year high-resolution climate history of the Chandra Tal area. Laboratory processing of samples for pollen records and geochemistry (Organic matter content) is in progress.

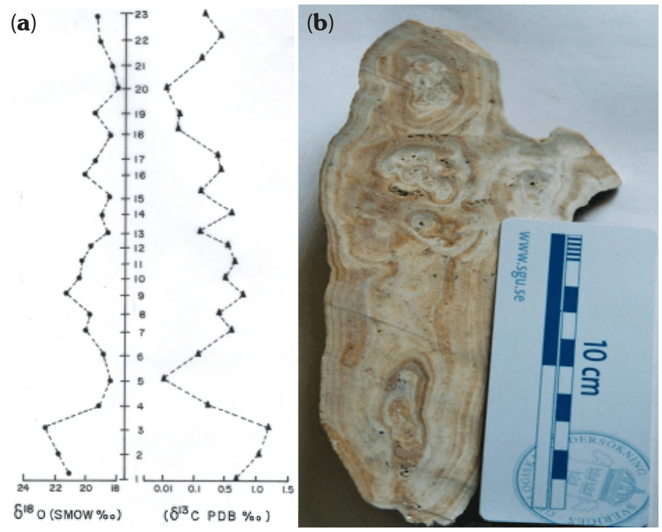


Fig.8. (**a**) Carbon and oxygen isotope ratio variation in the Speleothem from Meghalaya. (**b**) Polished slab of the stalagmite from the Mawsmai cave, Cherrapunji, Meghalaya showing alternating dark and light laminations indicating seasonal growth pattern.

Patsio paleolake: Field observations and lithological details of a paleolake deposit situated near the village Patsio revealed that the Bhaga River originating from the Bara Lacha Pass was dammed by the terminal moraine due to rapid glacial recession. The trench lithology exhibiting sharp lithological contact between the basal fluvial sediments and overlying glacial lake deposit suggests sudden damming of the river and subsequent very slow accumulation of lacustrine sediments. This lake deposit (~ 1.4 m thick) was trenched and sampled for climate proxies and chronology (TL/OSL dates). Magnetic susceptibility data indicate at least two major climatic events (around 73 and 30 cm depths) occurred during the deposition of this profile.

Hanley Wet land: An extensive wet land / marshy ground (>50 km) is found between Hanley and Chushul. The over-bank meadows developed along the meandering channel are the excellent repositories of Holocene climate records. Two sites near the Hanley were trenched and sampled at centimeter intervals for climate proxy records. Dating of samples and laboratory data analysis is awaited.

Dayara Peat: The interpretation of multi-parameter climate data retrieved from the Dayara peat profile (upper Bhagirathi Valley) was completed. The manuscript is at the final stage of communication.

2.6 Evolution of late Quaternary Deposits in the Dun valleys, sub-Himalaya: implication for climate and tectonics

(Suresh N. and Rohtash Kumar)

Late Quaternary stratigraphic successions in the Soan Dun (Fig. 9), northwest Sub-Himalaya, were studied to understand the evolution of landforms. The landforms are in the form of alluvial fans and fluvial deposits, but the alluvial fan deposits are dominant and exposed along the axis of the valley whereas fluvial deposits occur on the paleo-gorge in the detached Siwalik Hills (Fig. 9). The alluvial fans are aligned transverse to the valley axis, with their apexes at the foot of the Tertiary mountains or detached Siwalik Hills and their toes terminating at the axial river. A series of alluvial fans were deposited between Talwara in the west and Nangal in the east. Studies were carried out to document the Quaternary stratigraphic succession and associated lithofacies assemblage. The alluvial fan litho- stratigraphic successions (10 to 25 m thick) are dominated by sand-mud litho-units with rare occurrence of gravels. Detailed litho stratigraphic study was carried out on two alluvial fans – the Amb Fan from the northwestern and Barera Fan from the southeastern part of the dun (Figs. 10 and 11). The Barera Fan sequence is deposited in front of the anticlinally folded Upper Siwalik Formation whereas the Amb Fan sequence is deposited in front of the upfaulted Middle Siwalik Formation. On the other hand, thick fluvial succession (10-45 m thick) is observed in the paleo-gorge in the detached Siwalik hills. These fluvial successions are dominated by gravel and sandy facies (Fig. 12) suggesting its deposition by a major river. These fans and the fluvial deposits have been subsequently entrenched by streams and the surfaces are cut off from any sedimentation.

Based on quartz optically stimulated luminescence (OSL) dating, the alluvial fans are classified into older fan (36-29 ka B.P.; Fig. 11: Barera Fan) and younger fan (23-10 ka B.P.; Fig. 10: Amb Fan) units. The younger fan sequences were exposed in the northwestern part of the dun and the older fan sequences were exposed in the southeastern part of the dun. This indicates the distribution of alluvial fan sequence and associated landforms in the dun have a complex history of Late Quaternary paleoenvironmental changes and landscape evolution.

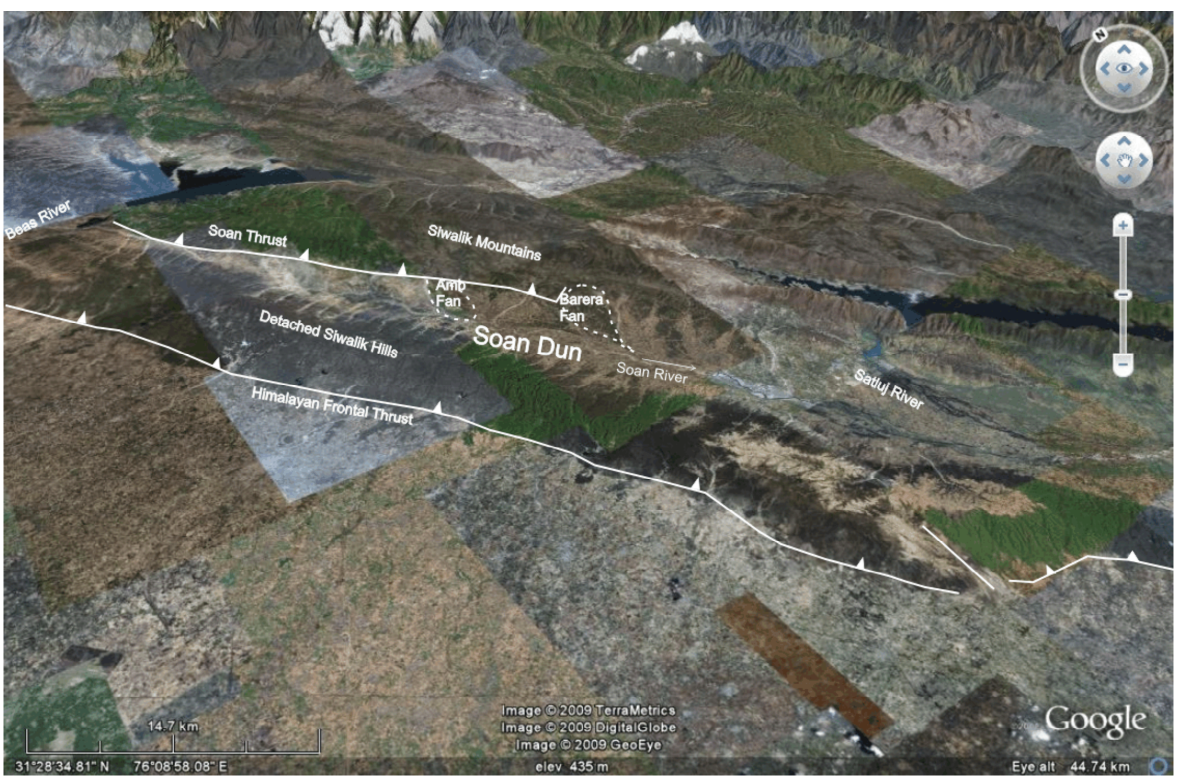


Fig.9. Google image of the Soan Dun bordered by Satluj and Beas rivers in the southeastern and northwestern margin. The position of two distinct fans, Berera and Amb, is marked, lying in the distinctive tectonic setting.

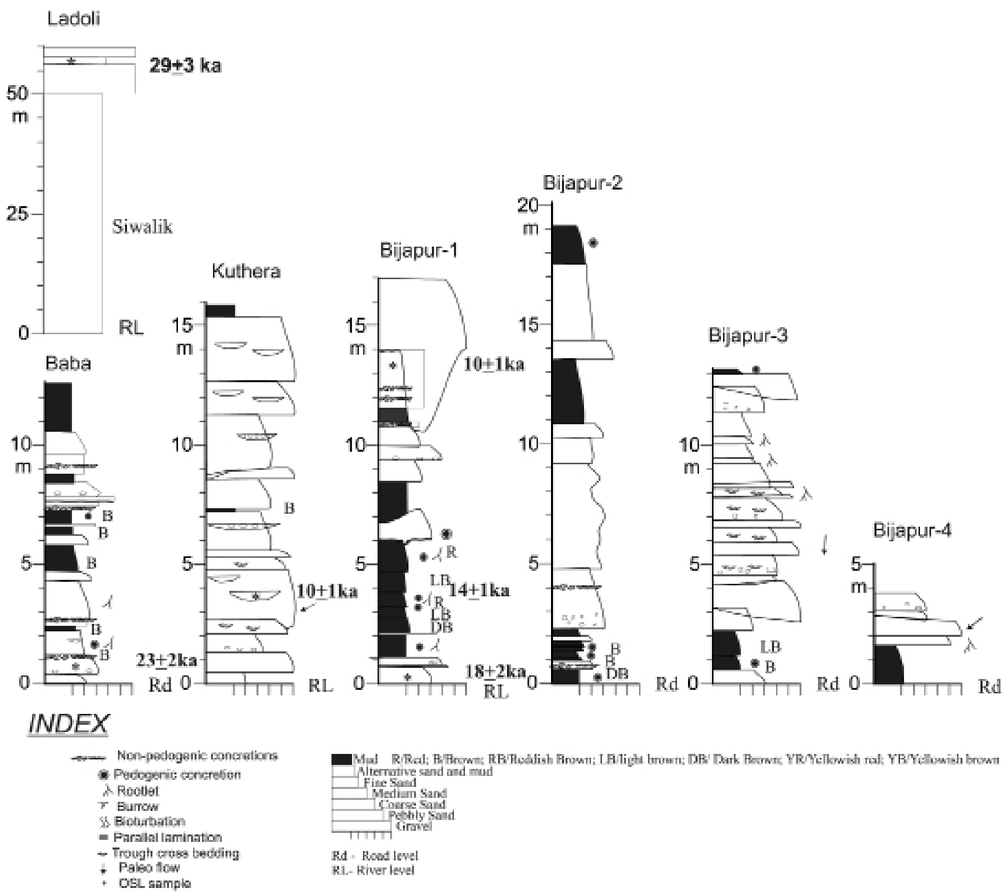


Fig.10. Measured vertical sections with luminescence ages and facies distribution for the Amb Fan in the northwestern part of the Dun. Palaeoflow directions are shown by arrows on the right hand side of the logs.

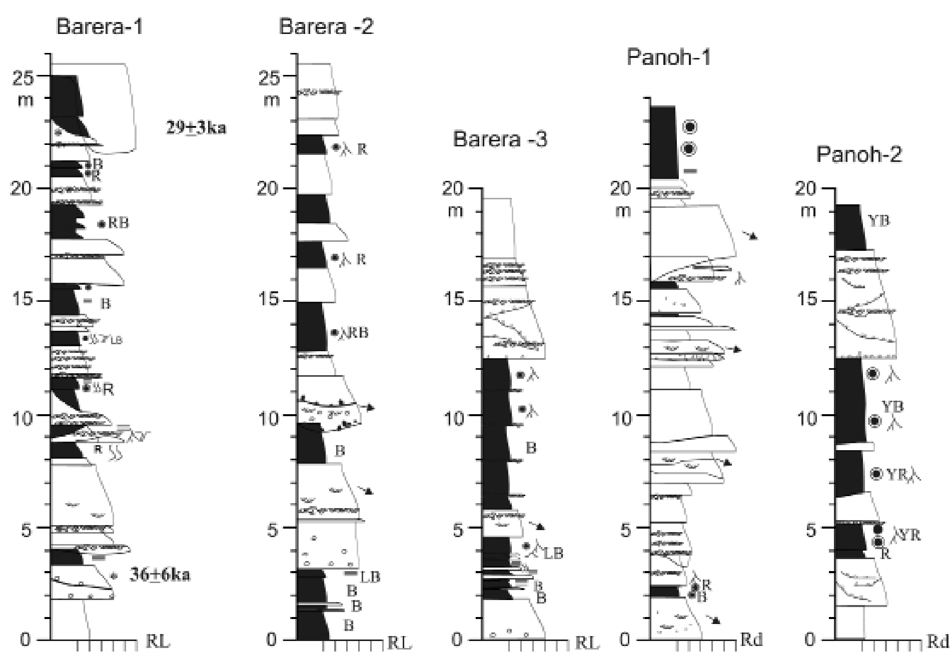


Fig.11. Measured vertical sections with luminescence ages and facies distribution for the Barera Fan in the southeastern part of the Dun. Palaeoflow directions are shown by arrows on the right hand side of the logs. For index see figure 10.

PROGRESS IN RESEARCH PROJECTS

Fig.12. Field photograph showing entrenched fluvial sedimentary sequence, dominated by gravel and sandy facies in the paleo gorge, detached Siwalik hills.

The alluvial fan sequences are deposited under variable tectonic setting with in the Soan Dun: the younger fans are observed in front of upfaulted Siwalik mountain range and have a thrusted contact with the overlying Siwalik rocks and the older fans are deposited in front of anticlinally folded Siwalik mountain range and have un-conformable contact with the underlying Siwalik rocks. The termination of sedimentation in the older fan and continuous sedimentation in the younger fan sequences reveal creation of accommodation space in the northwestern part of the dun. Moreover in the northwestern margin of the Dun, the fan succession is over thrust by Middle Siwalik Formation along Soan Thrust. The OSL ages of older and younger fans suggests that sedimentation ceased in the southeastern part of the dun around 29 ka B.P. where as in the northwestern part sedimentation continued till 10 ka. B.P. Moreover, the OSL age obtained from a sample from the top of the late Quaternary sedimentary sequence overlain the Middle Siwalik rocks from the hanging wall of Soan Thrust gives an age of 29 ka B.P (Fig. 10; Ladoli section). This suggests that the late Quaternary sedimentary succession was displaced due to the activity of Soan Thrust after 29 ka B.P. which also resulted in the creation of accommodation space in the northwestern part of the dun. The termination phase of sedimentation in the older and younger alluvial fans have occurred in the reported increased monsoon phases and can be correlated to variation in climate change which exerts a profound control on fluvial transport processes and hence on landscape development.

2.7 Tectono-climatic studies in Quaternary sediments along the Eastern Syntaxial Bend, Arunachal Pradesh

(D.K. Misra and Pradeep Srivastava)

Geological investigation reveals that the Siang River section in the NE India cuts through the Proterozoic to Cenozoic rocks, which occur in the form of eight distinct thrust bound litho-tectonic units. From SW to NE, in ascending structural order they are: Siwalik Group, Gondwana Group, Yinkiong Group, Miri Group, Bomdila Group, Sela Group, Tidding Formation and Lohit Plutonic Complex. Extensive field studies coupled with interpretation of topographic maps resulted in the identification and delineation of a large number of NNW to WNW-SSE to ESE, N-S, NNE to NE-SSW to SW and E-W trending active faults which post-date the boundary thrusts and shear zones. Recent movements on the faults have caused not only pronounced deflection of rivers and streams but also formed loops and present-day ponding. Movements along faults are also responsible for the abrupt rise of mountain front, occurrence of a planar scarp and triangular facets devoid of gullies or with a few straight furrows, huge landslides, and debris fan, abrupt narrowing down of wide meandering rivers and uplifted fluvial terraces. The Luminescence dating of the sediments collected from the terraces of Siyom at Along, Wak and Pangin indicated that the sedimentation and river aggradation in the Siyom Valley took place between 13-5 ka and river incised after 5 ka in response of tectonic uplift in the region. The upstream movement of the confluence of Siang and Siyom also took place at <7 ka. The Mid-Late Holocene saw the formation of younger terraces in the valley. In Siang valley, samples have been collected from several locations between Tuting and Pasighat.

2.8 Cenozoic Fluvial Deposits in Himalaya between Ravi and Ganga Rivers: Interaction of Tectonic and Climate

(Rohtash Kumar and Suresh N.)

Reversal magneto-stratigraphically constrained Ranital-Kangra section of the Kangra sub-basin, north of Jawalamukhi Thrust, shows exceptionally thick floodplain facies at ((I) between 480-620 m (10 - 9.85 Ma); (II) 790-850 m (9.35 to 9.25 Ma) and (III) 1680-1720 m (7.14 - 7.02 Ma) stratigraphic intervals. These floodplain deposits include crevasse-splay, levee, fine- to very fine-grained, 0.5 to 1 m thick buff and grey ribbon sandstone beds and overbank paleosol bound mudstone (Fig.13) and represent extreme precipitation, intermediate and extreme arid phase respectively. These are bounded by thick multistoried sandstone bodies representing major trunk braided stream deposits. Though floodplain deposits dominant by overbank mudstone but punctuated by small channel deposits. Overbank mudstone shows pedogenic alteration with developments of 5 to 8 cm thick pedond (Fig. 13C), and calcareous concretions (Fig. 13D). Grain-size analysis reveals increase clay content in the pedogenic horizons suggest in-situ break down of phylosilicate minerals confirm by high percentage of Al2O3.

Between 480-620 m stratigraphic interval, smectite clay mineralogy is almost absent but present in the under- and overlying sandstones. The other two floodplain deposits (between 790-850 m and 1680-1720 m stratigraphic interval) have abundant smectite. This reveals that lower floodplain sedimentation is govern by piedmont drainage which was originating from Lower Tertiary mountain front, however, upper two floodplains was deposited during high flooding events of the main braided stream.

These three thick floodplain deposits, bounded by trunk braided river deposits, is indicative of increase accommodation space in response to tectonic or climate. The sedimentation in the Kangra sub-basin primarily took place by lateral migrating perennial braided streams flowing along the basin axis toward southwest. All three sets of floodplain deposits reflect semi-humid to semi-arid climatic conditions with change in major channel position during aggradation on the floodplain. Therefore enhance accommodation space is not related to climate but controlled by tectonic pulsation along basin margin. Three hypotheses forwarded for these floodplains: (1) incision in response to change in geomorphic base-level; (2) avulsion and (3) change in channel pattern from braided to anastomosing river. Field data coupled with lab data reveals that lower floodplain developed in response to river incision during high discharge and remaining two are in response to frequent avulsion and anastomosing in response to increase accommodation space during isostatic adjustment.

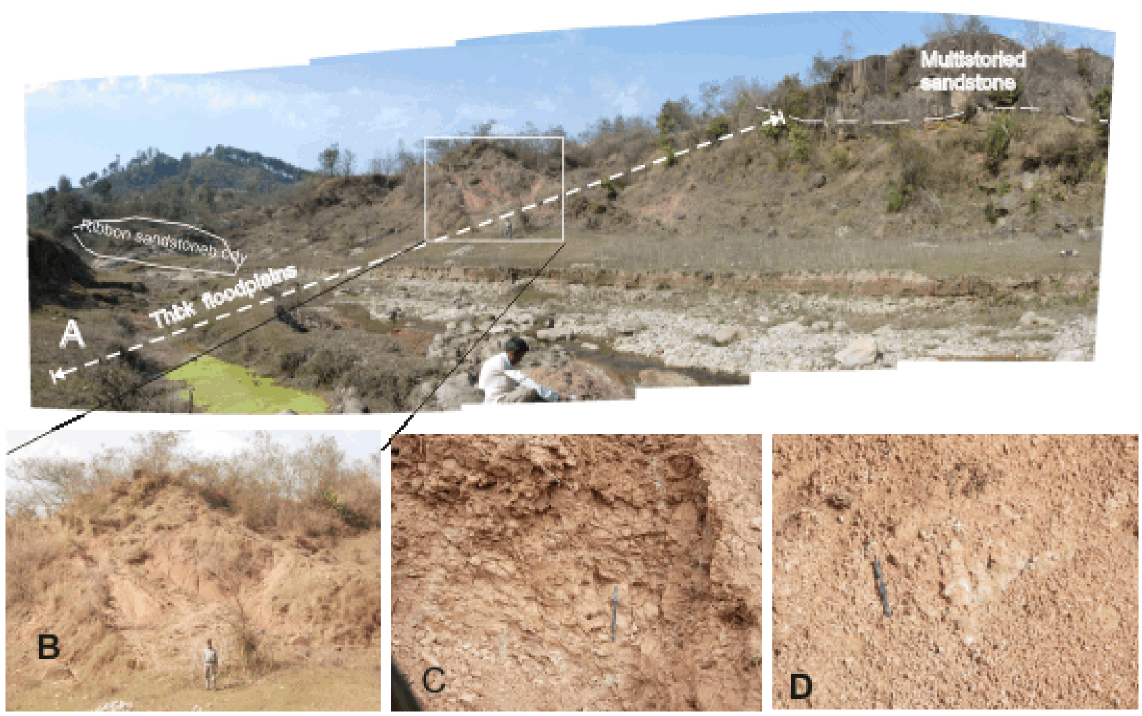


Fig.13. (A) Thick flood plain deposits, bounded by multistoried sandstone in the Ranital-Kangra section between 480 - 520 m stratigraphic interval, of the Kangra sub-basin. The flood plain succession comprises overbank paleosol bounded mudstone and ribbon sandstone bodies. **(B)** Red mudstone having well developed pedons and pedogenic calcretes. **(C)** Blocky pedons (5 to 8 cm size) in the lower part of B-horizon of the paleosol profile. **(D)** Pedogenic calcretes in the paleosol profile.

PROGRESS IN RESEARCH PROJECTS

2.9 Geochemistry and isotopic studies of source rocks and riverine phases in the Garhwal Himalaya: Implications for weathering and erosion

(S.K. Rai, H.K. Sachan, R. Islam and S.K. Ghosh)

The Himalaya is one of the major geomorphic features on the Earth's surface and undergoing intense denudation producing different landforms such as high rise peaks, deep gorges, flood plains and delta etc. On a global context, physical erosion and its spatial variability in the Himalaya has significance in regional tectonics and sediment supply to the plains and different basins. Tectonics, Lithology and the stream power (rainfall and relief) are the important parameters that control the rate of erosion in the mountainous terrains; however, their relative roles are debated. Therefore it is important to trace the sources of sediments and distribution of erosion intensities in the Himalayan drainage of the Ganga to understand erosion-climate-tectonics relationship in the region.

This work involves the geochemical and isotopic studies ($^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ measured at PRL, Ahmedabad) of the riverine phases (water and sediments) and the source rocks from the Indo-Ganga system. This work puts constrains on the sources of sediments and erosion over individual sub-basin. Studies completed on the Ganga system reveal that more than two thirds of the sediments of the Ganga plain are derived from the Higher Himalaya (HH) and its Gandak sub-basin dictates the sedimentary budget contributing about half of the bank sediments at Rajmahal. The erosion rates estimated in the Himalayan drainage of the different sub-basins of the Ganga range from 0.5±0.25 to 6±3 mm/y with the highest in the Gandak basin. High erosion rates in the Gandak sub basin is attributable to intense rainfall in its head water basins characterized by high relief. Results of this study along with those available in literature, suggest that, in general, the erosion rates in the HH are higher compared to other regions of the Himalaya, however even within the HH, there are hotspots where physical erosion is very rapid, 6 to 14 mm/y. These regions are the gorges of the Brahmaputra, the Indus and the Gandak. These hotspots undergo mechanical erosion quite disproportionate to their aerial coverage and contribute ~8% of sediment flux from rivers. Such focused erosion may also be contributing to regional tectonics. The high peaks of the Namche Barwa and Gyala Peri, Annapurna and Dhaulagiri and Nanga Parbat can arise due to isostatic rebound resulting from focused erosion.

Part of this project is underway to study the provenance characteristics, budgeting of sediments and erosion rates in the Himalayan sub-basin (Ganga: Bhilangana, Bhagirathi, Alaknanda, Mandakini, Pindar, Nandakini, Dhauli, Birahi & Saraswati; Indus: Tangtse, Shyok, Muglib, Nubra, Zanskar & Upsi) of the Ganga and Indus in the North West Himalaya. Such information is expected to be utilized to understand the interaction among erosion, climate and tectonics in this active mountainous regime.

MMP 3 : Biostratigraphy & Biodiversity-Environment linkage

3.1 Evolution - Radiation and Extinction Bioevents in the Cambrian – Ordovician successions of the Zanskar – Spiti Himalaya, their relation to Global Event Stratigraphy

(S.K. Parcha)

Fieldwork was carried out in the Parahio, Pin, Chandra Tal and in the Baralacha sections of the Spiti valley, and data on sedimentary structures and fauna assemblages was collected from the different horizons. The Cambrian succession in the Zanskar basin of Tethys Himalaya contains diverse assemblage of ichnofossils. The ichnofossils are stratigraphically important as they occur below the trilobite body fossils and are useful to define the basal part of the Cambrian. The ichnofossil assemblage reported from the Zanskar basin of Ladakh Himalaya is significant to demarcate the Early Cambrian age, due to lack of other faunal elements so far. The body fossils of trilobites recorded from the overlying beds indicates the earliest part of the Middle Cambrian age. Sixteen ichnogenera identified. The ichnogenera reported so far from this region belongs mostly to the traces of arthropod origin. The ichnofauna ranges in age from Lower Cambrian to late part of the Middle Cambrian. The distribution of ichnofossils shows that the ichnofossils are predominately less in occurrence in the sections where trilobites dominate. In absence of trilobites these ichnofossils are key element to decipher the stratigraphy of the Lower.

Cambrian successions in the Zanskar region

The Cambrian successions of the Spiti basin contains well preserved ichnofossils as well as trilobite assemblages. The ichnofossil assemblage reported from the Debsakhad

Member as well as from Parahio Member of Kunzum La Formation includes the nineteen ichnogenera. The ichnofossils reported from this section provide evidence regarding the development patterns during the early phase of life. The present assemblages of ichnofossil are very much significant in assigning the age of the Debsakhad Member. The abundance of ichnofossils in sandstone, siltstone, shale and rarely in quartzite, indicates important change in the benthic conditions. The change in the fossil assemblages is equally noticeable in the Parahio Member of the Kunzum La Formation. The body fossils in the basal part of Parahio Member indicate an early Middle Cambrian age. Due to the scantiness of body fossil, as well as microbiota in the lowermost beds of the Debsakhad Member, the Precambrian – Cambrian boundary cannot be demarcated. It indicates that the boundary could be below the ichnofossil horizon.

The Cambrian biostratigraphy of the Tethyan Himalayan regions in general and Middle Cambrian in particular based on the trilobite faunal assemblages. In the Spiti basin trilobites were reported from the Parahio section as well as from the Pin section. The trilobite fauna preserved in shale, sandstone and in limestone. The Middle Cambrian trilobite bearing limestone beds represent thin transgressive systems tract deposits developed over marine flooding surface. New faunal collections were recovered from the shale as well as from the Carbonate beds. The collection of well-preserved eodiscidae fauna from the Parahio section seems very much useful to understand the developmental stages of the eodiscidae. At present, the morphometric analysis of two genera of Pagetia is going on to understand their growth stages and ontogenic developments.

3.2 Palaeobiology of the Neoproterozoic - Early Cambrian sequence of inner and Outer Carbonate Belt with reference to its implications for evolution of life and global significance

(Meera Tiwari)

Worldwide documentation of microscopic fossils during Proterozoic has enormously improved understanding of early complex life. The organisms during this time frame were mostly represented by Organic walled microfossils including cyanobacteria, acritarch and early metazoans and metaphytes. From Gangolihat Dolomite two distinct evolutionary components are represented by the prokaryotic cyanobacterial remains and eukaryotic acritarchs and sponge spicules. Among the non- septate cyanobacterial filaments six species of Siphonophycus were recognized. These are Siphonophycus septatum, S. typicum, S. robustum, S. capitaneum, S. kestron and S. punctatum. Septate filaments identified as Gunflintia are represented by three species; these are Gunflintia minuta; Gunflintia grandis and Gunflintia barghoornii. The septate filaments are dominated by Oscillatoriopsis. Four species of septate filament Oscillatoriopsis are- Oscillatoriopsis obtusa, O. media, O. cuboides and O. sp. with bead like appearance is also present in large numbers. Few specimens of Nostocomorpha and Chlorogloeaopsis contexta are also present. The coiled filaments are represented by Obruchevella parvassima. Among the Coccoidal forms, Sphaerophycus parvum and Myxococcoides minor is quite common in the assemblage. Acritarchs are represented by Leiosphaeridia crassa, Trachyhystrichosphaera vidalii, T. sp., Micrhystridium pallidum and Cymatiosphaera minuta and Leiosphaeridia. Zang (1995) suggested that the assemblage represented by Trachyhystrichosphaera vidalii- T. aimika- Cymatiosphaera kullingii has been used for global correlation in the early Neoproterozoic. Sponge spicules are present in the Utrora and Chandag sections. These are found as either fused spicules forming rigid skeleton or scattered spicules forming non-rigid skeleton within the Mesohyl. In the present collection the spicules are all Hexactinellid with few monaxons and are found as dense spicular accumulation within the rock.

Major environmental changes occur during Neoproterozoic (1000 – 542 Ma). Frequent glaciation, tectonic upheaval and enormous storage of organic matter on a global scale resulted in the evolution of metazoans and biomineralization. It was also pointed out that microfossils document a major transition in the biological world near the Mesoproterozoic-Neoproterozoic (Mid Riphean –Upper Riphean) boundary (Knoll & Sergeev, 1995; Sergeev et al. 1997). During the Neoproterozoic-Cambrian transition, sponges are proved to be a key to understand early animal evolution (Muller, 2001; Yuan et al. 2002). Due to their minute size and simple morphology, sponge spicules were unnoticed in the Neoproterozoic. Recently, Mc Caffrey et al. (1994) have reported sponge biomarkers in lower Neoproterozoic rocks and advocated the presence of stem-group sponges. Li et al. (1998) reported an assemblage of monaxons sponge with well preserved soft tissue from Doushantuo phosphate deposit of south China, and considered them to be pre-Ediacarian and Early Vendian (~580ma) in age. From southwestern

Mongolia Late Ediacarian (543 – 549 Ma) hexactinellid sponge spicules were reported (Brasier et al. 1997). The Neoproterozoic Ediacara fauna of south Australia, some disk- like bodies interpreted as hexactinellid spicular impression were documented (Gehling & Rigby, 1996) and were reinterpreted as stem- group sponge (Mehl 1998), at the same time the interpretation was found to be controversial (Li et al. 1998).

Radiometrically, the age of the Gangolihat Dolomite (Deoban Formation) is poorly constrained due to inconsistency of isotopic data; therefore no definite age could be established. Sarkar et al. (2000) obtained model Pb-Pb age of 1550- 1700 Ma of galena hosted by silicified carbonate rocks present in Deoban Formation exposed in Bageshwar with a view that the model ages of ore deposit is semiquantitative and a more accurate age of host rock need to be confirmed through more analysis. Earlier, Raha et al. (1978) had suggested 967 Ma for Jammu Limestone on the basis of Pb –isotopic age of galena. However, recently, an age of 839±139 Ma was depicted on the basis of Re- Os isochron from black shale of homotaxial Shali Formation exposed in Himachal Lesser Himalaya by Singh et al. (1999). On the other hand, Deoban Formation has contributed significantly to the microbial record in recent years. A rich and diversified microbiota is described from Deoban Formation and the geological age was confined to Neoproterozoic. The fossil assemblage is dominated by long ranging hypobradytelic cyanobacteria, the geological age of Gangolihat Dolomite may be confined to the Terminal Neoproterozoic (Ediacaran) on the basis of significant association of acritarchs and sponge spicules within the assemblage. Till date, such association of acritarchs and sponge spicules is unknown from Riphean age worldwide. Besides, presence of phosphorite and chert within the Gangolihat Dolomite thus provides an excellent source for understanding the early evolution of animal life.

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

(R. J. Azmi)

The Sataun and Deoban Limestone Formations of the "Inner Carbonate Belt", which are generally considered by most of the Himalayan geologists to be of Early-Middle Riphean or Mesoproterozoic age (~1200-1400 Ma), have yielded additional potential Lower Cambrian SSF assemblage comprising protoconodonts, Platysolenites and arenaceous foraminifera, hyolithelminths and Sabellidites tubes, animal embryos and abundant calcareous skeletal

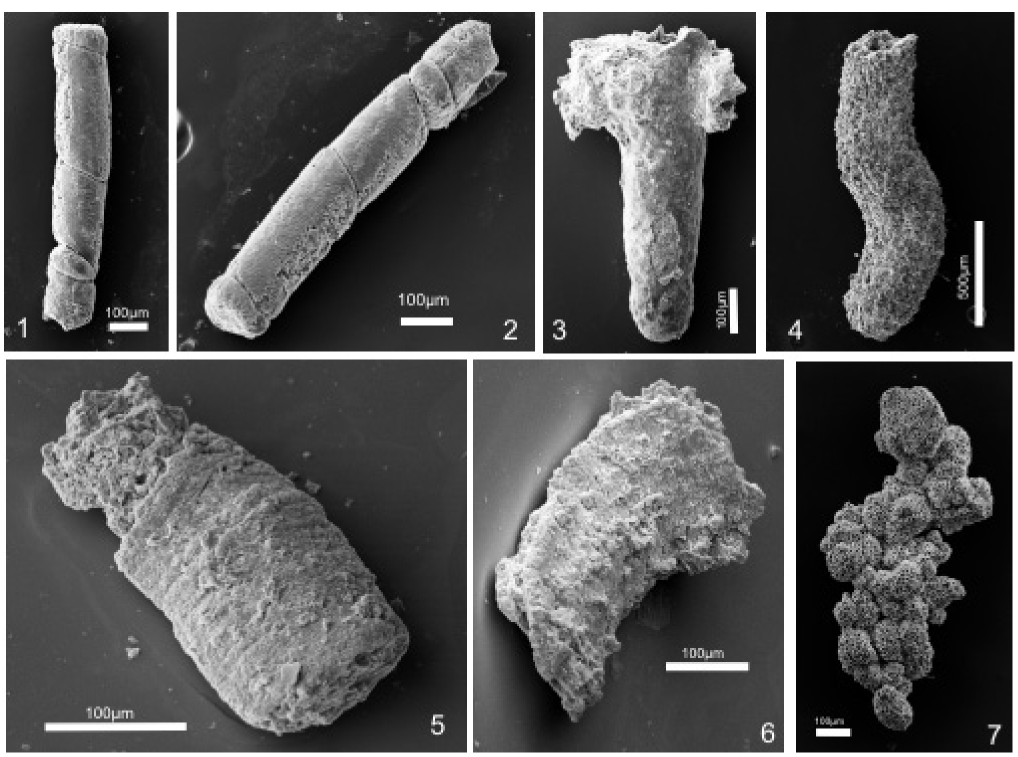


Fig.14a. Cambrian small shelly fossils and calcareous algae from the type localities of Deoban (**1-4**) and Sataun Limestone Formations (**5-7**), Lesser Himalaya.

algae (Fig. 14a**)**. This additional fossil evidence thus further confirms the validity of the major chronostratigraphic revision and for the new correlation scheme for the Lesser Himalayan formations, earlier suggested by Azmi and Paul (2004, Current Science, v. 86, no. 12, pp. 1653-1660). All these lead to the natural corollary that the "Inner Carbonate Belt" is chronostratigraphically equivalent to the Krol Belt or the "Outer Carbonate Belt", and therefore, both are of Vendian-Early Cambrian age. This stratigraphic contribution would seemingly put end of several decades of prevailing dilemma in the geology of the Lesser Himalaya which can now be satisfactorily utilized in balancing the Himalayan tectono-stratigraphic cross sections and for correct estimation of the amount of shortening in the Lesser Himalayan fold-thrust belt.

From the Lower Vindhyan, besides the typical P€-€ boundary SSFs in the Patwadh Section of Son Valley and delicately preserved abundant phosphatized animal embryos in the Tirohan Dolomite of Chitrakoot, a significant Ediacaran fossil jellyfish (Scyphozoa) (Fig. 14 b) has been recovered from the lower part of the Rohtas Formation of the Badanpur Limestone Quarry section, near Maihar, M.P. This is an important megascopic fossil finding suggesting maximum age to the Rohtas Formation as Ediacaran (<530 Ma). Our view that the Lower Vindhyans are rather much younger, as Vendian to Early Cambrian in age, has thus gained much ground and is certainly against the Paleoproterozoic age to it which is exclusively based on the geochronological data.

The regional perspective of the above biostratigraphic results is that all major carbonate successions of the Lesser Himalaya and the Vindhyans and their equivalents in the northern peninsula are contemporaneous which belong to a single shallow marine platform that formed a part of the "Greater Vindhyan Basin". All these were deposited with over a billion-year hiatus on the highly deformed and peneplained Paleoproterozoic basement during the Vendian – early Cambrian transgression from the main Paleotethys sea.

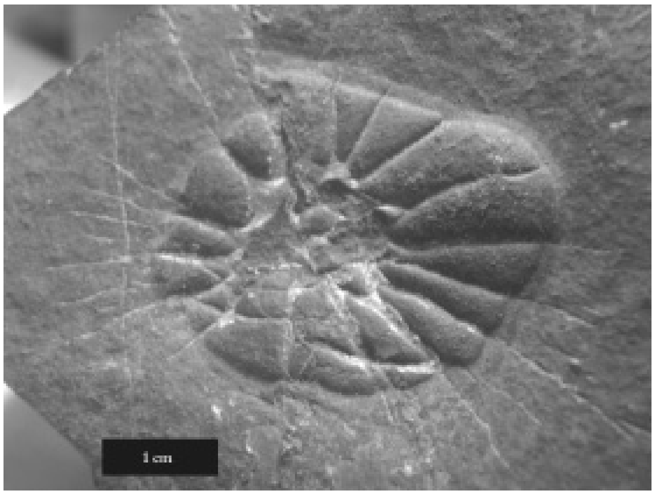


Fig.14b. Ediacaran fossil jellyfish (Scyphozoa) from the Lower Vindhyan Rohtas Formation of Badanpur Limestone Quarry, near Maihar, Madhya Pradesh.

Yet another significant development is the independent confirmation of the "Cambrian" fossils from the Lower Vindhyan (Bengtson et al., 2009, PNAS), Interestingly, the fossil yielding lithology (phosphorite intraclasts of Tirohan Dolomite of Chitrakoot) yielded an age of 1650 ± 89 Ma (Pb/Pb regression age). These authors are of the opinion that the "shelly" biota discovered by Azmi and his team (during 1998-2008) gives new insight into the nature of the Paleoproterozoic biosphere. However, the Paleoproterozoic age of the Lower Vindhyan is a complete misfit with the regional geology, because 1800-1600 Ma is the age of its folded basement rocks (Bijawar and Delhi Supergroups and the Hindoli Group) which were involved in the orogenic movements prior to the Vindhyan sedimentation. In any case, Vindhyans have to be far younger than the Paleoproterozoic. Our view of Vendian – early Cambrian age for the Vindhyans is consistent with the regional geology and stratigraphy of the northern Indian Peninsula and the Himalaya.

3.4 Terrestrial and aquatic biota from the nonmarine post – Subathu horizons of the Kangra Valley, Himachal Pradesh

(B.N. Tiwari)

Fossils reveal early Miocene beginning of the antecedent river system: On the basis of faunal remains, in early Miocene faunas from India, found associated with cyprinid (=primary freshwater fish) remains that was native to Asia, we can date the beginning of riverine connection joining Himalayan region with the Arabian Sea coast in Kutch. In the backdrop of pertinent studies, cyprinid fishes in Kutch fauna reveal us early Miocene antiquity of the lost Saraswati River. It was most likely so as workers in many disciplines e.g. Archaeologists, geologists, geophysicists, etc have independent rationale to convince that only a few, say 4 to 6, thousand years ago there was a mighty river named Saraswati; it drained the now perennial river-starved terrain extending from south Haryana, Rajasthan and further south up to Kutch in Gujarat. With this perspective critical evidence of primary fresh water fish taxon of Asian origin in fossil assemblage of central Kutch and also reported from coeval levels of Dharmsala (H P) and Ladakh region in the Himalaya is clue to early Miocene beginning of now the lost Saraswati River.

Discovery of fossiliferous epikarst breccias in the Himalaya, Northern India

In January 2009 in the Lesser Himalayan terrain near Arki, in Solan District of the Himachal Pradesh, we noted the presence of typical superficial karst geomorphology in a vast Proterozoic massif of limestone, mapped as Basantpur Formation of Simla Group. Examination of road cuts through this limestone revealed the presence of characteristic superficial karst features including caves, galleries, dissolution fissures, speleothem drapery, stalagmites and masses of epikarst breccia. Many of the breccia exposures examined yielded abundant fossil terrestrial gastropods that are likely of Pleistocene age. We aim to record the presence of fossiliferous epikarst and spelean deposits in a limestone massif in Lesser Himalaya towards northwest of Arki (near Subathu) in Himachal Pradesh, India. This is important because till now few fossiliferous karst deposits are known in the Indian Subcontinent, but among these are the richly endowed Karnool caves in peninsular India. Further, although caves have been noted in the Himalaya, many of which are the sites of shrines, no previous reports of epikarst or spelean breccias have been made.

Miocene terrestrial mammals from Circum-Indian Ocean: Implications for geochronology, biogeography, eustacy and Himalayan orogenesis

An integrated view of migratory elements in the circum Indian Ocean Miocene mammal faunas is important in assessing the temporal relations of these faunas and has implications for biogeography, eustacy and, most interestingly, for the Himalayan orogeny. Early/middle Miocene terrestrial mammals from the Indian localities in western Himalaya and Kutch are now better known and the presence of two proboscidean taxa (Deinotheriidae, Gomphotheriidae) in the assemblages, correlated biochronologically to the latest Burdigalian - basal Langhian, documents the basal Middle Miocene. Out-of-Africa dispersal event, suggesting that the assemblage post-dates 17.5 Ma. We estimate an age of 16.5+1 Ma for these fossils. The Indian mammal faunas provide evidence for early Miocene faunal exchanges between Afro-Arabia and the Indian subcontinent, including anthracotheres, suids, tragulids and possibly giraffids.

The latest fossil collections assume significance in view of the hitherto poorly known nature of the earliest Neogene fossil faunas from the Murree, Dagshai/Kasauli, and Dharmsala beds in the NW Outer Himalaya, and the Kargil Formation of Ladakh in the NW Trans-Himalaya and Kutch. The Kutch deposits, attributed to the Khari Nadi Formation, are distal clastic deposits derived ultimately from the rising Himalaya and deposited in Kutch during a high sea stand, probably the C5 Marine Transgression dated to ca 16.5 Ma. They therefore provide evidence not only of aspects of Himalayan orogeny but also of eustacy. Study of fossiliferous successions in the circum-Indian Ocean tract reveals reflection of the interplay between global tectonics and eustatic history during the early Neogene.

Cenozoic terrestrial faunal assemblages of the Himalaya in the context of biotic dispersal

Ladakh Molasse Group is the only known sedimentary sequence in the India-Asia collision zone (Indus Suture Zone) of NW Himalaya that yields terrestrial faunal remains. However, our knowledge of these faunas from a few fossiliferous sections in the molasse sequence (Kargil, Basgo, Nyoma and Liyan) offers us to investigate the question of subaerial connections and faunal exchanges between the contemporaneous terrestrial communities of the Indian and Asian landmasses in the context of out-of-India or in-to-India hypothesis.

Larger and smaller mammals from molasse sections around Kargil (Akchamal and Baru localities) indicate that nascent Oligo-Miocene terrestrial habitats with basic biomass in the basin attracted primary consumers from contiguous areas in sutured India+Asia Cenozoic landmass. However, record of a rhinocerotoid, a large mammal, from the Liyan section in eastern Ladakh extends the beginnings of terrestrial environments back in time, to the Eocene/Oligocene transition. This find is apparently consistent with the new estimates of the timing of collision (~34 Ma) between the Indian subcontinent and the Tibetan block.

Our latest endeavors tell that freshwater faunal remains are better than terrestrial mammals in providing insight into the dynamics of biotic dispersal. Reach of inland water channels of colliding continent to the suture zone and then integration of substantial south Tibetan catchment with the Indus/Sarswati river system/s has a bearing on inter-plate biotic connectivity. This is manifested in the record of Cyprinidae, a primary freshwater teleost taxon of Asian origin, in the Eocene/Oligocene horizons of Liyan molassic sequence and in early Miocene Kargil and other broadly coeval Indian assemblages in Dharmsala (Himachal Pradesh) and Kutch (Gujarat). Chronology of their presence reveals antiquity of geomorphic-cum-biotic event and subsequent river reorganizations and attendant fish dispersals respectively. This new insight gained from the study of mid-Cenozoic freshwater cyprinids adds an interesting dimension to our understanding of biotic connectivity in the collision zone. Freshwater ostracods from the Ladakh Molasse too reveal that the ISZ was a melting pot of the faunal communities from the sutured land masses. Further detailed palaeontological investigations of the molasse sequences will bring to fore their refined biogeographic perspective.

Field Work: Investigated Mangarh Fort Section of Siwalik Group in the vicinity of Dera Gopipur in Kangra Valley of Himachal Pradesh with Prof Martin Pickford, France from Jan 4 to Jan 12, 2009; it was planned to ascertain Sivapithecus locality in the region. While getting back from the field located epikarst breccia in the Basantpur Limestone massif and discovered fossils of land-snails in these exposures of least understood lithology. Earlier to it one day field trip in Nov, 2008 with Dr Frank Kohler, Australia and Ms Ansuya Bhandari in Mohand area besides visiting nearby places namely Saloni River, Aasan Barrage etc.

Laboratory Work: Prolonged interaction with Martin Pickford in field gave me the benefit of knowing latest technique for pulverizing stubborn matrix with calcium carbonate cement with glacial acetic acid, a common regent used in our labs. Dried specimens are soaked in undiluted acid for 3-4 days in covered container and then specimens are shifted to water filled container to see amazing successful maceration. Many microfossils do get pulverized but still many remains to be stored and studied from the collected fossiliferous rock sample. This technique has been found very effective. Numerous isolated fish teeth, chara gyragonites and a few ostracods, isolated snake vertebrae, mammalian enamel fragments, seeds, etc have been added with the facilities in our vertebrate paleontology laboratory. Using advanced microscopes available in other Lab of the Group besides SEM lab makes microfossil studies easier than ever.

3.5 Biotic, mineralogical and geochemical investigations of Early Tertiary sequences of the NW Himalaya with reference to India-Asia collision

(K. Kumar, N.S. Siddaiah and Kapesa Lokho)

Rhythmically bedded shallow marine cherty limestone/ calcareous shale units of the late Cretaceous-Paleocene Kakara Formation in the Tal Valley area of Uttarakhand were studied to trace the involvement of volcanic component during their deposition. The calcareous shale/ marl beds are relatively thin (~2-10 cm) compared to the cherty-limestone units with a variable thickness of 20 to 60 cm (Fig. 15). The cherty-limestone units consists of 30-40 wt % CaO, 30-35 wt % SiO_2, 0.1-0.2 wt % TiO_2, 0.2-1.4 wt % Al_2O_3, 150 ppm Sr, 20 ppm Zr, and 70 ppm total REE, where as calcareous shale/marl layers have 12-18 wt % CaO, 45-67 wt % SiO_2, 0.4-0.6 wt % TiO_2, 2-4.4 wt % Al_2O_3, 50-70 ppm Sr, 100-460 ppm Zr, and total REE 150-220 ppm.

The chondrite-normalized REE patterns of the whole-rock samples have similar shape with LREE enriched relative to the HREE along with a small negative Eu anomaly. Carbonate fractions have relatively low abundances of REE compared to the whole-rock samples and their chondrite-normalized patterns in general are similar to those of the whole-rock patterns, but show a typical tetrad character indicating the aqueous conditions of the basin waters. The chondrite-normalized REE patterns of the silicate fractions have steep negative slopes for the

Fig.15. Outcrop photograph of bedded cherty limestone and calcareous shale/marl units of the Late Cretaceous-Paleocene Kakara Formation at Bidasini, Tal valley, Uttarakhand.

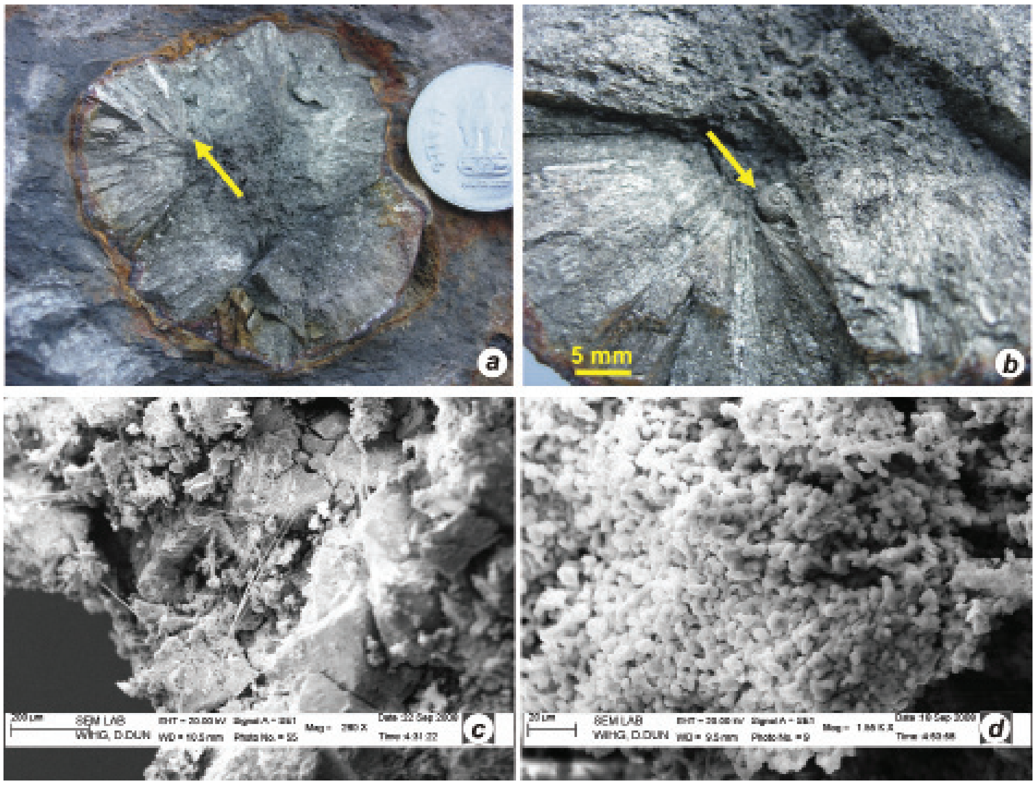


Fig.16. Digital (**a, b**) and SEM (**c, d**) images of the pyrite nodule from the Kakara Formation of type area (Himachal Pradesh) showing biotic nuclei (**a, b**) and filamentous (**c**) and coccoidal forms of pyrite. The coccoidal structures appear to be of microbial affinity.

light REE (LREE) and slightly positive slopes for heavy REE (HREE) along with a minor negative Eu anomaly, which is distinctly different from that of the whole-rock pattern as well as to that of the terrigenous sediment. This pattern is similar to the REE pattern reported for high-silica rhyolites. This suggests the involvement of a volcanogenic component in the genesis of rhythmites in the Kakara Formation.

The study of the Early Eocene vertebrate fauna from the Himalayan and peninsular Indian regions, particularly the terrestrial mammals, their affinities and implications for palaeogeographic reconstructions was continued. The mammal faunal groups that received focus during the year include Primates and Tillodontia. The oldest Primates from India were roughly contemporary with, or perhaps predated, the India-Asia collision. New Early Eocene euprimate fossils (jaws teeth and limb bones) are placed in the new subfamily Asiadapinae, which is most similar to primitive European Cercamoniinae such as Donrussellia and Protoadapis. Asiadapines were small primates in the size range of extant smaller bushbabies. Euprimate postcrania studied include humeri, radii, femora, calcanei, and tali bones, most of which show typical notharctid features and are probably attributable to asiadapines. Morphology of the limb elements indicates that they represent active arboreal quadrupedal primates. Although definitive conclusions are premature, available evidence suggests that the oldest Indian adapoids were derived from western European stock that reached India near the Paleocene-Eocene boundary.

Find of tillodont teeth from the lower Eocene sediments constitutes the oldest record of Tillodontia from India. Comparisons of these teeth to the 20 or so genera of currently known tillodonts indicate that the closest similarity is to the esthonychine Esthonyx, though close relationship to North American Azygonyx or European Plesiesthonyx or Franchaius cannot be ruled out. It is significant that the Indian form shows no particular resemblance or likely close relationship with any of the 14 tillodont genera known from Asia, with the possible exception of Paresthonyx and Basalina. The likelihood that the Indian tillodont is closely allied to a western European or Euramerican taxon provides additional evidence of faunal interchange between the Indian subcontinent and Europe during the early Eocene.

An attempt was made to explore the possibility of occurrence of pyritized microbial fossils within the pyrite nodules from the Late Paleocene Kakara Formation. The pyrite nodules are fairly common in both Kakara as well as Subathu formations particularly in their lower carbonaceous parts, yet these were never investigated for their microbiota. Some nodules were found to contain biotic nuclei such as gastropods. Systematic examination of a few such specimens of nodules under the scanning electron microscope revealed the presence of unique and rare filamentous as well as coccoidal, and crystalline forms of pyrite (Fig. 16). Of these, the coccoidal structures are most likely to be of microbial affinity. Detailed study is in progress.

The osteological characters of a Paleocene fish Taverneichthys bikanericus were restudied with a view to specify its systematic position within the Family Osteoglossidae. Based on snout morphology this fish was placed between genera such as Chanopsis and Phareodus, which possess a primitive snout with a large dermethmoid reaching the frontals and separating the two nasals from each other, and such as Brychaetus, Musperia, Osteoglossum and Scleropages, which exhibit an evolved snout.

Some important fossils currently under study include pristichampsine crocodiles, hyracodontid perissodactyls, and dichobunid artiodactyls from the Paleogene, and charophytes (lime shells as well as plant impressions) and hitherto unidentified vertebrate bones from the Neogene succession.

3.6 Himalayan Paleozoic Trilobites

(S.K. Parcha)

The Paleozoic successions of the Indian part of Himalaya have provided a diverse population of trilobites. This data is available in a large number of publications including the publications from Indian journals. The majority of the Cambrian trilobites described so far from the Himalayan regions seem to be tectonically deformed. Due to difficult terrain, various sections that were not studied in detailed earlier were studied during the recent years by the investigator. It is necessary to consolidate this work and to provide a uniform and co-ordinated picture, including revision and updating of nomenclature. So trilobite fauna described by earlier workers were listed and the status of each genus was updated. Also detailed study of three more genera was completed and the existing data was re-evaluated with additional inputs and the overspliting of the various species within these genera were corrected. The studies show, that in the Lesser Himalayan successions Early Cambrian is well preserved and contains few trilobite genera.

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

(Kapesa Lokho)

Planktonic and benthic foraminifera including uvigerinids are documented from the Upper Bhubhan Formation, exposed at Thingdawl village, Kolasib district, Mizoram. This is the first record of uvigerinids from the Bhubhan Formation of Mizo Hills. Though the foraminiferal assemblage (Fig. 17) is poorly preserved, it contains index fossils useful for precise biochronology of sediments and interpretation of the depositional environment. A total of 10 benthic and 6 planktonic foraminiferal species are described. Among the 10 benthic species, 6 species belong to the genus Uvigerina.

A wide range of views on the age and the paleoenvironment of the Upper Bhubhan Formation were published (Ganguly 1975; 1993; Sinha et al. 1982; Tiwari 2001; Mandaokar 2000; Jauhri et al. 2003; Tiwari et al. 2007; Lokho & Raju 2007). Some of the previous workers considered it to be poorly fossiliferous (Ganguly 1975), others stated to be long ranging and not of much biostratigraphic significance based on bivalves and few foraminifers (Jauhri et al. 2003, Tiwari et al. 2007). Its age was inferred differently by different workers as Miocene (Sinha et al. 1982), Early Miocene (Tiwari 2001), Late Miocene (Mandaokar 2000) and Early to Middle Miocene (Jauhri et al. 2003). A recent report on planktonic foraminiferal data from Thuampui section, Aizawl town, favored an early Middle Miocene (Langhian) age, equivalent to planktonic foraminiferal zones N8-N9 for the Upper Bhubhan Formation of Mizoram (Lokho & Raju 2007). The present work provides a definitive evidence of an early Middle Miocene age for the Upper Bhubhan Formation of Mizoram.

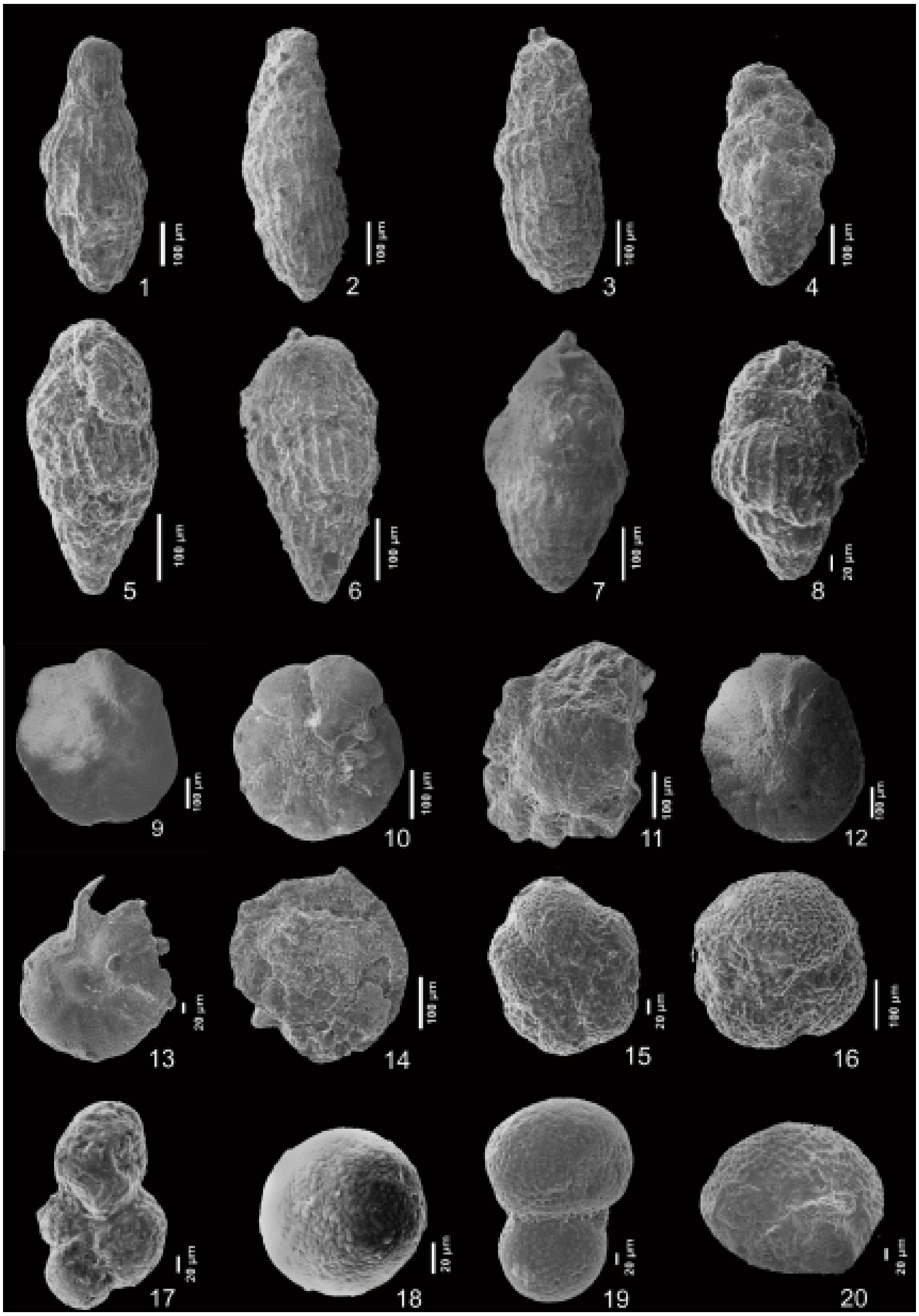


Fig.17. Sem photomicrographs of foraminifera from the Bhubhan Formation, Mizoram NE India. 1. Uvigerina schencki WIMF/A 2201; 2,3.U.subtriata WIMF/A 2202,2203; 4. U.cf.kernensis WIMF/A 2204; 5,6. U.cf.sparicostata WIMF/A 2295, 2206; 7. U.piluta WIMF/A 2207; 8. U.rutila WIMF/A 2208; 9. Ammonia sp. WIMF/A 2209; 10. Ammonia beccarii WIMF/A 2210;11. Ammonia ikebei WIMF/A 211; 12-14. Ammonia umbonata WIMF/A 2212-14; 15. Globorotalia peripheroronda WIMF/A 2215; 16. Globigerinoides bisphericus WIMF/A 2216; 17. Clavetorella cf.sturanii WIMF/A 2217; 18. Orbulina universa WIMF/A 2218; Orbulina bilobata WIMF/A 2219; 20. Praeorbulina glomerosa glomerosa WIMF/A 2220.

Earlier concept of the paleoenvironment for the Upper Bhubhan Formation of Mizoram was also inferred differently as lagoonal (Jauhri 2003), inner-neritic shelf (Tiwari 2001) and deltaic (Mandaokar 2000). The foraminiferal assemblage of Ammonia umbonata, Orbulina cf. bilobata and Praeorbulina glomerosa circularis, and P. cf. transitoria suggested a deeper plaeobathymetry of around 50 m for the Upper Bhubhan Formation at Thuampui, Aizawl District, Mizoram (Lokho & Raju 2007). Present uvigerinids data allows a more accurate interpretation of the paleoenvironment/ paleobathymetry for the Upper Bhubhan Formation of Mizo Hills.

Uvigerinids mainly occur in muddy sediments at shallow in-sediment depths, have a vagile mode of life, and prefer relatively cold marine waters of shelf to bathyal zones (Murray 1991). The uvigerinid assemblage from Thingdual comprises Uvigerina schencki, U. substriata, U. cf. kernensis, U. cf. sparicostata, U. cf. pilulata and U. rutila. Other associated benthic foraminifera are Ammonia sp., A. beccari, A. ikebei and A. umbonata. Intermediate water depth assemblage, whose species live predominantly in the 50 to 100 m depth range, consists of both spinose (Orbulina) and non-spinose forms (Hart, 1980). The uvigerinids and other foraminiferal assemblage indicate a paleobathymetry of middle to upper part of outer shelf (50 to 120 m). Present data strengthens the recorded outer neritic to bathyal setting for the Lower and Middle Bhubhan Formations for subsurface of Cachar area (Ramesh, 2004). The assemblage contains a few marginal marine and inner neritic foraminifera, which are abraded or have broken edges indicating that they were transported from inner neritic to deeper outer neritic zones.

MMP 4 : Sustainable Natural Resources

4.1 Mineralization 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 in Uttarakhand and Himachal Himalaya.

(R.S. Rawat)

Granites samples collected during field work were subjected to a variety of studies. The samples were subjected to melt temperature determinations of the granites through homogenization – quenching experiments in the Experimental Petrological Lab. It was observed that after homogenization at 1050˚C in 48 hours, the experimental products are indicating the phase transformations in the alkali feldspars i.e. from a low temperature (low structural state) to a high temperature (high structural state) form (triclinic to monoclinic phase transformation i.e. microcline to orthoclase formation). There is also colour change from white microcline to pinkish/flesh colour of orthoclase. On the basis of SEM-EDX study of the homogenized alkali feldspars samples, the pink or flesh colouration in the alkali feldspars is most likely due to cation exchange between the containers and the experimental runs i.e. the traces of iron present in the platinum crucibles is responsible for it. The above homogenization experimental studies were carried on granites occurring in different lithotectonic setups i.e. the granites were ranging in space and time, are from different Northwestern Himalayan domains and their homogenization studies indicated a temperature of more than 700˚C for their melts. The results are also supported by Lal (1991) technique i.e. on the basis of Ti contents in the co-existing biotite and muscovite micas in the studied granites, which is further confirmed by Green & Usdansky (1986 a & b) techniques too.

Similarly, the importance of structural state of feldspars is used to demonstrate that once we know the structural state of the feldspars, we can pin point a particular geothermometer to be used in determining the temperature of an assemblage containing the two feldspars i.e. Whitney & Stromer (1977a) is the most suitable two feldspar geothermometer for metagranites and gneisses in a metamorphic terrain.

The field and the mineral paragenesis study on the NW Himalayan Granites when combined together clearly indicated that the Tertiary Himalayan Orogeny is responsible for deformation and metamorphism of these granites in space and time. This is more so- on the basis of detailed study of 20 my old Badrinath Granite i.e. the Badrinath leucogranite is a metagranite-deformed and metamorphosed in nature and must be by an orogenic event after its crystallsation-indicating towards the Tertiary Himalayan Orogeny but definitely prior to the deposition of the earliest Siwalik Group sediments in the Outer Himalayan zone. It is concluded that this event is responsible for deformation and metamorphism of

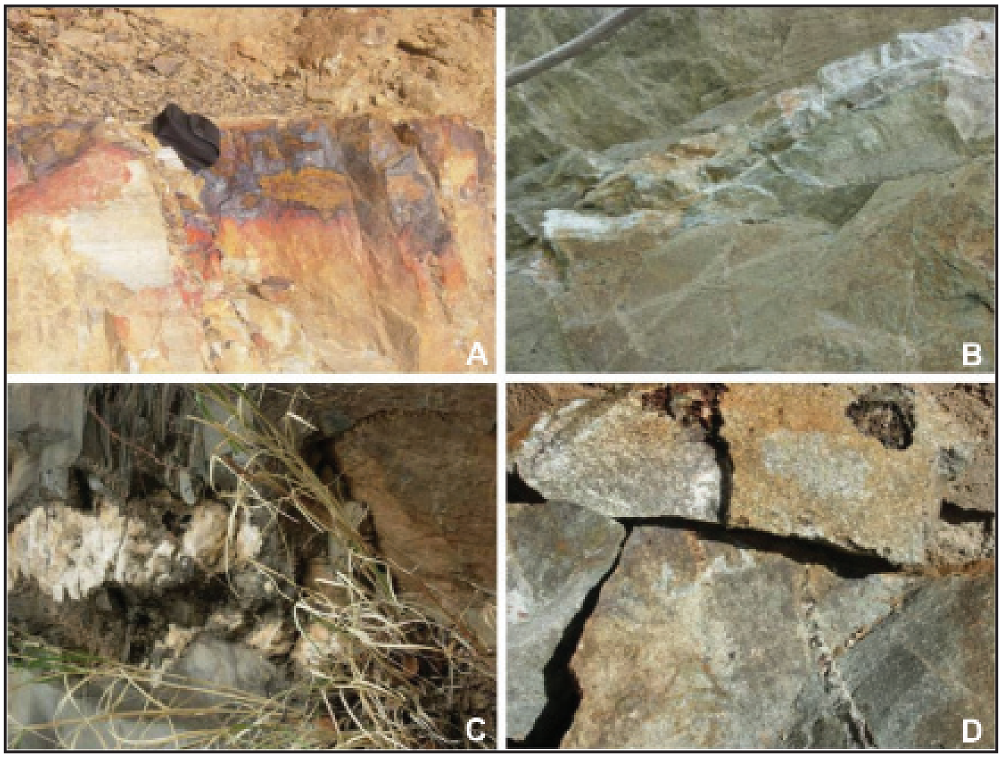


Fig.18. Nature of Polymetallic sulphides in Western Garhwal. **A–** synsedimentary and later deformed in quartzite, **B–** synsedimentary in deformed calcareous quartzite, **C-** Quartz vien in talcose schistose rock and **D-** Fracture filled in metabasics in Tehri and Rudraprayag Districts.

pre-existing rocks and associated mineralizations in the Himalayan terrain.

During the field investigations in the Inner Garhwal Lesser Himalaya some new occurrences of polymettalic sulphide mineralization were observed in the Western Garhwal (Dagar-Badiyar-Kothar region). The mineralized zones show a variety of features in the host rocks i.e. poorly preserved syngenetic type in basic rocks to synsedimentary nature in the sedimentary-metasedimentary rocks of the studied area, which were effected later on by deformation and metamorphism to yield the conspicuous later remobilized hydrothermal types in these rocks (Fig 18 A-D). The syngenetic/synsedimentary (primary) mineralization is mainly confined in the autocthonous zone rocks-in carbonates, basics and sheared quartzites. However, the hydrothermally remobilized secondary type is confined in the thrust sheet's rocks- in calcareous quartzites, epidiorites, talcose schists and in sheared granites-particularly along the Alaknanda Thrust and North Almora Thrust in the area. Further, the study of complex fluids and lithotectonics of the area revealed that these had a vital role for the potential mineralization in this terrain. It is also observed that there are tectonic slivers of crystallines in the Autocthonous/ Para-autothonous zone in this area. In addition to the study on mineralization in the area, a huge highly deformed and metamorphosed granitic batholith, occurring in this area is also studied in the field. This granitic body is extending from Toneta (near Tilwara- west of Mandakini River) to Mayali and beyond Chirbatiya towards Ghutu (in Tehri District-east of Bhilangana River).

4.2 Mineralization and Metallogeny in Kumaun Region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao)

Significant graphite is found in metasedimentary rocks of the Gumalikhet Formation, Almora Group. Ten days field work was carried out in the graphite mineralized areas in Almora Crystallines, Kumaun Himalaya. Traverses were taken in Sirar, Petsal, Kalimat, Makraun and in Jalali-Masi areas. Attempt was made to understand the distribution of carbonaceous rocks, association of graphite and variation in the nature of graphite. The host rocks comprises of garnetiferous mica schist, micaceous quartzites and the black carbonaceous phyllite. Graphite occurs as interbedded lenses, bands and pockets in the host schists and carbonaceous phyllite. Under microscope graphite is associated with quartz, biotite, muscovite, feldspar, garnet, occasional pyrite and rare chalcopyrite. The SEM-EDX study of the graphite schist presents characteristic features like significant ash material, flakes of graphite interlayered with quartz, well developed crenulations and uncommon nodular structure. The cracks developed in it are likely because of the high carbon content and devolatization. At several spots the EDX work presents a well defined carbon peak. Preliminary results of fluid inclusion study on quartz and garnet associated with graphite show that unlike to the graphite free zone aqueous inclusions are rare in graphite enriched zone and the dense carbonic inclusions are common. An unidentified opaque mineral is noticed in some of the inclusions.

Fluid inclusion study of mineralized quartz near Gasku shows that the early hydrothermal circulation is represented by aqueous inclusions which occur in isolation and in small groups. They are homogenized at about 280 to 318°C. Limited sulphur isotope data could be available on the sulphides from this area. The $\delta^{34}S$ ‰ values (0.9 to 6.4) of the sulphide minerals are restricted in a narrow range and point that magmatic derived sulphur was involved in the mineralization. Sulphur isotope data on the sulphide minerals from potential Askot pollymetallic sulphides in Kumaun also generated. The obtained range of $\delta^{34}S$ ‰ values (3.9 to 6.8) for Askot sulphide mineralization closely matches with the sulphides from the Chiplakot Crystalline Belt. This intern indicates possibility of a regional hydrothermal fluid activity in these klippen. Fluid inclusion study of mineralized quartz near Gasku shows that the early hydrothermal circulation is represented by the aqueous inclusions which occur in isolation and in small groups. They show temperatures of about 280 to 318°C.

4.3 Geochemical investigation of soils and stream sediments in the south - east foothills (Pinjore—Una Dun) of Himachal Himalaya

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

Sediments are considered, as the most representative of surface environment and thus most suitable for exploration technique in various climates and geological environments, as well as has traditionally been found to be very useful in assessing environmental degradation, source rock composition and provenance, as it reflects the signatures that are directly related to the geochemistry of bed rock. During the year one week field work was carried out in the Pinjaur- Soan Dun area, and fifty one stream sediment samples were collected from Sirsa and Jhajra catchment stream drainage network covering an area of about 400 sq km. The sediments were collected from the uppermost part (5-15 cm) of the stream drainage. Samples were dried at 110˚C and screened through 80 mesh standard sieve. Part of the samples were finally ground to about 200 mesh using Tungsten Carbide Mill. Pressed powder pellets were prepared by mixing with 4-5 drops of polyvinyl alcohol as binding agent (Stork et al., 1987; Saini et al., 2000). All samples and reference standards used for calibration and quality control were made under identical conditions to avoid any error introduced by the sample preparation. The pellets were analyzed for the major and trace elemental abundance by standard Wavelength Dispersive X-ray Fluorescence Spectrometer (WD-XRF) technique on a Sequential X-ray Fluorescence Spectrometer (Siemens SRS-3000). The heavy metal concentrations in the fraction of – 200 mesh (< 75 um) of Pinjaur Valley sediments vary in the ranges of <1-15 for Co, 2-35 for Ni, 5-134 for Cu, 33-241 for Zn, 12-339 for Pb, 11114-36208 for Fe, 347-1078 for Mn and 2520-4320 ppm for Ti. Considerable variation in heavy metal concentrations between these two catchments is observed.

The higher concentration of heavy metals (particularly Pb, Zn, Cu, and to some extent Ni and Co) is mainly observed along Jhajra catchment and around highly populated areas, such as Kalka, Pinjaur and Parwanoo. The higher Cu, Zn and Pb concentrations might be due to the presence of the Kalka municipal area in the upper valley, as well as by the existence of Parwanoo industrial area, mainly having chemiplast group of industries. However, for the purpose of environmental evaluation of the heavy metals distribution in the investigated area, the method of calculating the geo-accumulation index (I-geo) (Muller 1969; Ntekim & others 1993) was applied. Müller's Geo-accumulation index is basically a single metal approach to quantify metal pollution in sediments. Sediments were classified as practically uncontaminated (Class 0) for Fe, Co, Ni. Sediments in Sirsa catchment in general are not polluted with Cu, Zn and Pb, but in the Jhajra catchment though Zn falls within uncontaminated category but certain individual sediments contain much higher concentration and thus range between uncontaminated to moderately contaminated category. Cu is also found to be moderately contaminated (Class 0-1), where as Pb falls within moderately contaminated to strongly contaminated category (Class 1-3).

4.4 Hydrochemistry of Water Sources in the Himalaya: an assessment of quality and chemical weathering

(S.K. Bartarya)

The water resources in the Mandakini catchment comprises streams, groundwater (springs and handpumps), and lakes at high altitude. The main tributaries of the Mandakini are Madhyamaheshwar, Mandani, Rawan Ganga and Laster gad. The stream water has chemical fluxes from glaciers in high altitude region and from springs (subsurface water) at lower altitude. Surface and groundwater samples were collected from the tributary streams and handpumps and springs. The total dissolves solids and conductivity of the tributary streams, varies from 42 to 160 mg/L and 72 to 230 µ siemens/cm and in groundwater it ranges from 90 to 380 mg/L and 130 to 540 µsiemens/cm respectively. Thus in general the stream water is diluted than groundwater. The order of cations is Ca>K>Na>Mg and anion dominance is HCO_3>SO_4>Cl. Hydrochemically the waters are $CaHCO_3$ type. The differences in the major ion concentrations of these water potentially reflects the differences in geochemistry/mineralogy of the geologic material through which water flows and contact time.

Chorabari and other glaciers have distinct chemical flux to the Mandakini river. The relatively higher concentrations of potassium and calcium compared to other cations in streams receiving glacial water is probably due to dissolution of soluble trace phases, such as carbonates, exposed by grinding, and cation leaching from biotite and plagioclase. Breaking of mineral lattices by grinding increases dissolution rates and high surface area make glacial sediments exceptionally weatherable.

Comparing the chemistry of handpumps, springs and stream water, the springs represent shallow, short contact time flow path (with the exception of hot spring at Gaurikund which has deep circulation), the handpumps show relatively deep and long contact time path and streams shows mixing and dilution from water having low dissolve solids.

The low concentration of cations and silica in stream and spring water compared with groundwater(in handpumps) during post monsoon season indicate flushing of pore spaces in soil and overburden during more extensive saturation and increased hydraulic gradient at high flows after rains. Two mechanisms probably derive the low ionic concentrations in streams with increased discharges after post rainy season. First, the contribution of dilute water from the soil directly to the runoff without routing through the bedrock. This is occurring during rainfall when zone of subsurface saturation develops in the colluvium. As this subsurface variable source area grows during rainfall, the direct contribution of low solute soil water to runoff increases. Second, increased saturation within the bedrock could fill partially saturated fractures, and allow low concentration water derived from the soil to move through the bed rock rapidly and without significant chemical interaction. This explains the low ionic concentration in streams and springs in comparison to groundwater. However, dilution of stream water with increasing discharges due to addition of new water from rain and dilution due to low concentration water from glaciers also contribute to low ionic concentration in stream water.

4.5 Glaciological studies of Chorabari and Dokriani glaciers: An integrated approach

(R.K. Chaujar, S.K. Bartarya and P.S. Negi)

The work deals mainly with the Climate change and its impact on the Himalayan Glaciers on the basis of study of the landforms formed by the Chorabari and Dokriani glaciers, Garhwal Himalaya, and dating of various cycles of their advance and retreat by lichenometry. The most common lichen growing on the slope boulders is Rhizocarpons geographicum. It belongs to the yellow green Section Rhizocarpons most frequently used in lichenometry.

Four stages of advance and retreat, on the basis of loops of terminal and lateral moraines, of the two glaciers are noticed. Largest lichens on the boulder of moraines of different loops of advance and retreat of the glaciers are 173 mm, 155 mm, 94 mm and 43 mm (Chorabari), and 160 mm, 144 mm, 58 mm and 48 mm (Dokriani) of stage I, II, III and IV respectively.

The colonization delay and growth rate of the lichens, as calculated by field observations, are 85 yr and 1mm/yr (Chorabari) and 72 yr and 0.66 mm/yr (Dokriani) respectively. Based on these values the dates of deglaciation of four stages of advance of the glaciers are 258, 240, 170 and 128 yr (Chorabari) and 314, 224, 159 and 144 yr (Dokriani) respectively. These dates of different loops of deglaciation indicate the influence of climate change on the glaciers and differences in values suggest the effect of orientation of two glaciers-. North facing Dokriani Glacier in the Garhwal Himalaya indicates 'Little Ice Age' maximum during AD 1692 whereas south facing Chorabari glacier show its maximum during AD 1748. The overall average rate of retreat of two glaciers are 14.53 m/yr (3750 m/258 yr) and 14.33 m/yr (4500 m/314 yr) respectively.

Melt water Chemistry

Meltwater chemistry is fully integrated (mixed) at the point of sampling. The dominant cations in meltwater of Chorabari glacier is Ca followed by K, Na and Mg and dominant anions are HCO_3 and SO_4 in varying proportions. This is consistent with chemistry data of other surface waters of the Mandakini catchment which is dominated by calcium bicabonate. However, glacial meltwaters demonstrate significant chemical enrichment over relatively short distances, between their origin as dilute snow and icemelt and their emergence at the glacier snout.

The chemical data of Chorabari glacier shows diurnal variation in Ca, Mg, Na, K, HCO_3, SO_4, pH and electrical conductivity. The diurnal variations in the magnitude and pattern of discharge, suspended sediment concentration, Ca, Mg, Na, K, HCO_3, SO_4, pH and electrical conductivity are indicative of timing of the meltwater transmission through the subglacial drainage. Glacier drainage systems consist of a mix of supraglacial, englacial, and subglacial components and chemical weathering rates can vary among these components. The major ions chemistry of the glacier melts suggest two major flow components (Fig. 19)

- A widespread distributed drainage system consist of elements such as film- flow or porous flow through permeable subglacial sediments, linked cavities and broad low canals, all of these transport meltwaters at relatively slow rate.
- A more discrete channelised system incised either upwards into the basal ice layer or engraved into the underlying bedrock which transports meltwaters rapidly through the glacier. Through these major conduits, turbulent meltwaters access, mobilize, transport and evacuate significant quantities of suspended sediment from the subglacial environment. This is substantiated by relatively higher discharge, suspended and total dissolved solids (TDS) data. As ablation season progresses, this channelised system expands headwards, following the retreat of seasonal snow cover.

Snow / Timber line fluctuations, lichen ecology and its relation with climate

Dokriani glacier is visited in the month of June with the view to study the impact of climate change on ecologically sensitive ecotones such as tree line and snow line. The fundamental floristic survey is conducted to sample and identify the tree species representing the tree line and its spatial migration in response the climatic variation. The climate change signature associated to the tree line and it's upwards migration, has been recognized, surveyed and recorded for future study, especially in relation to time and

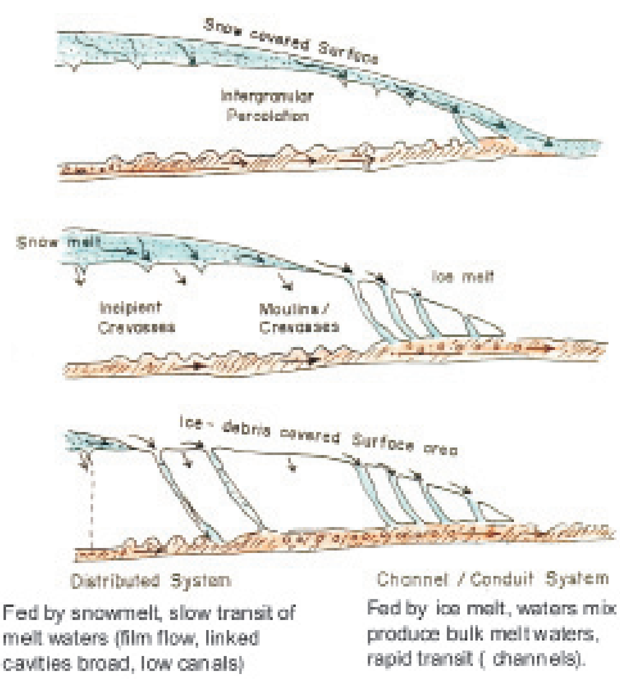


Fig.19. Diagramatic section of glacier showing two component of flow controlling the diurnal variation in glacier melts water chemistry.

PROGRESS IN RESEARCH PROJECTS

space. The preliminary survey related to the snow line is also started.

Chorabari glacier snout proximity is witnessed by presence of 274.32 mm size of Acarospora sp. (Lichen thalium) which is suggestive of rapidly changing habitat and climatic conditions associated to the glacier resource near terminal moraine. The marked variation in lichen growth rate from 0.56 mm/year to 0.84 mm/year at different aspects of moraines is indicative of important influence of microclimatic scenario prevailed over a period of time. Since lichen ecology is least known in the World and therefore aspect factor was ignored. But present study confirm that it has decisive role and need to considered for precise dating related to glacier recession and other climate change studies.

4.6 Mass Balance studies of Dokriani and Chorabari Glaciers, Garhwal Himalaya

(D.P. Dobhal)

The work deals mainly with the routine monitoring of Dokriani (7 sq km, NWW facing) and Chorabari (6.9 sq km, South facing) glaciers mass balance vis- a -vis climate change and its impact on the Himalayan Glaciers. Annual mass balance, snout fluctuation, glacier discharge measurement and meteorological observation on Dokriani and Chorabari glaciers has been carried out during the year 2007/08.

Chorabari Glacier

The results obtained on glacier monitoring work in 2007-08 are summarized as follows: i) during the period 2007-08, net annual balance was calculated negative with specific balance of (-) 0.75 m. ii) The ELA found at altitude of 5065 m compared to ELA altitude 5060 m in 2007. iii) During the period 2007-08 the snout retreated 12 m in the centre and 7m in the right limb of the glaciers. It is noticed that the left limb of the glacier tongue is thickly covered with debris and has gentle slope and is stagnant at the pervious position.

Discharge measurement in Chorabari glacier was carried for the period of June to August. The result shows the total discharge during the period was 22.10 x 106 m^3 with an average daily discharge of 0.34 x 106 m^3. The maximum and minimum daily discharges were 0.30 x 106 m^3 in July and 0.12 x 106 m^3 in first week of June. Meteorological data collected during the period from 25 May 2007 to 5 April 2008 near the snout of Chorabari glacier shows that the maximum temperature recorded during the period was 16.0˚C (26 June 2007), where as the minimum temperature recorded -17.3˚C (31 January 08). The seasonal rainfall is observed to be about 1040.9 mm in summer period June to October. Further net winter snow falls was about 20 cm measured from standing snow near the snout (3865 m asl) in 1st June 2008.

Dokriani Glacier

Annual mass balance of the Dokriani glacier has been determined for the year 2007/08 by applying the direct glaciological method (Stake network). The winter balance was surveyed in the month of June and again in first week of November 2008. The snow depth was measured at different elevations in accumulation zone by digging pits and by manual probing. The mean snow density was determined about 0.58 gm/cm^3. The total accumulation during the period 2007/08 was ca 0.55m w. eq., where as the mean average ablation was 2.75 m w.eq. The net annual balance was calculated negative. The Equilibrium line altitude (ELA) was estimated from the field observation as well as vertical mass balance gradient and found at an elevation of 5095 m asl. The snout of the glacier was monitored by EDM survey and manually (chain-Tape method, in respect to old maker made near the snout) to determine the recession during the year 2007 - 2008. The total recession of the snout at centre was 17m. It is observed the snout has retreated more on the right flank in comparison to the left flank. The present snout elevation is 3915m.

Melt water discharge and total discharge were measured at two observatory , 700 m and 17km down from present glacier snout (3810 m asl) and Tela camp (2300 m) respectively. The data collected during the period is yet to be analyzed. Meteorological data collected during this period (March to November 2008) at Dokriani bases camp shows that the maximum temperature recorded during the period was 17.0˚C (12 June 2008) and minimum temperature recorded -8.4.3˚C (17 April January 2008). The total participation observed to be about 1332.4 mm and was comparatively higher than pervious year.

The recent studies reveal that both the glacier show negative mass balance and continuous retreat of

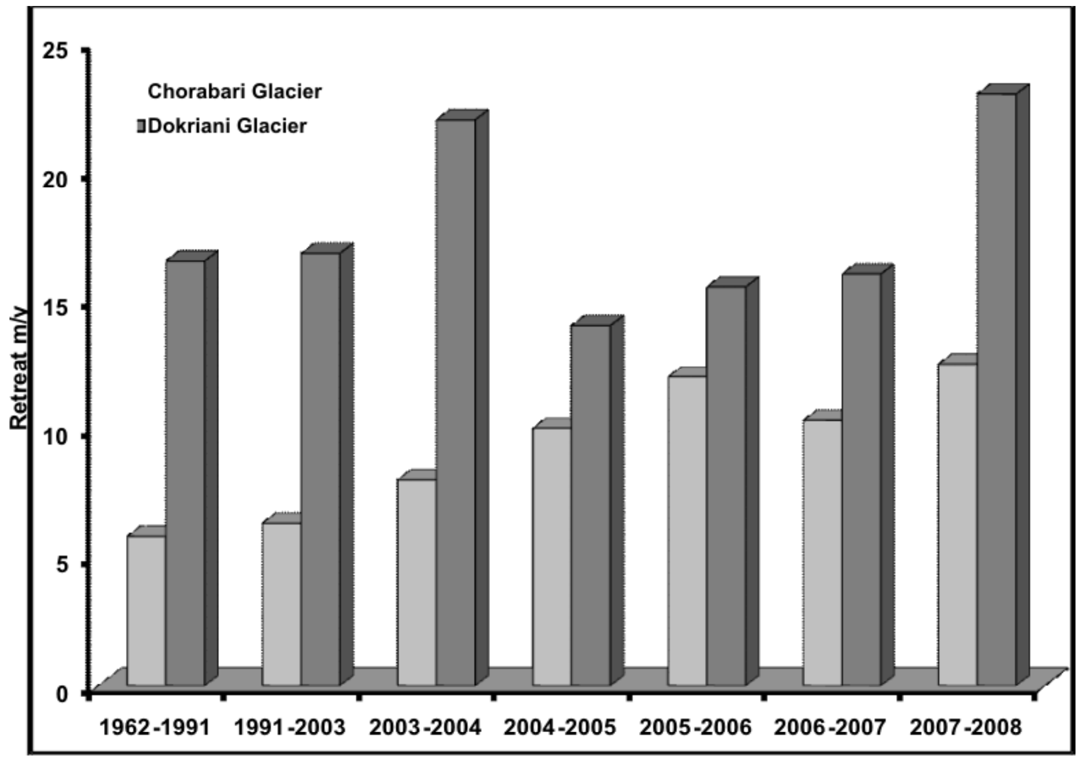


Fig.20. Snout recession trend of Dokriani and Chorabari Glacier, Garhwal Himalaya (1962-2008).

frontal portion (Snout), but the rate of recession is different for both the glaciers while geometry of glaciers is more or less same and they are located in same climatic regime. Dokriani glacier is north facing, less debris covered (30-35%) and have narrow snout where as the Chorabari glacier is south facing, thick debris covered (60-65%) and having a broad snout. The snout recession trend during the last eight years of both the glacier shows that the Dokriani glacier has a faster rate than the Chorabari glacier (Fig. 20).

MMP 5 : Real Time Geology for Society: Coping with Natural Hazards

5.1 Study of active faults and neotectonic activity in parts of Himachal and Uttarakhand Himalaya between the Himalayan Frontal Thrust and the Main Central Thrust.

(G. Philip, S. S. Bhakuni and N. Suresh)

During the year selected parts in the Pinjaur Dun and Soan Dun have been taken up for the study of active faults.

Pinjaur Dun

Using CORONA satellite photographs, multi-spectral satellite data of IRS-ID-LISS-III and PAN, and black and white aerial photographs a prominent fault, named as Nalagarh Active Fault (NAF) in the Quaternary fan, has been identified at Nalagarh in the Pinjaur Dun, northwestern Sub-Himalaya, Himachal Pradesh. The NAF is located in the northwestern segment of Pinjaur Dun and close to the tectonic lobe of the Nalagarh Thrust which borders the Tertiary rocks from the Quaternary deposits. The displacement of the Quaternary deposits along the Nalagarh Thrust indicates its reactivation in the Quaternary times. The surface expression of the subdued and modified scarp of the NAF on fan surface at Kirpalpur village, Nalagarh, is about 5 km in length, which extends further eastward into the adjacent fan surface. Considering the attitude of the fault scarp, a trench excavation survey was carried out in the alluvial fan for paleoseismic studies. The NAF is a thrust fault, displacing all the stratified litho units of the fan sequence, with an average dip of 26° due northeast and 2m vertical displacement and 4.6 m slip along the fault (Fig. 21). The litho units, consisting of alternating sand and gravel, show back

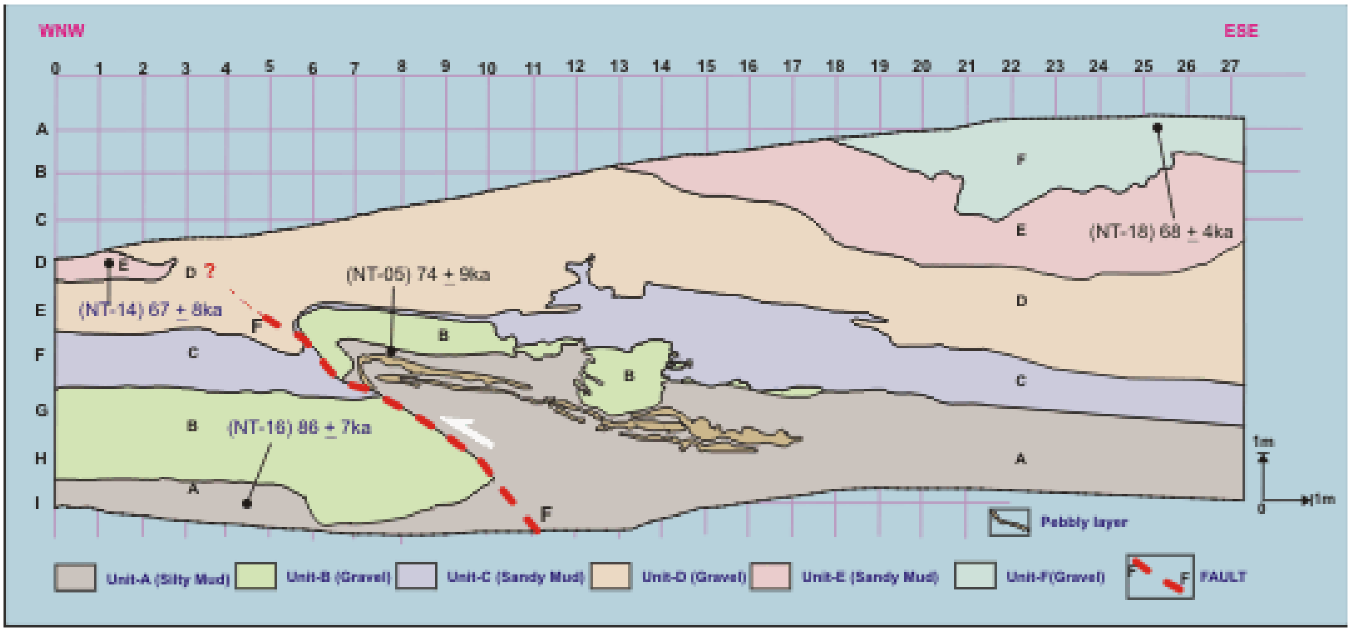


Fig.21. Trench wall log showing displaced (2m vertical) Quaternary sediments along an active reverse fault (F-F), Nalagarh Active Fault, near Nalagarh in Pinjaur Dun.

tilting towards NE direction and asymmetrical tight folding with fractures close to the core of the fold in the hanging wall whereas they maintained original attitude in the footwall. Representative sandy samples from hanging wall and footwall have been dated using optically stimulated luminescence techniques to constrain the chronology. Based on OSL ages, the oldest unit in the trench is 86 ka BP and the youngest is 67 ka BP. We infer that the ongoing north-south convergence between the Indian and Eurasian plates has resulted fault propagation folding and subsequent large magnitude earthquake along the NAF. The proximity of the NAF close to the tectonic lobe of the Nalagarh Thrust suggests that this may be a splay of the Nalagarh Thrust which had activated/reactivated due to the reactivation of the Nalagarh Thrust. The NAF substantiates the seismic potential of the Pinjaur Dun and calls for more concentrated study of paleoearthquakes of this highly populous mountainous region.

Soan Dun

A new active fault trace, which is oblique to the Himalayan Frontal Thrust has been recognized in the northwestern Frontal Himalaya near Chamuhi in the Soan Dun. Topographic features indicative of long-term uplift/deformation along the fault in the current tectonic regime and cumulative slip along the fault reflect the manifestation of normal faulting with a strike slip component. This N-S trending fault, traceable for over 4 km, is steeply dipping due west. The fault has also caused shift of drainage channels of major and minor streams. OSL samples are being dated to establish the chronology of the Quaternary deposition and to infer faulting related to past seismic event.

5.2 Engineering Geological Characteristics of rock mass in the Satluj and Alaknanda valleys

(Vikram Gupta)

Geomechanical characterization of all the rocks exposed in the Alaknanda and the Satluj valleys has been carried out using Schmidt Hammer. Four rock types viz. quartz mica gneiss, schist, quartzite and calc-silicate were used to test whether a Schmidt hammer can be used to distinguish rock surfaces affected by various natural and man-induced processes like manual smoothing of rock surfaces by grindstone, surface weathering, deep weathering, fluvial polishing and blasting during road construction. It has been observed that variability of the R-values for the fresh natural surfaces is substantially higher than for the treated surfaces for the same rock type. This can be explained by the variation in factors such as surface roughness and length of exposure to exogenic condition. It should also be noted that in the case of quartzite and calc-silicate composed dominantly of single mineral, the spread of R-values is less compared to the quartz mica gneiss and the schist.

The unconfined compressive strength (UCS) of quartz mica gneiss, quartzite and calc-silicate have also been calculated and correlated with the R-values for the fresh natural surfaces and the treated surfaces. It can be observed that, for all rock types, the strength of the relationship between R-values and UCS is higher for the treated surfaces than for the fresh natural surface and the UCS. It is 0.90, 0.89 and 0.58 for the treated surface of quartz mica gneiss, quartzite and calc-silicate; and 0.72, 0.54 and 0.49 for the fresh natural surfaces, respectively.

Schmidt hammer R- values from the water-polished bedrock surfaces have been compared with the R- values of the same rock located in the adjoining area. The rock type studied was quartz mica gneiss in both the valleys. It should be noted that the R-values on the water-polished surfaces are much higher with an average of 68 (Range 62 - 69) than on the fresh natural surfaces, which have an average R-value of 54 (Range 47 - 57). Furthermore the variability of R-values on the water-polished surfaces is much less than the R-values on the fresh natural surfaces. This is mainly due to the removal of projections of the grains of quartz and feldspar, resulting in the smooth and polished surfaces.

On the basis of visual observation, three stages of weathering (weathering class I, II and III) for the sample surface were identified in the field. Weathering class I is equivalent to the fresh surfaces, whereas weathering class II and III are slightly and moderately weathered respectively. Schmidt hammer tests were undertaken on each weathering class on the quartz mica gneiss, quartzite and calc-silicate. It can be noted that, for all the studied rock types, there is a slight difference in R-value (in the range between 2 and 3) between weathering class I and II. The mean of the R-value decreases with increasing weathering. The difference between weathering class II and III, particularly for the quartz mica gneiss is in the range of 3-13, whereas, for quartzite and calc-silicate the difference is in the range of 4-10. This is mainly because, the higher weathering class exhibits rough and undulating surfaces, thus exhibiting higher variability and lower mean R- values.

Schmidt hammer rebound (R-) values on the blast-affected rock surface, for all rock types, is lower than for any other surface, even surfaces of weathering class III. Summing up, the study draws the following conclusions:

- Rock surfaces polishing by fluvial processes yielded the highest Schmidt hammer rebound (R-) values.
- The mean R- value for blast-affected surfaces, for all rock types, is lower than any other surface, even surfaces of the highest weathering.
- Variations in R-value are reflected by the degree of weathering of the rock surfaces for a particular rock type.
- For all rock types, the strength of relationship between R-value and the unconfined compressive strength (UCS) is stronger for the treated surfaces (manual smoothing of rock surfaces by grindstone) than for the fresh natural surfaces. In order to estimate the strength parameter of the rock with Schmidt hammer, it is therefore, necessary to grind the surface with grindstone before measuring the rebound value.

5.3 Study of palaeo-mass movements in relation to climate change and neotectonic activity in the Satluj valley, Himachal Pradesh

(M. P. Sah and Vikram Gupta)

In the Satluj and lower Spiti valley Quaternary sediment deposits indicated damming of channel and creation of palaeo lakes along the main channel by landslide and massive debris flow mass deposited by the tributary channels. The dominance of high relative relief, channel gradient, channel discharge, mechanical weathering, surging of glaciers due to climate change, highly jointed nature of rocks and impact of neotectonic activity in the area provide a prevailing high energy environment that facilitated the mass movement and landslide process in the area. The breaching of these palaeo lakes created flash floods in area since Quaternary time and this phenomenon is also observed in recent years. The major past channel blockades are marked at Khab, Dubling, Spilo, Morang, Ribba/Akpa, Powari, Karchham, Kilba, Tapri and Wangtu in Satluj valley while along the lower Spiti valley such blockades are observed at Sumdo, Salkher and Leo villages.

The samples collected from some blocked sites are dated using the optically simulated luminous (OSL) techniques to know the age of these deposits. At the confluence of Satluj and Spiti river at Khab, 120 m thick lower lacustarine deposit lying over the erosional terrace is dated 41$\pm$2.6 Ka. The charcoal sample collected from the upper terrace sequence is dated 1447$\pm$103 Ka by C^{14} indicating a phase of fast glacier melting in the area. The erosional terrace at Khab is 180 m from the present river bed and considering the present erosion rate of Satluj at Khab 1.6 mm/year taken from the published data this terrace is ~288 Ka old. This gives an incision rate of ~4.1 mm/year. The deep gorge and high level of fluvial terraces are observed at Dubling, Poh, Spilo down stream of Khab indicate neotectonic activity in the area.

The top of lacustarine sequence at Morang is dated 21.54$\pm$1.03 Ka indicating Satluj blockade by the massive debris flow along the Morang Nala. This blockade at Morang caused sift in the course of Satluj towards the right side direction as indicated by the presence of past channel course of Satluj. The Satluj down stream of Morang takes a right angle turn from N-S to E-W direction which follows the strike of Tethyan Thrust. At Ribb/Akpa major Satluj blockade is marked which was caused by the massive rock fall and debris flow along the left side of the channel from the glaciers of Kinnar Kailash. The present Ribba/Akpa village and Khadara Dhang are formed by the thick sequence of glacial mass dumped by the degrading glaciers of Kinnar Kailash. The presence of fluvial terrace on the relatively flat glacial mass above the Khadara Dhang is a clear indication of Satluj blockade in this section of channel course. At Ribba/Akpa the upper alluvial terrace sand buried on glacial debris flow is dated 4.10$\pm$0.70 Ka while the debris fan is dated 2.29$\pm$0.25 Ka clearly indicate massive mass movement from the Kinnar Kailash area. There are more than two phases of Satluj blockade observed at Ribba. The evidence of earlier blockade is marked by the rounded pebble terrace deposit observed above the Khadra Dhang. The higher level terrace deposit along the right bank of Satluj opposite of Tridang Khad indicates the former level of palaeolake. This lake was short lived as inferred by the lack of lacustarine deposit in this section. The breaching of this landslide / debris flow dam can be related with the high amount of discharge along the Satluj river and contribution by the relatively high gradient Tridang Khad. The boulder sequences and fluvial terrace deposit along the right bank of Tridang Khad indicates the vertical uplift along the Tethyan Thrust in the area.

In Spiti valley the terrace material dated from the Chuling section indicates two distinct phases of upliftment. The upper terrace which about 235 m from the river bed is dated 51$\pm$5.93 Ka which represent the first phase of lake formation and river Spiti blockade caused by the palaeo mass movement along the valley slope. The lower sand bed at 50m from the river bed is dated 26.83$\pm$1.96 Ka represent second phase of major channel blockade in the area and reactivation of Kaurik-Chango Fault. The incision rate for Spiti along its lower reaches is calculated ~4.6 mm/year and the figure seems to be quite convincing considering the incision rate of Satluj at Khab. The relatively high incision rate of lower Spiti valley is due to high channel gradient as compared to Satluj river.

In the Spiti valley climatic variations are observed in the form of soft sediment deformation structures which are observed in the Quaternary lacustarine sediment sequences. These soft sediment deformations are primarily created by periglacial condition when the frost action was very dominant. The involutes and convolutes are lying between two clay rich sedimentary layers separating the upper and lower layers by undisturbed beds indicating their periglacial origin. The small and large involutes observed in the Quaternary lacustarine sequences indicate periglacial condition during the deposition of these sediments in the palaeolake. The small involute indicates seasonally frozen sediments while the large involutes at upper level indicate degradation of permafrost conditions, i.e, amelioration of climatic conditions in the region. The amplitude of these involutes and convulses is depend on the plasticity of the material and amount of frost action. At upper layers lateral movement of these deformed structures indicates less plasticity of material caused by the liquefaction. At some places these lacustarine sequences show fault and sand pipes which are related with the palaeo seismic events which is very prominent along the Kaurik-Chango Fault traversing along the north south in the Spiti river in this section. These fluidized structures are indicators of cold and warm phases and used in the chrono -lithostratigraphic correlation for the reconstruction of palaeoclimate. These structures are observed in lacustarine sediments of lower Spiti valley where as they are absent from the palaeolake deposits of Satluj valley.

The broad inferences deduced from the studies carried out so far indicates that upliftment along Tethyan Thrust are prominent during Quaternary period. Kaurik-Chango fault is very active and Leo Pargil (6791 m) horst show prominent uplift during Quaternary period. Uplift and retreat of glaciers along Leo Pargil block exposed more glacial sediment for rapid mass movement. In recent years increased wet precipitation along the cold desert area has put more area under mass movement as evident by the meteorological data collected from the region.

5.5 Real time monitoring and Analysis of Seismicity, Seismotectonics, and Seismic Hazard of NW Himalaya

(Sushil Kumar, Ajay Paul and Naresh Kumar)

Strains resulting from the continued collision between India-Asia Plates are manifested in number of large earthquakes along the Himalayan Arc. In the NW Himalaya, adjustments and activation of crustal blocks to accumulating/decaying strains continuous trigger micro-earthquakes. The understanding of earthquake source processes and the medium characterization provides the base tools for the assessment, mitigation and reduction of seismic hazards. In this direction, institute has a major research program in monitoring the local earthquake activity. Aim here is to design a homogenous network. To obtain these objectives we are operating a regional network of seismic stations in the NW Himalaya. The real time data analysis of micro earthquake in space and time domain can address to seismotectonics, and the evolution of stress pattern of the region. Accurate assessment of the earthquake hazard is critical step for seismic risk mitigation.

During the Year 2008-2009, we have replaced 5 short period seismographs into 5 broad band seismographs and added 10 more new Broad band seismographs in the NW Himalaya. Now Total 27 broad band and 3 short period seismographs are in operation in the NW Himalaya (Fig. 22). So far 11 broad band seismographs are connected through V- sat. In the monitoring programme we are monitoring the seismic activity in real time. We are also preparing the seismic data bulletin of local and regional

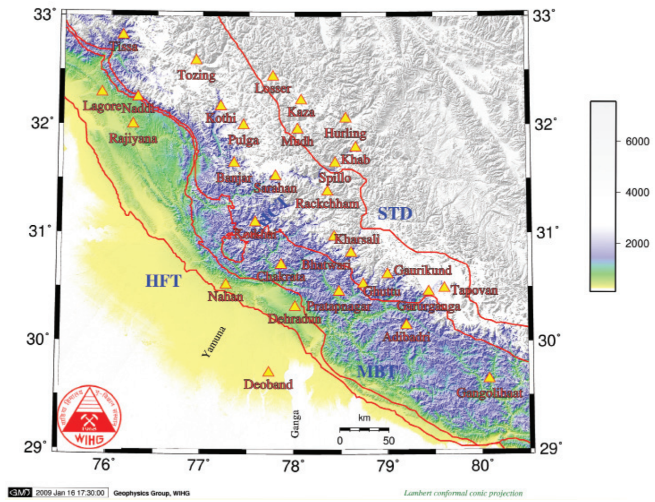


Fig.22. Broad-band and short period seismographs are in operation in the NW Himalaya shown with the triangles.

earthquakes including total data sets, which includes the data from stand-alone stations and V-sat connected broad band seismographs, short period seismographs and school seismographs (these are being operated under DST project and helpful in better earthquakes locations). From April 1, 2008 to March 30, 2009, we have recorded and processed 300 local earthquakes, 613 regional earthquakes and 436 teleseismic events. The focal depths of most events range between 0.0 and 40.0 km, nearly 85% confined to upper 20 km. The local magnitude ranged between 1.3 and 4.9. The space distribution of earthquakes clearly reinforces the earlier suggestions that major seismic activity is confined to a narrow zone centered just south of the Main Central Thrust, named Himalayan Seismic Belt (Fig. 23). However, the longitudinally seismic activity in this belt is not uniform. The data of one year show two clusters; one in narrow pocket centered on Adibadri-Guri Kund and another in an extended zone stretching from Kharsali to Kotkhai with intervening sector showing only scattered seismicity. Apart from this two unusual activities were observed, which is briefly described below:

Seasonal variations observed in the seismicity of the NW Himalaya, India

We also observed Seasonal variations in the seismicity of the NW Himalaya, at all available magnitudes, there were twice as many earthquakes during the winter months December through February as during the summer

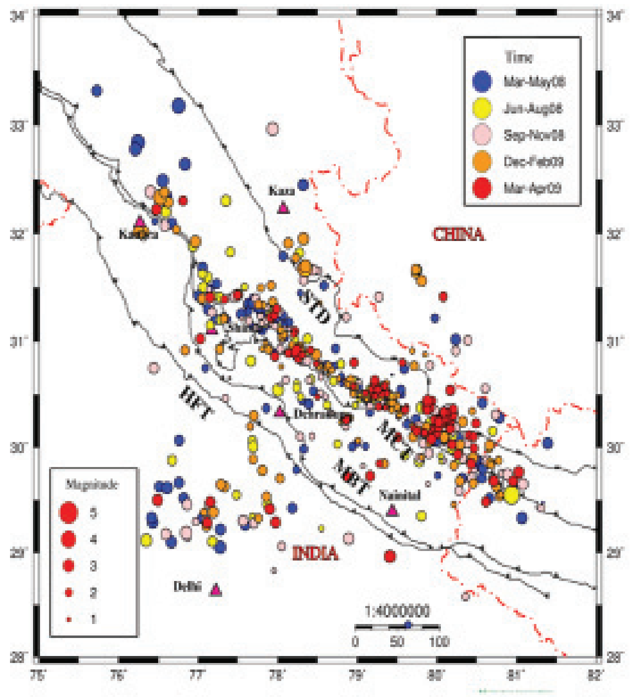


Fig.23. Epicenter plot of WIHG seismic data from March, 2008 to April, 2009. Triangles are seismic stations plotted with short names. Stars are moderate earthquakes triggered in the last decade. HFT, MBT, MCT and STFS are abbreviation Himalayan Frontal Thrust, Main Boundary Thrust, Main Central Thrust and South Tibetan fault system respectively. Epicenters shown with colored circles are described in the legend.

months May through July. That is, in winter there are up to 245 earthquakes of magnitude range 1.8 to 6.8, in decade period (1999-2008), and in summer, around 125. It indicates that the out of the total number, the earthquakes triggered notably season wise; about 65% in the winter season, compare to 35% in summer season (Fig. 24). Relatively, in the current years 2008-2009, when WIHG having dense seismic network consisting 20 modern seismic stations in the NW Himalaya, the earthquakes triggering are found consistently justifying the above observations; and there were significantly more earthquakes triggered in the winter season than in the summer season. During 2006-07, for magnitude up to three (more than detection limit) the winter average is 9 per month; while in summer the rate is 2 per month. For magnitude range $3 < M \leq 5$, the winter average is 6 per month, while the summer average less than 2. In the year 2007-08, for magnitude up to three, the winter average is 7 per month; while in summer the rate is 3 per month. These

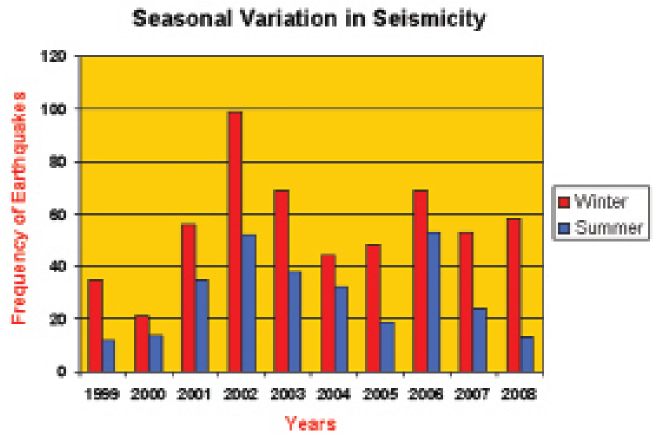


Fig.24. Seasonal variations in seismicity of NW Himalaya observed during 1999 to 2008. In winter, December-February month's total events are plotted and in summer, May-July month's total events are plotted.

statistical calculations of triggered seismicity showing the seasonal signal can not be ruled out considering merely due to chance. Stresses and pore pressure due to natural processes may already have accumulated in crustal rocks after monsoon season in the High to frontal foothill regions to near critical levels for fresh faulting or renewed slip on pre-existing faults. The stresses and pore pressure induced by overloading of water after the monsoon season may explain the tendencies to such failures and trigger or induce large number of earthquakes.

Enhanced local earthquake activity observed in the SE of Tapovan seismic station

During April 7th and 13th April 2009, a sudden increase in seismic activity was observed at 50 km SE of Tapovan. During this period total 45 local events were recorded (Fig. 25). The magnitude ranges between 2.1 to 2.8. On 8th, 9th and 10th events were very frequent, approximately one event in every two hour interval. Though nearby region have many hot springs but no new hot spring activity has been reported in this period. Also no lineament passes through the epicentral region of these events. But in the east and west of the seismic activity some lineaments are there, which follows the NE-SW trend that is transverse to the NW-SE trending Main Himalayan thrust. Source characteristics of this activity are being analyzed to understand the cause of this phenomenon. The source region of this activity is far from the source zone of 1999 Chamoli Earthquake of magnitude (Mb) 6.8.

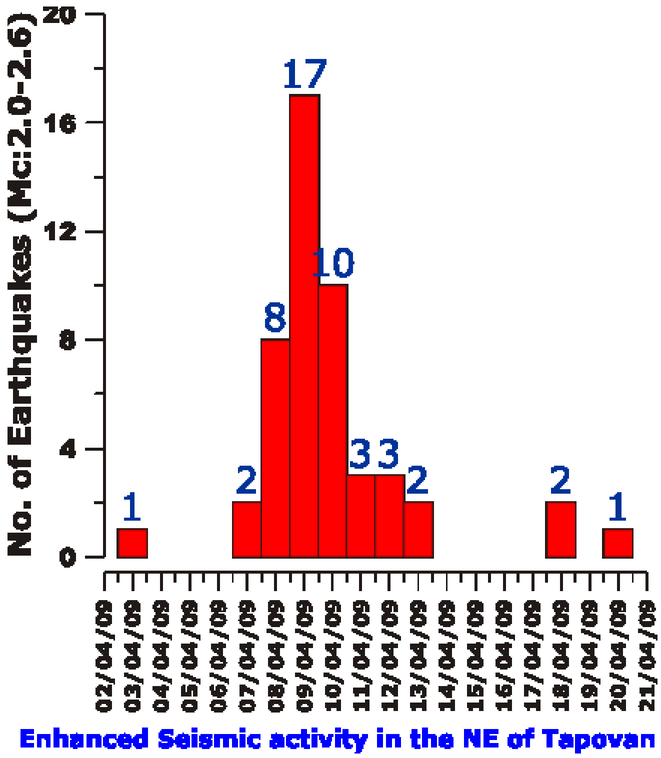


Fig.25. Histogram of the enhanced seismic activity.

5.6 Subsurface Structure and Tectonic Deformation investigation in the NW Himalaya using local earthquake data

(Naresh Kumar, Ajay Paul and B.R. Arora)

The 1D and 3D crustal velocity models have been established for the Kangra-Chamba region of NW Himalaya. The new velocity model helped to improve the location of the local seismic events, which are very much useful for seismo-tectonic implications and other related studies. During this year more than 500 local seismic events have been recorded, most of which have been located in the Garhwal-Kumaun Himalaya. The micro-earthquake data of Garhwal-Kumaun region have been used to develop the local velocity model for that region. The new velocity model is very useful to refine the locations of the earthquakes. The micro-seismic trend in this region shows that the seismicity is mainly confined to the south and very near to main central thrust (MCT). Therefore, the MCT is seismically active in the Garhwal-Kumaun Himalaya while main boundary thrust (MBT) and Panjal thrust are the active faults in the adjoining western part of Kangra-Chamba region. In depth section, most of the earthquake sources in the Garhwal-Kumaun region are from 5 to 15 km depth whereas in Kangra-Chamba region these sources are confined from surface to 15 km depth.

The improved earthquake locations helped to obtain the fault plane solutions of twenty five individual seismic events of bigger size and few composite fault plane solutions. The focal mechanism solutions (FMS) of M4.9 Kharsali earthquake and its bigger aftershock (M3.4) indicate that the displacement occurred on the MCT with NE dipping movement. The main shock is deeper with a dip of nearly 50 degree while the aftershock located at shallow depth with higher dip. The FMS solution of M3.5 near Gaurikund and to the NW of 1999 Chamoli earthquake (M6.6) shows a pure strike slip deformation with almost vertical dip. One fault plane of this solution is striking NE while the other one is EW. The FMS solution of M4.5 occurred near Kullu in the intermediate section of Garhwal-Kumaun and Kangra-Chamba is thrust fault with minor strike slip component. Its fault plane is nearly NE dipping to west which is opposite to other two parts of the region. The seismicity in the Garhwal-Kumaun region also shows two clusters one is in the Kharsali region and the other one is near Gaurikund. These clusters are within the network and therefore all the earthquakes are well located. Four composite FMSs have been obtained for these clusters showing reverse fault and strike slip movements. The aftershocks sequence of Kharsali earthquake is divided into three parts, two occurring at shallow depth above the main shock and one cluster in the detachment zone. The source locations of the aftershocks that the new activity is generated perpendicular to the MCT and along a lineament parallel to the Yamuna river at a shallow depth to the main shock

The local seismicity helps to obtain the seismotectonic models. The salient features of investigation are

- The upper crust of Kangra-Chamba region is divided into four layers with anomalous low S-wave velocity and higher Vp/Vs from 15-18 km.
- The low Vs High Vp/Vs ratio is defined as fluid filled detachment zone as brittle-ductile transition and the cut-off depth of crustal seismicity.

- The seismicity in the Kangra-Chamba region is confined in the upper crust from surface to 15 km depth while in the Garhwal-Kumaun region the earthquake sources are mainly located from 5 to 15 km.

- The improved hypocenter location is useful to define the sub-surface extension of major tectonic features.

5.7 Source Mechanism of Earthquakes by Waveform Modeling

(Ajay Paul, Naresh Kumar and D.K.Yadav)

Waveform modeling of Kharsali earthquake: The program successfully developed for computation of time series of the 22nd July 2007 ML 4.9 Kharsali earthquake using geometric ray theory and Green's function approach. The method for computing time series consists in integrating the far field contributions of Green's function for a number of distributed point source. It has been found that location of point of initiation of rupture, rupture velocity, rise time and distribution of slip amplitude on the fault are the most critical parameters in generation of synthetic seismograms. The generated waveforms have been compared with the observed ones (Fig. 26). From the comparison of waveforms it has been inferred that the Kharsali earthquake has been caused due to a northerly dipping high angle thrust fault at a depth of 14km on strike N279°E , dip 14° and rake 121. The fault surface had two asperities and the rupture which has been considered as circular in nature initiated from the asperity at a greater depth shifting gradually upwards. The two asperities cover only 10% of the total area of the fault plane.

Source character studies of Kharsali earthquake and aftershocks: At 04:32:13.5 (IST) a moderate (M_L = 4.9, M_w = 5.0) shallow focused earthquake occurred in the Garhwal Himalaya. The local seismic network of Wadia Institute of Himalayan Geology (WIHG), Dehradun located the earthquake near Kharsali (30.91°N, 78.32°E), which is about 50 km northwest to the epicenter of October 20, 1991 strong (M6.4) Uttarkashi earthquake. It awakened many people of northern India and was felt as far as Delhi in the upper part of few multi story buildings, however meizoseismal intensity was observed around VI (EMS scale) near Kharsali. The source of the earthquake is located in the upper crust (15 km depth from surface) followed by a large number of shallow focused aftershocks of magnitudes less than 3.4. The variation in seismic pattern, stress field and source characterization were examined with the existing geotectonic setting. The fault plane solutions of the main shock and the biggest aftershock (M3.4) are almost similar, making deformation due to reverse fault with a significant strike slip component. For main shock, the trend and plunge of the major and minor principal axes P/T are 166°/1° and 258°/67° respectively. In these solutions one fault plane is dipping to NE that coincides with the major tectonics of the region and the other fault plane is dipping to SE. The observed isoseismal trend was along NW-SE that also coincides with major tectonics of the region. However, the distribution of aftershocks in depth section is perpendicular to the major tectonics and coincides with local lineament parallel to the Yamuna River. The source parameters obtained from the recently established VSAT linked BB seismic stations are the seismic moment 4.15 x 106 Nm, source radius 1.66 km and stress drop 41.3 bars.

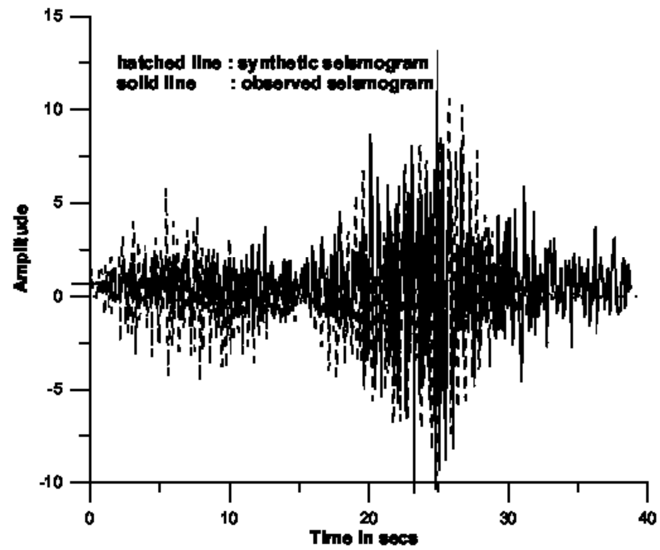


Fig.26. The superimposed time series (observed and synthetic) for the seismograms of Kharsali earthquake recorded at Tapovan site (N-S) component. Time : 40 secs. Solid line : observed seismogram, hatched line : synthetic seismogram.

Stress pattern studies in NW Himalaya: Microearthquake data from 2004-2007 in the magnitude range 1.0-5.0 of NW Himalaya has been analyzed to asses the tectonic behavior and stress pattern studies in the India-Eurasia continent-continent collision zone. The seismic pattern shows three clusters of events along these major faults/lineaments, first cluster is located around Kangra-

Chamba region, which is the site of 1905 great Kangra earthquake (M=8.0), second cluster is the region between Garhwal region, and the third cluster is SE of Dehradun i.e. Kumaun. Fault plane solutions are determined for the earthquake events having atleast 10 number of P-wave first motion polarity. The P-T axis obtained from these fault plane solutions (FPS) are plotted on a focal sphere to observe the P-T axes distribution. Most of the P-axes of cluster-I are concentrated near the horizontal and which indicates thrust faulting in this region and majority of P-axes shows NNE trend. In cluster-II fault plane solutions of 14 events are determined, in this cluster most of the events have thrust and strike-slip fault plane solutions. The P-axes are concentrated near periphery and it shows thrust to strike-slip type of faulting. In the cluster-III, we have taken fault plane solutions determined by Previous workers and USGS, P-T axes plot on a lower hemisphere projection of focal sphere shows the P-T axes trends towards NNE direction. For the stress tensor inversion in our study region, we have considered the fault plane solution data of events of cluster-I, II and III. Since the inversion results satisfies our acceptable criteria of 95% confidence, the region of the greatest and least principal stress components do not overlap, and the misfits are $\leq 12^o$. we have inverted 21 fault plane solutions for cluster-I, the inversion result shows average misfit of 8.5^o and stress magnitude value R=0.5 with maximum principal stress axis ($\sigma1$) trending 220^o and having plunge of 44^o, intermediate principal stress ($\sigma2$) trends 335^o and plunges 24^o and least principal stress axis ($\sigma3$) trends 84^o and plunges 37^o respectively. In the cluster-II, the inversion result shows, strike–slip type of faulting in the region with misfit amounting to 7.9^o, and stress magnitude ration R=0.4. The maximum principal stress axis ($\sigma1$) trending 282^o and having shallow plunge of 14^o, intermediate principal stress($\sigma2$) trends 159^o and almost vertical plunges 65^o and least principal stress axis($\sigma3$) trends 17^o and shallow plunges 20^o respectively. The stress regime is suggesting reverse to strike-slip regime due to oblique attitude of intermediate and minimum stress axis. In the stress tensor inversion for the FPSs of cluster-III, the principal compressive stress($\sigma1$) trends 219.5^o with 13.6^o of plunge, intermediate stress axis trends 126.3^o and plunge 13.1^o and the minimum compressive stress axis trends at 353.9^o and plunges at 70.6^o with a stress magnitude ratio of 0.46, the misfit is amounting to 3.5^o. The principal compressive axis shows NNE directed orientation with thrust type of faulting in this sector of NW Himalaya

5.8 Seismic microzonation and shallow subsurface studies in NW Himalaya and adjoining areas

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

The thick gravel sequence of the Dehradun fan, located in the intermontane Doon valley in frontal Himalaya, is imaged in terms of shear-wave velocity using the principle of Multichannel Analysis of Surface Waves (MASW). The study enables us to divide the Dehradun fan into three different zones which gave some insight into tectonics and climatic condition prevailing during the past. The subsurface velocity variability helps to track climate-tectonic controlled three phases in the temporal evolution of the fan. During the phase I, gravel deposition was marked by bi-variant high velocity distribution (400-550 m/s; >550-700 m/s) in the deeper part of the proximal zone bordering the Main Boundary Thrust (MBT), which is attributed to the spatial distribution of calcareous cement. The phase II in the evolution of the fan was marked by the period of erosion and carbonate dissolution in the entire fan resulting in cavity like features seen as Low Velocity Enclosures (LVE) in a high velocity sequence. The end of phase II was marked by sedimentation of moderate velocity (>250 m/s – 450 m/s) sequence associated with silty/sandy gravel sequence, which smoothened the relief of the pre-existing surface. Phase III is identified with the reactivation of MBT in the north and Mohand anticline in the south. This resulted in deposition of unconsolidated gravels with muddy matrix. This sediment is characterized as low velocity sequence (200-280 m/s) with thickest section in the narrow channel like structure created immediately south of the Bansiwala Thrust, perhaps due to tectonic upliftment of the middle zone.

5.9 Site Response Studies in Major Population Centres / Cities of North Western India

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

Jammu city

Jammu city is located close to the Main Boundary Thrust (MBT) and in between two active seismic source zones i.e. Kashmir seismic zone and Kangra seismic zone. Jammu city is characterized by soft sediments and strong seismological site effects so subjected to a large seismic risk. A site amplification study of this city was presented

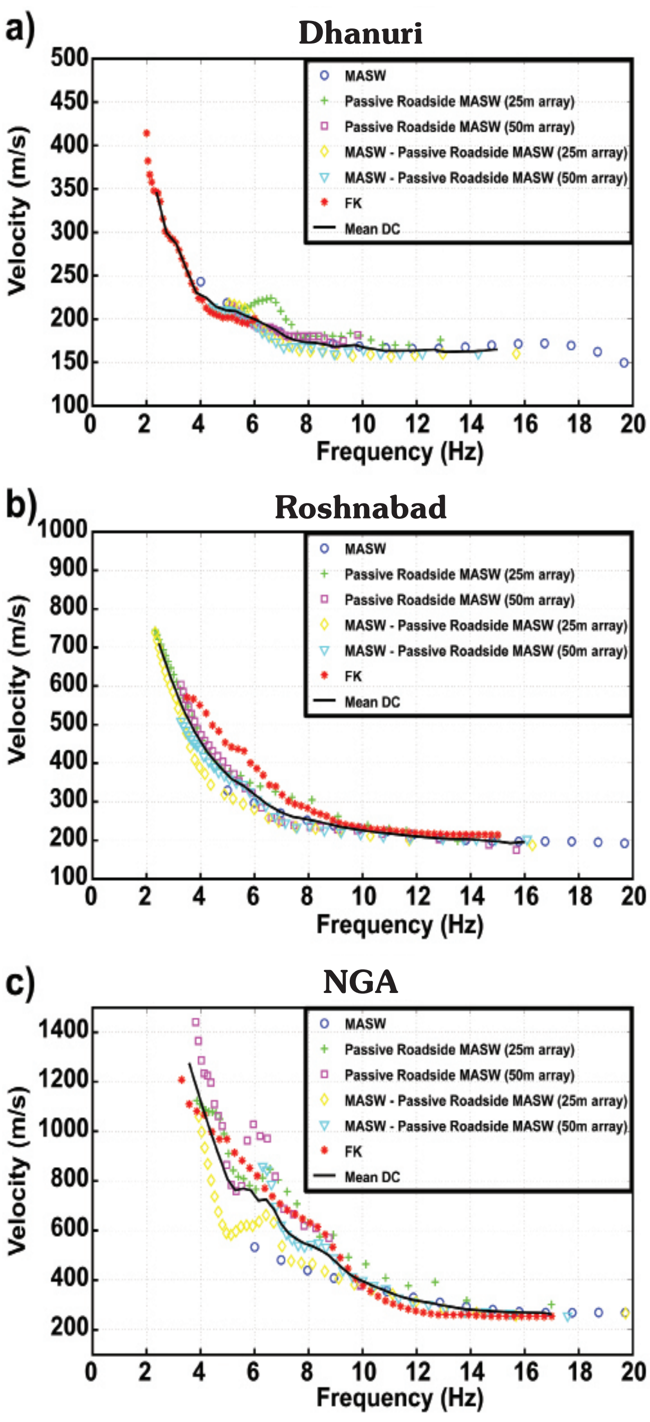


Fig.27. **a)** Shows amplification curve derived using model HVSR for Talabtilo. Red line is observed HVSR (from field microtremor measurement). Blue line is theoretical HVSR of starting model (in accordance with shallow seismic reflection profiling) and black line is HVSR of final model that best fits observed data. **b)** Vs profile derived from MASW. **c)** a comparison of 1-D Vs versus depth is shown for MASW and modelHVSR. d) Resonance frequency of same site using HVSR.

by two different methods i.e. active MASW (Multichannel Analysis of Surface Waves), seismic reflection method at 30 sites and HVSR (Horizontal-to-Vertical Spectral Ratios) using single-station noise measurements at 136 sites. Shear wave velocity (Vs) derived from 30 representative sites of the city for the upper 30 m soil column shows Vs ranges from 180 m/s – 700 m/s. According to the NEHRP classification the city can be divided into three major classes i.e. class C (> 360 m/s), D (180-360 m/s) and E (<180 m/s). Active MASW proved most useful in a case of target depth which does not normally exceeds more than 30 m but since the central part of the city is underlying with upper Siwalik conglomerate deposits, the surface wave penetrates up to a depth of 50-70 m. Using shear wave velocity (low strain values) of soil profiles up to 30 m depth, coupled with strong motion data (magnitude 6.8 mb) and other geotechnical properties, the seismic response shows resonance frequencies of the order of 1.55 Hz to 3.3 Hz. On the other hand the extensive HVSR survey allowed the fundamental resonance frequency (0.432 to 4 Hz) of these sediment cover to be mapped and identify areas prone to site amplification. The HVSR method yield direct estimates of the fundamental frequency and depth of soft sediments. The results of both the methods (common sites) are in good agreement with the distribution of geological units, indicating a progressive decrease in resonance frequencies in the northern and southern direction of the city w.r.t. central NW-SE extending zone, where bedrock is exposed at shallower depth. However, it is observed that where the impedance contrast between the bed rock and near surface sediments was high, HVSR results shows good agreement with MASW in terms of Vs and depth (Fig. 27). The comparison of MASW and the inverse model of HVSR at few sites (MAM College, JKPS Kunjwani) show coherence in results within confidence limit of 10 -15% variation.

5.10 Dynamics of Crustal shortening and Lithospheric Structure of Garhwal-Kumaun Himalaya

(Rajesh Sathyaseelan)

The total geoid anomalies obtained from the satellite geopotential method is shown in Fig. 28. The lithospheric geoid anomalies were delineated from the total geoid. In general, the total geoid anomaly over the Himalaya-Tibet region varies from -70 m to -15 m. The low geoid anomaly in the Indo-Gangetic basin is mainly due to the flexure of the Indian lithosphere rather than that due to the sediment load. Modeling of the observed geoid anomaly is under progress in order to estimate the lithospheric rheological parameters. The signatures of the low density lithospheric mantle geoid observed in the Garhwal-Kumaun Himalaya region are used as model inputs to decipher the viscosity parameters. A few high resolution geo-potential coefficients from the recent satellite missions have been incorporated to compute the geoid anomalies. The developed theoretical formalism has been used to do the multiple wavelength analysis of the geoid. This has helped to disintegrate the various harmonic coefficients according to the depth of the anomalous body.

Analysis of geoid anomalies over the Himalaya and its contiguous oceanic zone in the Indian plate are also studied. The observed strong regional density anomaly dipolar field in the Indian plate suggests the existence of a regional north to south lateral lower mantle flow with in the Indian plate.

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

(Swapnamita Choudhury)

Available ENVISAT and ERS satellite data processing for deformation study for the Bam earthquake, Iran (26 December 2004) and the Chamoli Earthquake, India (29 March 1999) have been done to study coseismic deformation. Interferograms produced bring out the deformation in the earthquakes as observed from satellite line of sight.

The data has been selected in a 100 km x 100 km window surrounding the Tehri Dam based on time intervals of a few months to more than a year and low baseline difference. The general strain conditions for the region prior to reservoir filling have to be assessed. This will be the background for further studies after reservoir filling. GPS observations in the same region will compliment the observations through InSAR.

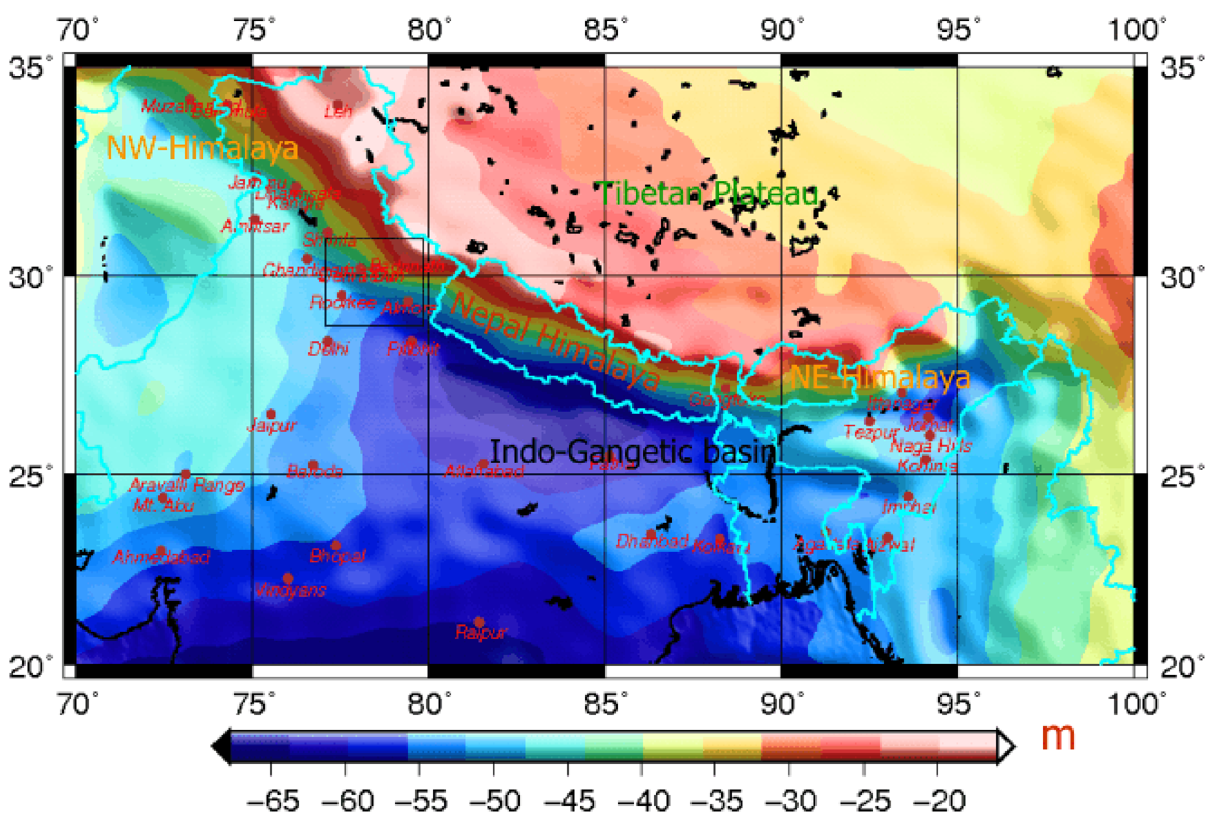


Fig.28. Geoid anomalies over the Himalaya-Tibet region.

Apart from crustal deformation, analysis of ERS tandem data for glacier movement rate for the Gangotri Glacier, India has also been attempted using InSAR.

5.12 Monitoring of geophysical and hydrological change due to impounding of reservoir

(B.R. Arora, V. M. Choubey, Gautam Rawat and P.K.R. Gautam)

With objective of monitoring geophysical changes due to impounding of reservoir, one campaign mode observations to record total magnetic and GPS data at 16 bench marks around Tehri reservoir was completed. Geomagnetic signals are superposition of various signals originated from various sources inside and outside the Earth. Tectonomagnetic origin signal is week and sophisticated method is required in order to observe week signals associated with tectonomagnetic origin if any. Two continuous magnetic stations at Bhatwari, Pipaldali along with continuous data from MPGO Ghuttu are taken for reference to draw differential plot for day and night. Differential plots are used to get preliminary indication of anomalous field of local origin. A more sophisticated method Principal component analysis (PCA) was used to discriminate these small signals. The method is applied continuously to each benchmark along with simultaneous data from two station of continuous recording of total magnetic field.

During the 5th campaign (June –July 2008) radon data was collected from the existing 16 bench marks around the Tehri dam reservoir. The radon value varies from 5036 Bq/m3 to maximum of 35900 Bq/m3 with an average of 15075 Bq/m3. Beside radon, atmospheric pressure and temperature was also recorded on the respective bench marks. The radon data collected during last five campaign periods have been analyzed with reference to other parameters like Tehri reservoir water level, air temperature and atmospheric pressure. In general no significant correlation of radon emanation has been observed with the atmospheric parameters. Whereas week positive relation between radon emanation and reservoir water level was observed during second, fourth and fifth campaign period.

GPS data has been collected in five campaigns (Oct. 06, July 07, Nov. 07 and May 08) at fifteen bench marks established around Tehri reservoir. The data has been collected alternatively pre monsoon and post monsoon continuously for five days at each bench mark. To observe the effect of pore pressure due to reservoir water loading GPS data was processed using 10.32 version of GMIT / GLOBK Linux based software. In the processing we take care for all assumptions and norms which are designed for the precise processing. Initially three campaigns (Oct. 06, July 07, and Nov. 07) of GPS data have been processed with respect to global igs sites and analyze the results with different sets of combinations. Later for obtaining the regional geological / geophysical variation, we have considered the local permanent GPS station and include the fourth campaign GPS data (May 08) in the processing and got the results with respect to our permanent GPS site Ghuttu.

We have analyzed the computed results and correlate the velocity vectors, time series at each bench mark for different campaign. The changes in velocity vectors during different campaign period probably due to loading and unloading of water level in the reservoir that causes ground deformation in the area.

SPONSORED PROJECTS

PROJECT

Multi-parametric Geophysical Observatory for Earthquake precursor studies

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

Although the high precision equipments have the requisite sensitivities to record characteristic stress-induced perturbations, the isolation of weak precursory signals is still mathematical challenge as each geophysical time series has characteristic time variability related to varied sources. This year the main focus was to develop methodologies for understanding the characteristics of time variability in different time series. In this direction, the formulation of principal component analysis is found effective in magneto-telluric data to isolate the waveform changes related to magneto-spheric and seismo-tectonic origin in the geomagnetic field intensity. Fractal approach is successfully applied to distinguish the varied dimension component associated with distant EM waves resulting from solar wind-magnetospheric interactions and those from near surface waves emanating from the straining of crustal rocks. The wavelet approach was adopted to isolate the unwanted noises in the gravity data of SG.

The MPGO is established in the central part of active seismic zone in the Garhwal Himalaya which is corroborated by a close network of BB seismic stations. This seismic network is linked through VSAT to monitor real time seismicity at the Central Recording Station (CRS) at Dehradun. After the installation of MPGO, as a part of independent project of MoES, we have strengthened seismic network in the Garhwal Himalaya that lowered down the earthquake detection threshold to nearly M1.8 from M2.5 existing in 1999. The recent data of earthquakes ($M \geq 1.8$) have highlighted a high seismic activity in the region south and very close of MCT. One observation from the seismic data is to evaluate the Vp/Vs ratio on daily basis for using it as a tool of earthquake precursor. The variation of Vp/Vs from July 07 to December 08 shows that the value of Vp/Vs is uniform around 1.73 and the phenomenon of drop of Vp/Vs (by about 10-15%) and its recovery has not been observed till date that is necessary as precursory signal.

Continuous gravity measurements are being carried out using sophisticated superconducting gravimeter (SG) installed at MPGO Ghuttu for observing the gravity variation produced by continental convergence. The SG is so sensitive that is measure gravity variation up to µGal level that is sufficient to observe the small subsurface variation up to few tens kms. Two years gravity observations show a heavy influence of tidal forces, atmospheric pressure and hydrological effects. The recorded data is sufficient to remove the continuous and systematic effects of tidal forces and atmospheric pressure using regression analysis. The usefulness of data adoptive techniques like wavelet and singular spectrum analysis developed to de-noise and estimate the time varying amplitude of tidal effects as well as atmospheric pressure. After removing these effects the hydrological influence of rainy season has been observed that has an influence up to 30 µGal. Major emphasis is on to adopt an approach which allows parameterizing the influence of tides, pressure and hydrology in the gravity data. The principal component analysis and the wavelet analysis procedure are being utilized to remove the atmospheric and co-seismic effects to isolate the earthquake precursors.

The continuous observation through SG at Ghuttu has been shown in Fig. 29a in nm/s2 that is cleared from gaps, spikes and steps. The atmospheric pressure variation in mbar for the same period observed at Ghuttu is given in Fig. 29b. The residual obtained after removing the effect of tidal and pressure is given in Fig. 30c. In order to investigate the variation related to hydrological effect in the gravity residual continuous observation of water table level is recorded in the borehole. In the Himalayan region heavy rainfall of over 25 mm/h is occurred in the rainy season from June to August. We investigated the gravity variation for whole rainy season as well as for short period before and after heavy rainfall. The short period influence caused gravity changes in the order of 1 µGal after occurrence of heavy rainfall while the overall effect is up to 30 µGal as shown in Fig. 29c.

Continuous radon monitoring has been deployed in 68m deep borehole (water well) near the Main Central Thrust. The recording of radon emanation in counts is carried out at 15 min intervals along with ancillary environmental parameters. The most obvious feature in

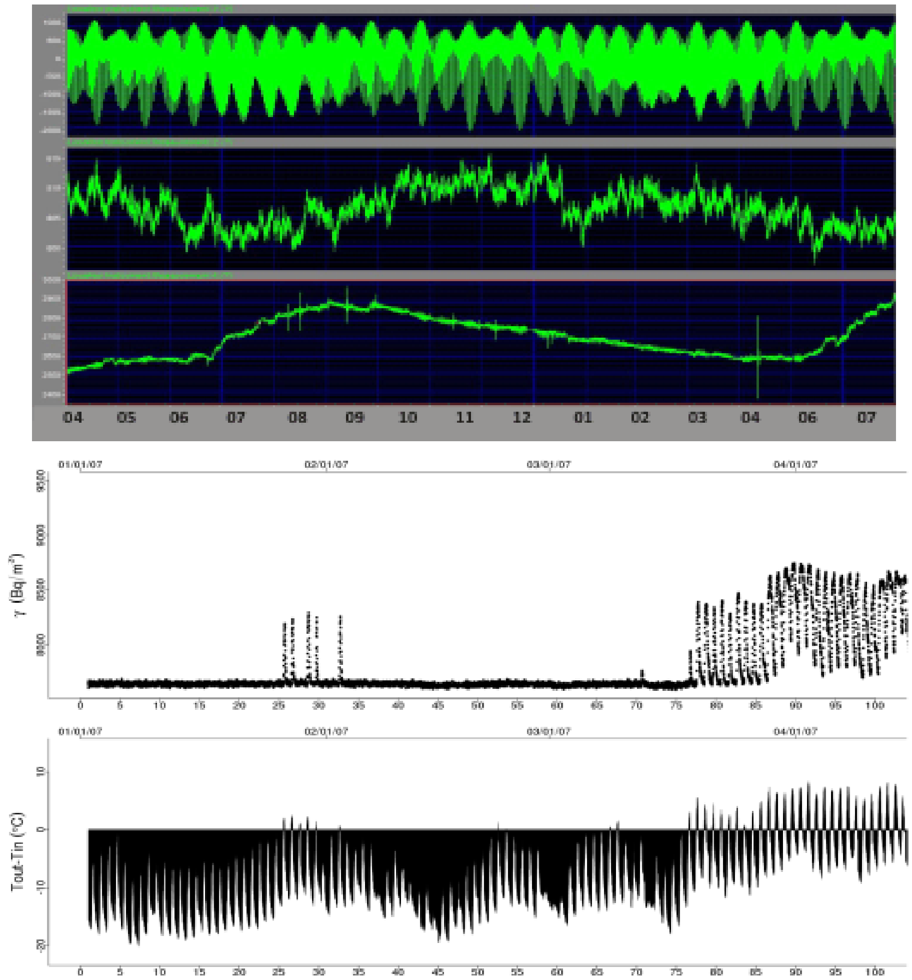


Fig.29. Continuous **(a)** gravity recording by superconducting **(b)** atmospheric pressure and the residual of gravity obtained after removing tidal and pressure effect.

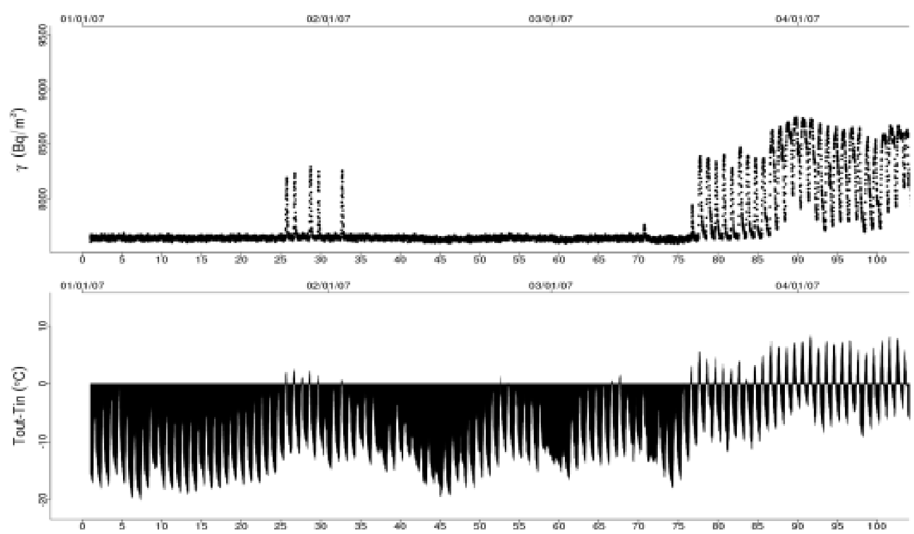


Fig.30. Convection effect for enhancing the radon emanation **(a)** Radon concentration **(b)** Borehole inside and outside temperature difference.

the time series of Radon measurements is the seasonal (annual) cycle of variability in emanation, with high values in summer/rainy season (July to September) and low values in the winter months (January to March). Radon daily variability does not follow a systematic pattern throughout the year. Three types of peaks were observed in the radon time series. The Rn concentration starts in the early afternoon (14:00) and reaches a maximum around 18:00, returning to the background concentration level by the end of the day. In spring, the radon variability at the daily scale exhibits a distinct pattern, with a well defined daily cycle starting around 10:00, peaking at 20:00 and decreasing slowly during the rest of the day. Over three months data has been plotted in Fig. 30.

Considering radon data series of last two years (2007-2008) we realized that the periodicity in radon peaks during the typical months of the year is not only controlled by outside temperature but mainly influenced by the difference between the outside air temperature and the stable temperature inside the borehole (Fig. 31). When the temperature difference is negative (i.e. when the outside air temperature is lower than the temperature inside the borehole), as happens during winter, the radon concentration displays a stable level. However, if the gradient is reversed (i.e. if the outside temperature is larger than the inside temperature) then the radon concentration increased. This increased value has a lag of a few hours following the gradient reversal. This mechanism is particularly obvious in the winter period. In the autumn period, radon variability seems to be influenced not only by the thermal gradient, but also by high water level following the monsoon that plays an additional role. Nevertheless the temperature difference to the outside and inside of the borehole is a dominant factor influencing the temporal variability of radon.

PROJECT

Multiple Geophysical Investigations around Eastern Himalayan Syntaxis

(DST Deep Continental Studies)

(B.R.Arora, Sriram, Gautam Rawat and Devajit Hazarika)

Passive Seismic Experiment

Twelve broadband seismic stations were under operation in the eastern flank of the Eastern Himalayan syntaxis (Lohit province – Mishmi Hills, Arunachal Pradesh) during the period April 2007 – August 2008 in order to probe the deep subsurface structure of the region. A preliminary picture of the subsurface structure below the Eastern Himalayan Syntaxial region has been obtained based on receiver function estimations in these 12 broadband seismic stations, outlining the significant insights gained on the complexities of the crustal structure emerging from the syntaxial tectonics of the region. The receiver functions show an azimuthally varying lithosphere structure in the region. The majority of receiver functions for the events of NE back azimuths (30° to 85°) do not show clear Moho converted phase (Ps) depicting a very complex structure of the crust and upper mantle originated due to the complicated deformational style in the syntaxial bend. The time section plot of radial receiver functions from all the 12 stations shows a dipping structure of Moho from west to east. The results obtained from modelling of receiver functions confirm the gradual increase in Moho depth in the E-W profile, from 46$\pm$2 km at Brahmaputra valley (near Mahadevpur) to 62$\pm$2 km east Walong thrust. The complicated lithospheric structure at Tidding suture zone is well reflected from the multiple reflected phases in the receiver functions of Salangam (WSGM) seismic station. Further improvement of the results obtained from receiver function studies would be made integrating additional information from Magnetotelluric (MT) survey, gravity and surface wave imaging.

Measurement of the strength and orientation of azimuthal anisotropy using the SKS splitting technique have been carried out for some events recorded by 8 stations in the seismic station profile mentioned above. The standard grid search method of Silver and Chan (1991) was used. The fast axis orientation in these stations is observed to be ENE-WSW oriented with delay time 0.8 – 2.5. About 50 teleseismic events of magnitude >5.5 in the epicentral distance of 80-120 have been selected for mantle anisotropy study. The analyses for the other station data are under process.

Out of 11 occupied MT stations along the profile, seven have yielded acceptable transfer function for further modelling. The most conspicuous feature of all sounding curve is their phase is above 45 degree for both polarisation in all stations for the period band of 1sec to 100 sec indicating the presence of conductive features at mid crustal level. Nonlinear conjugate gradient inversion for 2-dimensional model of subsurface is in process utilising above mentioned seven MT transfer function.

PROJECT

Erection of Standard Reference Sections for the Siwalik Group in India, Linkage and Migration of the Siwalik Mammalian Faunas

(A.C. Nanda and R.K. Sehgal)

The work was confined to laboratory investigations. The investigations include interpretation of data including the field work carried out earlier, reconstruction and identification of mammalian fossils and writing of research papers/ monograph for publication. The stress was on relations of the Siwalik faunas with younger faunas including Recent Mammalian fauna. In addition Standard Reference Sections for the Siwalik Group in India were finalized. Linkage of the faunas with Europe, central Asia and Africa was established. The highlights are briefed below.

Combining the available magnetostratigraphic data and mammalian fossil data

For the first time in India, the P.I. identified in past two biostratigraphic interval-zones for the Upper Siwalik Subgroup. Now emphasis was to recognise the interval-zones for the Middle Siwalik Subgroup. Middle Siwalik faunal lists of Samba Mansar section, Jammu, Nurpur, Haritalyangar and Paonta were compiled and updated. Haritalyangar area is found rich in mammalian fossils and both Nagri and Dhok Pathan faunas are known. Nagri Fauna has 69 mammalian taxa, whereas Dhok Pathan Fauna has 21 taxa. Faunal elements of both "Hipparion s. l." Interval-Zone and Selenoportax lydekkeri Interval-Zone are present in Haritalyangar. However, "Hipparion s. l." Interval-Zone can be demarcated in Haritalyangar area, despite the fact that sections in Potwar Plateau are very rich if compared to Indian section. Common taxa include "Hipparian s.l." (represented in Haritalyangar by Hipparian antilopinum and Cormohipparion theobaldi), Progonomys sp. (represented in Haritalyangar by P. choprai), Propotamochoerus hysudricus, Dorcobune nagrii, large giraffe (represented by Hydaspitherium megacephalum) and Tetraconodon magnus.

Relations of the Siwalik faunas with the post-Siwalik, Kurnool and the Recent faunas

Relation of the Siwalik faunas with post- Siwalik faunas has been worked out earlier and work was published. Now the detailed investigations on the relation of Siwalik faunas with the younger faunas (including Kurnool Cave Fauna, and Recent Fauna) are undertaken for the first time in India. List of Kurnool Fauna and list of Recent Fauna with reference to Siwalik genera are compiled and updated. Their generic nomenclature is also revised and updated. Elephas is very dominating form in all faunas, but missing in Kurnool Fauna.

For the first time relations of Siwalik faunas, with younger faunas (includes post- Siwalik faunas of Indo-Gangetic Plain and Peninsular India, Kurnool Cave Fauna and Recent Fauna) was established. Elements of Recent mammalian faunas start appearing in the late Middle Siwalik and these were established in the Pinjor Formation. There are 36 common genera between the Siwalik and Recent Fauna. These thirty six Siwalik genera are represented by 112 species in Recent Fauna. There are 23 common genera and 14 common species between the post-Siwalik and Recent faunas. There are 32 common genera and 16 common species between the Kurnool and Recent faunas. There was constant increase from Siwalik to post-Siwalik to Kurnool to Recent faunas. It shows the strengthening of the elements of Recent Fauna.

Siwalik Compendium

The work on Siwalik compendium of the faunal varieties has been restarted. Work on proboscidean fossils, including identification and Systematic Palaeontology, was completed. Identified proboscidean collection includes Stegolophodon stegodontoides, Anancus sivalensis, Stegodon insignis, S. katliensis, Elephas planifrons and E. hysudricus. A rare juvenile elephant skull belonging to E. hysudricus is identified and described. In addition a partial skull is referred to E. planifrons. Works concerning the recent advances in Siwalik biostratigraphy and systematic palaeontology of other mammalian groups are under progress.

Erection of Standard Reference Sections

Standard Reference Sections for the Chinji, Nagri, Dhok Pathan and Tatrot formations are finalized in Indian Siwalik belt. In addition, type sections for the Pinjor and Boulder Conglomerate formations are also established. While recognizing the Standard Reference Sections or type sections, the emphasis was mainly on fossiliferous area and availability of magnetostratigraphic data.

Linkage of the various Siwalik faunas with the contemporary faunas of Europe, Africa and Asia

This work was also finalized. Linkages of the Siwalik faunas were established with equivalent horizons of Europe, Africa, central Asia and Turkey. Till Oligo-Miocene the main Himalayan Range was not a barrier for the migration of the fauna. Even in Oligo-Miocene, Kargil area of Trans Himalaya region provided a link between central Asian localities and Bugti area of Pakistan. It was during the deposition of Siwalik Group that Himalaya started acting as a barrier for migration across its width.

PROJECT

Himalaya School earthquake Laboratory Programme

(A.K. Mahajan)

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

PROJECT

Telemetric Seismic Monitoring of Garhwal for Developing Hazard Scenario in Uttaranchal

(B.R.Arora, Ajay Paul and Naresh Kumar)

A ten station telemetered seismological network of Broad Band Seisomograph (BBS) was installed in Garhwal Himalaya by July 2007. Each station is equipped with Trillium-240 (broadband) seismometer and of high dynamic range (>138 dB) Taurus data acquisition system (DAS). High accuracy GPS synchronies the DAS clock every minute. All the stations of the network are connected to the central station at Dehradun by VSAT. The network is shown in figure 31 on the tectonic map of the region along with seismic activity. The seismic data is being acquired in real time and it is processed immediately to monitor the local seismic activity of the region. If a local event of M >3.5 is recorded then its phase data is passed on to IMD for assessing the seismic activity on regional basis.

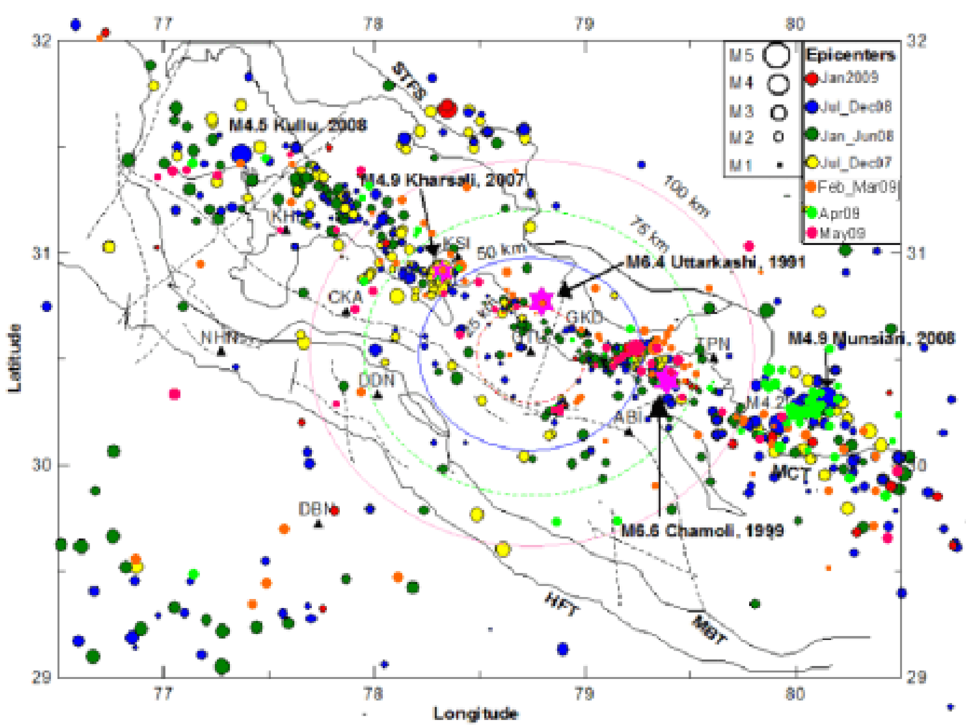


Fig.31. Epicenter plot of online data from July 2007 to May 2009.

During this period the largest earthquake of M4.9 was recorded near Kharsali. Its epicenter was located at a distance of 60 km from 1991 Uttarkashi earthquake. The location of this earthquake is given in Fig. 31. Since installation, five thousand nine hundred and thirty eight (5,938) events have been recorded by the network till May 2009. Of these, one thousand five hundred seventy six events (1876) events are teleseismic recorded from more than 1000 km from the central station Dehradun. Two thousand seven hundred twenty four (2724) events are regional recorded from 300 to 1000 km distance. One thousand five hundred thirty eight (1538) events are of local origin most of which are located within the network. The dense network has brought down the minimum detection magnitude threshold to 1.8M.

Figure 31 shows the local seismic activity is concentrated in the south to the main central thrust (MCT). These events have magnitude range 1.0-5.0 which includes Kharsali earthquake of M4.9. The accumulated number of earthquakes shows the clustering of seismic activity at few places. Out of these, two clusters are prominent one is in and around the epicenter of Kharsali earthquake and the second one is very near and towards NW of the epicenter of Chamoli earthquake (Mb 6.6, 1999). The clustering of seismicity at few places has been observed from the beginning and became more prominent with passage of time. The location of clusters has been shown in figure 32. The most conspicuous feature of epicenter plot is the clustering of events (M≤3.5) in the source zone of Chamoli earthquake and Kharsali earthquake (Ml 4.9, 2007)

To better understand the seismoteconic behavior of the region, the P-wave polarity information recorded at different stations for seismic events with in the network and having magnitude more than 3.0 is utilized to obtain the fault plane solutions. We obtained the fault plane solutions of three earthquakes occurred near Kharsali, Guarikund and Kullu of the study region. Two of these earthquakes show reverse fault motion with strike slip component while the third one near to Gaurikund has pure strike slip movement. The strike slip movement near Gaurikund has nearly vertical dip.

The space time pattern are regularly being examined to demarcate space time patterns of enhanced/ quiescence that invariably precede large earthquakes in this region. No anomalous pattern identified in the short period of 1.5 years (Fig. 32).

PROJECT

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

(A. Krishnakanta Singh)

Chromian spinel (Cr-spinel) chemistry plays an important role in classifying mantle-derived peridotites in terms of geotectonic setting and also an important petrogenetic indicator in ultramafic / mafic rocks because it contains several cations as major and minor constituents and recognized as sensitive mineral for deducing the ambient conditions during magma crystallization. The main factors responsible for compositional control of Cr-spinel are the composition of parent melt, composition of minerals crystallizing with Cr-spinel, melting behaviour of mantle, nature of crystallization and physico-chemical parameters (temperature, pressure, fO2, etc). In view of such significance, mineral chemistry of Cr-spinels in peridotites of Manipur Ophiolite Complex (MOC), Indo-Myanmar Orogenic Belt (IMOB) has been studied in

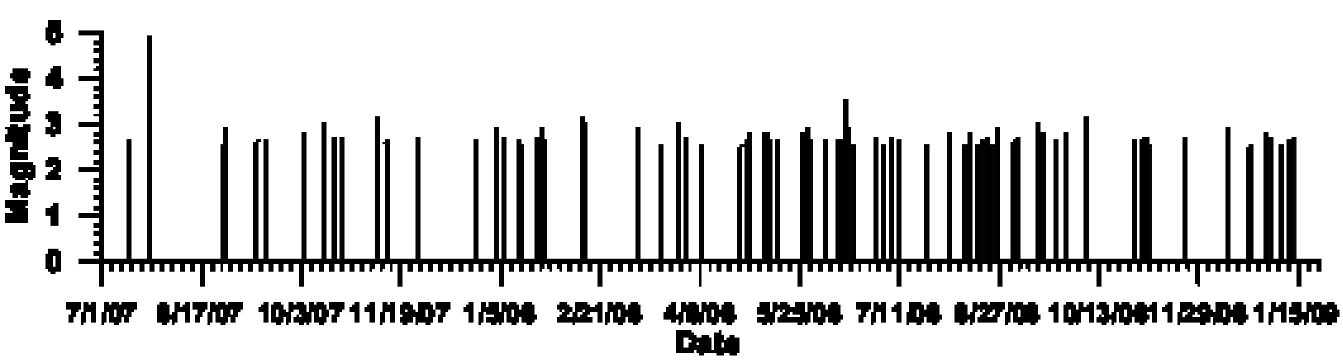


Fig.32. Chronological sequence of earthquakes (M.2.5) recorded by VSAT online network.

order to understand their nature of parental magma and geotectonic setting.

The Cr-spinel in peridotites (Fig. 33a, b&c) characterized by low Cr_2O_3 (10.03-23.37 wt.%) and high Al_2O_3 (43.77–55.86 wt.%), FeO (11.45–12.45 wt.%) and MgO (16.98–18.41 wt.%). The Cr # and Al # has spacious ranges of 18.00 to 26.36 and 74.26-88.36 respectively. Overall data of Cr_2O_3 shows negative correlations with Al_2O_3 and MgO. High Mg # (70.58-73.43) in the samples reflects the subsolidus exchange of Fe-Mg between Cr-spinel and surrounding silicate minerals. The TiO_2 content varies from 0.01 to 1.0 wt.%. Thus their chemistry is comparable to those of observed in Cr-spinel of alpine and abyssal peridotites. This feature is also supported by the binary plot of Mg # - Cr # Cr-spinels (Fig. 34a) and triangular plot of Al-(Fe_3+Fe_2+2Ti)-Cr. The investigated Cr-spinels have Cr # (~21) which are comparable with the mid oceanic ridge tholeiites (Cr # = 20-54). However, these values are lower than the values of those of layered intrusions such as Bushveld and Stillwater (Cr # = 70-85) and those of boninites (Cr # = 80-90). The TiO_2 contents (0.01–1.0) of Cr- spinel are also comparable with those of the Mid Oceanic Ridge tholeiites (TiO_2 = 0.16-0.85 wt.%). Low Fe_3+ # (0.59-1.56) and Fe_3+/Fe_2+ (0.04-0.11) values. In the present analyzed Cr- spinel grains suggests that these ultramafic formed at low fO_2. The Al_2O_3-TiO_2 variations (Fig. 34b) and Al_2O_3-Fe+2/Fe+3 variations in Cr-spinel of MOC in comparison to modern-day tectonic settings depict MORB-type peridotite. Thus the characteristics of host rocks and Cr #, Al_2O_3 and TiO_2 values suggest that the Al-rich chromian spinel of MOC may have derived from a tholeiitic melt of MORB setting at the low degree of partial melting.

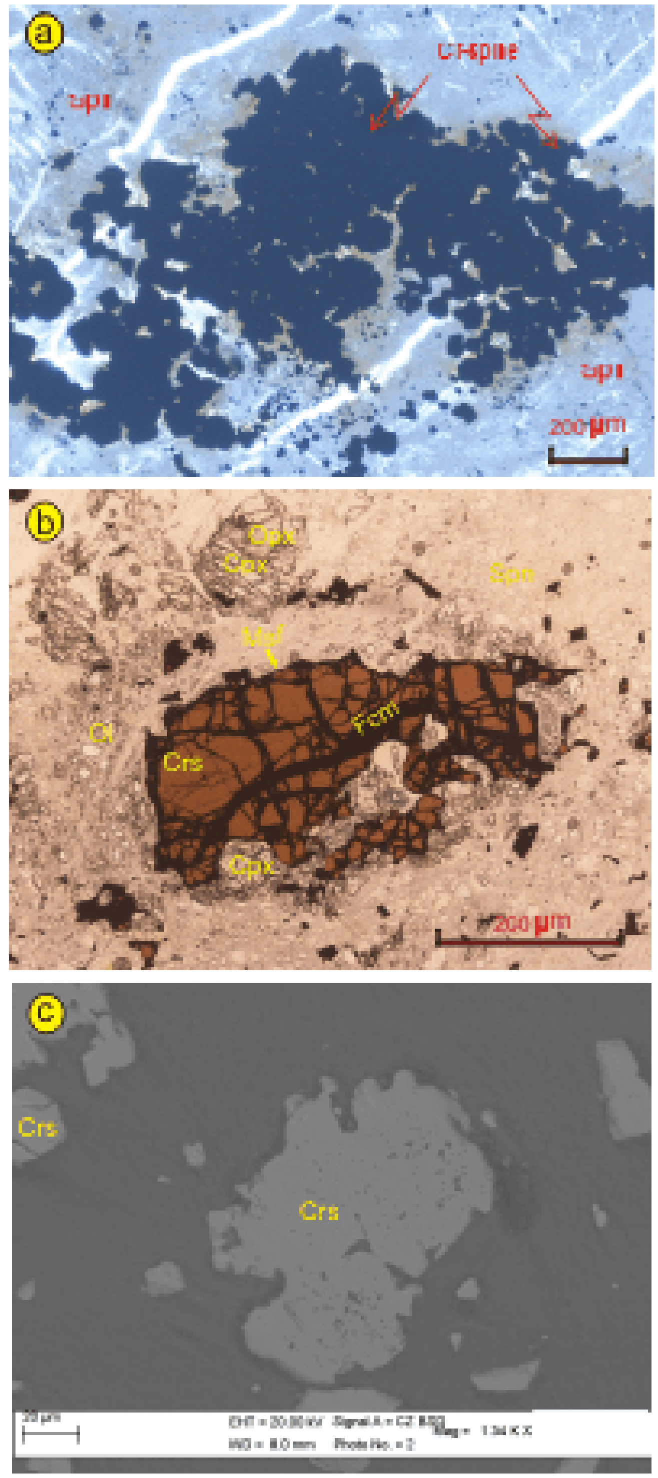


Fig.33. Photomicrographs of (a) Euhedral to subhedral Cr-spinel in serpentinite and (b) Isolated Cr-spinel grain (c) Back-scattered electron image of Isolated Cr-spinel grain. Crs = Chromian spinel; Fcm = Ferritchromite; Msf = Magnesioferrite; Ol = Olivine; Opx = Othopyroxene; Cpx = Clinopyroxene; Spn = Serpentine.

PROJECT

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

(DST-SERC)

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

Field work was carried out in different sections of the Spiti basin. The faunal assemblages, sedimentological features and lithostratigraphy of three sections were studied. Lithostratigraphic column of Pin and Parahio Valley were

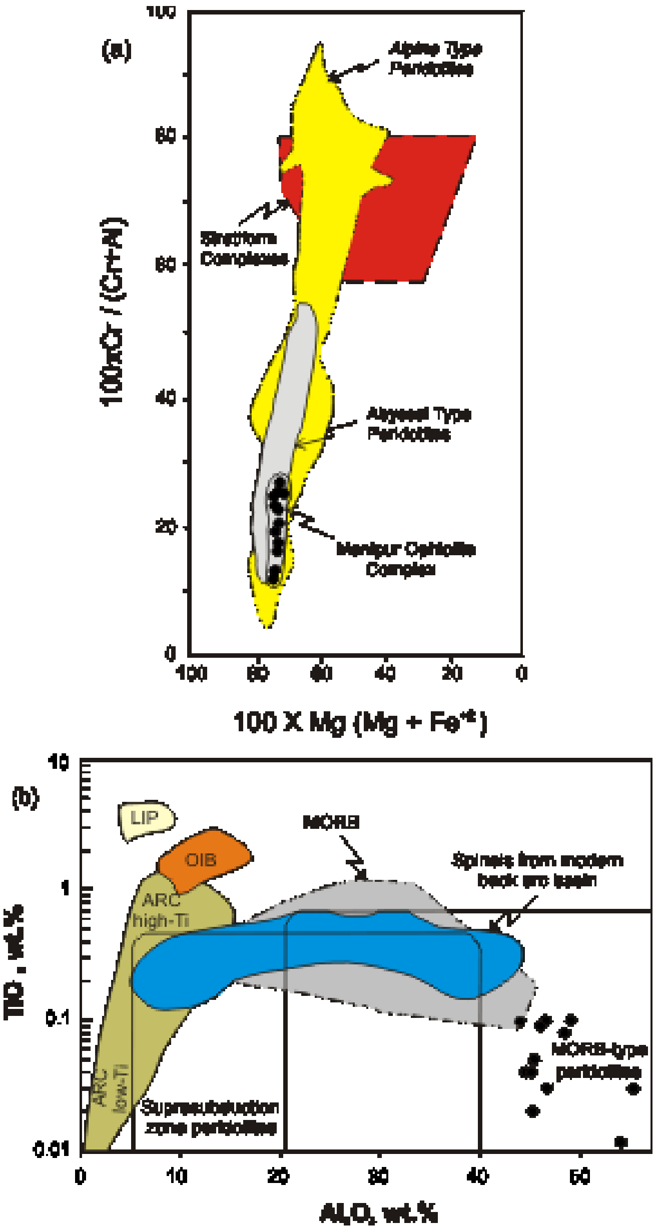


Fig.34. (a) Binary plot of 100Cr/(Cr+Al) vs 100Mg/(Mg+Fe) and (b) TiO_2-Al_2O_3 plot of Cr-spinels of peridotites of the Manipur Ophiolite Complex, Indo Myanmar Orogenic Belt.

prepared. Based on petrography and lithological studies distinct lithofacies identified. The fauna collected from the different sections mainly belonging to the different genera of trilobites, trace fossils and some brachiopods. Few species of trilobites belongs to the Parahio Valley were selected for the Morphometric analysis. Applying the Morphometric techniques three genera of trilobite identified they are as Pagetia, Eodiscus, and Oryctocephalus. These three genera are indicative of the Middle Cambrian age. The genus Pagetia selected for the detailed ontogenic studies. Simultaneously the sedimentological part is also in progress.

PROJECT

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

(NSF- National Science Foundation, USA)

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

Detailed stratigraphy of Cambrian and Ordovician successions was studied during a fieldwork. The depositional ages of several units in the Everest region were studied. The siliciclastic strata and the underlying Yellow carbonate band shows the late Middle Cambrian age. The detrital zircon data also contains a similar age to those from the Middle Cambrian strata in northern India, which supports the depositional age and continuity of depositional system along the length of the Himalaya. The North Col Formation rocks (= Everest series), between the Qomolangma and Lhotse detachments of the South Tibetan detachment system, and locally preserved sedimentary textures and primary stratigraphy match with the Cambrian strata ~1100 km to the west in northern India reveals. This was demonstrated a coherency of depositional systems and stratigraphic architecture for Cambrian deposits along much of the Himalaya Tethyan margin.

PROJECT

Active faults and neotectonic activity (with reference to seismic hazards) in parts of the Frontal Himalaya and the Piedmont zone between the Satluj and Yamuna rivers in eastern Himachal Pradesh (AFNAH-II)

(DST Seismology Programme)

(N.S. Virdi and G. Philip)

An area covering the Tons, Giri and Gambhar drainage basin has been scanned using satellite images and 1:50000 scale toposheets. Preliminary pre-field survey along the Satluj river up to Khab where the Spiti river joins the Satluj has helped to demarcate some areas for detailed work along the Chail, Jutogh thrusts in the Lesser

Himalaya and Vaikrata thrust and S.T.D. (South Tibetan detachment) in the Higher Himalaya. Major alluvial fans and four to five levels of terraces occur up to the M.C.T. zone upstream of Rampur. Beyond Rampur, the Satluj flows through a deep gorge and few terraces have been noticed at higher levels. At Jeori, Wangtu, Tapri, Khadra and Tidong evidences of past blockades have been observed. Along major tributaries of Satluj e.g. Baspa and Ropa, landslides or moraines from retreating glaciers have blocked the channels and produced extensive lacustrine deposits. These could provide good evidence of past neotectonic activity.

The area south of Narkanda-Mahasu abnormal ridge, which defines the water divide between Satluj and Yamuna-Tons has been broadly divided into (a) lying between the MBF (Bilaspur thrust) and the MBT encompassing the Lower Tertiary sediments (Subathu, Dagshai- Kasauli sequences) covering a time span from Paleocene to Miocene. This terrain is also traversed by a number of major intra basinal thrusts which have caused repetition and often obliteration of litho-units. (b) Terrain lying north and north-east of the MBT in the catchments of Pabar, Giri and Gambhar rivers is constituted by pre-Tertiary sediments of the Krol belt, its basement of Simla-Jaunsar in the south and thrusted over by the metamorphic thrust sheets (Chail and Jutogh) in the upper reaches of the major rivers. The Chail and the Jutogh thrust sheets occupy high altitude (2500-3500 m) terrain around Shimla and Chur peaks and extend further in the Higher Himalaya.

Outer Himalaya

The MBF separates the Siwalik sediments from the Lower Tertiaries. The thrust zone has been examined in details at Kalawar in the Tons valley and Dhon in the upper catchment of Markanda River. Good evidences of strike-slip movement along the MBF have been collected at these and some other localities along the extension of the thrust zone NW of Kalka in the catchment of the Baddi and the Kuthar nadi west of Subathu. Lacustrine deposits at Dhon and a number of localities NW of Kalka deposited in pull-apart basins are good candidates for OSL dating.

Intra-basinal faults

East Nahna, Sirauli and the Surajpur thrusts are major intra-basinal thrusts in the Lower Tertiary belt showing evidences of strike slip and have exercised strong control on topography and drainage alignment. At a number of localities evidences of past diversion or river capture and creation of wind gaps have also been observed.

Lesser Himalaya

The MBT separates the Lesser and the Outer Himalaya. The Lower Tertiary belt which is only 0.25 to 0.5 km wide between Tons and the Giri River widens out NW of Baila and Dadahu to over 20km. The Krol thrust has now a separate status separating the Krol belt from the Lower Tertiaries in contrast to the Doon valley, where the Siwaliks are directly over ridden by the Krol belt. The thrust zone has exercised profound control on alignment of major streams. Deflection of major tributaries near the fault zone show evidence of strike slip apart from uplift in the hanging wall. This shows that over all movement is oblique to regional NW-SE strike. The MBT zone is also subjected to frequent slope failure.

The Giri Thrust/Kandaghat Fault

The Giri thrust separates the Simla-(Jaunsar) group sediments from the Krol Belt. The fault traceable along the Giri River upstream of Dadahu follows the Ashni River between Dudham and Kandaghat. NW of Kandaghat it is traceable up to Jamrot. Between Kandaghat and Jamrot it behaves as a strike slip fault with upthrown eastern block. In general the Giri thrust dips steeply due north east (60 to 65o) though in some sectors the dip is moderate 30 to 35o. The thrust zone has exercised strong control on the alignment of the Giri and Ashni rivers when they flow NW to SE as axial streams along the regional strike.

The topography in the hanging wall of Giri thrust has high altitude with Chur (3647 m) while on the footwall the highest point is Krol peak (2253 m). The Giri and Ashni axial rivers running NW-SE are joined by big stream/ rivers from NE. Ashni (transverse segment), Giri (transverse segment), Nait-ka-khala, Palor ka khala, Nait khala all have their own wide drainage basins with perennial flow draining into the Giri axial river. The streams flowing from south between Solan and Dadahu are relatively shorter in length. This indicates an asymmetrical behavior of the Giri basin with tilting to the SW. The transverse segment of the Gambhar River joins the main axial segment and then joins the Satluj River south of Bilaspur.

Evidences of Neotectonic Activity

Apart from possible activity along major faults, we have observed evidences of neotectonic activity resulting into:

1. Drainage diversion along strike slip faults.
   a) Examples along the Taksal fault (HFT) dextral slip and pull apart basins,
   b) Giri linear = Kandaghat fault, dextral slip again shown by major tributaries.

2. Tilting of Quaternary drainage basins observed along:
   a) Giri main channel and the Ashni (NW-SE trend) upto Kandaghat.
   b) Baliana nadi beyond Kandaghat.
   c) Kuthar nadi west Subathu.

The tectonic tilting of the longitudinal drainage basins is more apparent in the outer part of the Lesser Himalaya and the major part of the Outer Himalaya. Morphometric parameters such as Drainage basin asymmetry, Ratio of valley floor width to valley height (Vf) and Transverse topographic Symmetry factor (T) are being calculated for both the longitudinal and transverse segments of major drainage basins to ascertain the effects of Neotectonic activity.

Transverse fault / lineaments

Apart from longitudinal faults/thrust which show strike slip, the area is traversed by a number of major and minor transverse faults/lineaments. These trends NE-SW or NNE-SSW i.e. perpendicular and oblique to the regional NW-SE strike of major structural and lithological belts. Major lineaments include the Giri, Ashni and Gambhar. The Giri and Ashni linears control the drainage channels of Giri and Ashni transverse segments which join the main Giri River at right angle. These linears possibly lie parallel to some basements structures (Virdi, 1979) which extend from the peninsular region below the Gangetic Plains into the Outer Himalaya and possibly under the Lesser Himalaya. The Rohru lineament controls the Pabar River which after flowing E-W takes a right angle turn and flows to the south downstream of Rohru. Two prominent NS faults have also been observed upstream of Rohru and control the tributaries draining N to S. Along the Tons river also preliminary scanning has shown three or four zones showing neotectonic activities. Man ka Khala upstream of Koti dam reservoir shows evidence of diversion and possible piracy in future.

PROJECT

Neotectonic - Active Tectonics of 1905 Kangra Earthquake Meizoseismal Region in Kangra and Soan Dun in Himachal Pradesh, NW Himalaya

(DST Seismology Programme)

(V.C.Thakur)

The MSK intensities, isoseismals, of 1905 Kangra earthquake extended 300 km to the SE along the regional Himalayan trend upto Dehradun and 100 km SW to the Indo-Gangetic plain. Active tectonics of three areas were studied having direct relevance in understanding the kinematics and seismotectonics of large earthquakes like that of 1905 Kangra earthquake.

Partitioning of convergence/slip rate in Kangra re-entrant and Dehradun region

The geodetic measurements indicate 18-20 mm/yr, out of total 45-50 mm/yr, of convergence/slip is consumed in the Himalaya (Bilham et al. 1997), and the remaining shortening is accommodated farther north of Himalaya in Tibet and Central Asia. It was demonstrated in Nepal Sub-Himalaya (Lave and Avouac, 2000) that ~18 mm/yr convergence is accommodated on the Main Frontal Thrust (HFT). We have established the Piedmont Fault (PF) south of the HFT in the Ganga plain and out of sequence fault faulting, Bhauwala Thrust, occurred in the Dehradun region. The 1905 Kangra earthquake of magnitude MW 7.6 affected the maximum intensity on the northern part of the Kangra reentrant. In the Kangra reentrant, the long term shortening rate between the MBT and the HFT calculated on the basis of balanced-cross-section and GPS measurement are 14 ± 1 mm/yr are 14 ± 2 mm/yr (Powers et al. 1998, Banerjee and Burgmann 2002). Using strath terraces along the Banganga river between Kangra and Guler, and dating of an abandoned alluvial fan on the culmination (hinge zone) of the Janauri anticline, we have calculated the convergence/slip rates of the Jawalamukhi Thrust and the HFT. Our results indicate out of the total shortening/slip rate 14-15 mm/yr, 3 ± 0.5 mm/yr and 6 ± 0.5 are accommodated on the Jawalamukhi Thrust and the HFT respectively. The remaining balance ~ 3 mm/yr, may have been consumed by the Soan Thrust and the Palampur Thrust. Our observations indicate partitioning of convergence/slip by the HFT, Soan Thrust, Jawalamukhi Thrust and Palampur Thrust.

Earthquake generated Chandigarh anticlinal ridge

North of Chandigarh, the NW-SE tending frontal Siwalik range is made of an asymmetric and broad open fold of the folded upper Siwalik strata. The large fold is designated the Chandigarh anticline. The Himalayan Frontal Thrust (HFT) demarcates the physiographic and tectonic boundary between the southern limb of the Chandigarh anticline and the Panjab alluvial plain. The Chandigarh anticline was formed as a fault-bend fold as a result of slip over the HFT. The northern limb of the fold extends into the broad and wide sym formal structure of the Pinjor dun. Post-Siwalik Pinjor dun sediments built by the coalescing alluvial fans range in (OSL) age 90 to 20 ka with young Holocene terraces. The evolution of Pinjor dun and its complementary Chandigarh anticline initiated during Post-Siwalik (500 Ka) and pre dun (~100 Ka) interval. The paleoearthquakes breaking the surface have been documented along the HFT scarps in the Holocene sediments near Chandigarh. The surface ruptures of paleoearthquake showing single displacement of 12 m to 30 m slip and 9 m-13 m vertical uplift on the HFT have been reported in Nepal and Garhwal Sub-Himalayan front. More recently post-earthquake survey of 2005 Kashmir earthquake of magnitude 7.6 has shown 3-5 m and maximum 7 m of vertical separation, denoting uplift, along the surface rupture. The Chandigarh anticline and its resultant ridge topography was built in fault band/ propagated fold as a result of cumulative slip generated on the HFT by successive earthquakes during a time span post-Siwalik (0.5 Ma) and pre Pinjor dun sediments (~0.1 Ma). Assuming a lower value of average coseismic slip of 5 m produced by the large earthquakes of magnitude MW ≥8 on the HFT decollement with recurrence interval of 1000 years in earthquake cycle will generate >1000 m height topography within the time span of 200,000 years. Since the Chandigarh anticline ridge is <10 km wide and the anticlinal fold has grown over the decollement <8 km at depth, this segment width cannot invoke isostatic uplift.

Extension of Balakote-Bagh Fault to Reasi Thrust (MBF)- an active fault system between Jhelum and Yamuna.

Muzaffarabad-Tanda active fault was mapped by Japanese workers before the 2005 Kashmir earthquake. the 2005 earthquake produced surface rupture ~70 km long trending NW-SE and showing vertical separation (uplift) 3-5 m. The surface rupture occurred on the trace of the earlier mapped fault, designated after the earthquake as the Balakote-Bagh Fault (BBF). Hussain et al. (2008) described the southeast extension of the BBF with right-step to the Reasi Thrust of the Jammu region. We (VCT, RJ, MM) have undertaken active tectonic study in Reasi-Katra area. The Reasi Thrust in Reasi-Katra area of Jammu region lies between the stromatolite bearing Proterozoic Jammu/Sirban Limestone and the overlying Subathus and Murrees forming the hanging wall and the underlying Siwalik constituting the footwall. The post-Siwalik Vaishnu Devi layered gravels (late Quaternary-Holocene) dip NE 30 to 45o are folded at some places. Four geomorphic surfaces with gravels cover are recognized. The S1 and S2, older surfaces, show tectonic scarps which were developed as a result of thrust fault, F1 and F2, dipping NE at low angles. The F1 and F2 faults are interpreted as imbricates developed on the footwall of the Riasi Thrust.

In the present nomenclature, the Main Boundary Thrust (MBT) defines a tectonic boundary between the Tertiary Sub-Himalaya and the pre-Tertiary Lesser Himalaya. South of the MBT, we have established another tectonically important fault that extends from Muzaffarabad (river Jhelum) and Reasi in Jammu and Kashmir to Bilaspur and Nahan (river Yamuna). In Jammu and Kashmir, Wadia (1931) had designated the fault separating the lower Tertiary with limestone inliers from the Siwaliks as the Main Boundary Fault (MBF). The same fault between the lower Tertiaries and the Neogene Siwaliks was called the Main Boundary Fault (MBF) by Medlicott (1869) in the Simla hills. Later workers gave local area names to the MBF as the Reasi Thrust in Jammu, the Palampur Thrust and the Bilaspur Thrust in Kangra reentrant and the Nahan Thrust in Sirmur. Wadia's MBF extends east of Hazara-Kashmir syntaxis to the river Yamuna, covering a distance of ~ 700 km. The MBF shows evidence of reactivation and neo-active tectonic activity on the Balakote Bagh Fault, Reasi Thrust, Palampur Thrust, Bilaspur Thrust and Nahan Thrust. The MBF lies within the rupture zone of 2005 Kashmir earthquake, instrumental seismicity belt of 1905 Kangra earthquake rupture, the Pinjor Garden Fault rupture zone and probably 1555 Kashmir earthquake rupture zone. The instrumental seismicity belt, that lies south of the topographic front of the High Himalaya, extends northwest encompassing the Dhauladhar and Pir Panjal ranges. The redefined Wadia's MBF represent an active and seismogenic fault system that extends from Jhelum to Yamuna.

PROJECT

Rock Properties Laboratory -A National Facility (DST- Earth Science)

(Vikram Gupta)

With the objective to create a database on the various physical, elastic and mechanical properties of the Himalayan rocks, field work has been carried out in the Alaknanda and Bhagirathi valleys covering rock types of the Lesser and the Higher Himalaya. About 80 block samples of different lithology like gneisses, migmatites, schists, phyllites, limestones, quartzites, and metabasics were collected from the field and about 450 cylindrical cores were drilled from the block samples in the laboratory. Physical properties like density and porosity; elastic properties like compressional (P-) and shear (S-) wave velocities and attenuation characteristics and the mechanical properties like Schmidt hammer rebound (R-) values and unconfined compressive strength (UCS) were measured and their inter-relationship established.

Preliminary results indicate that there is a positive linear relationship between density and velocity and between velocity and attenuation characteristics for all the rock types. Amongst the rock types studied, metabasics exhibit the highest density, P- and S- wave velocities and Poisson's ratio, whereas, metaquartzite belonging to the Pandukeshwar Formation exhibits the lowest P- and S- wave velocities ranging between 2018 m/s and 2671 m/s and between 1273 m/s and 1780 m/s, respectively. This is mainly attributed to the presence of micaceous minerals which significantly reduces both the P- and S- wave velocities. There seems to be no effect of porosity on the various properties as it is <1 % in all the rock types studied.

It has further been noted that there is a large variation in the elastic and mechanical properties of orthoquartzite belonging to the Berinag Formation of Lesser Himalaya, despite being composed predominantly of about 90-95% quartz. This has been attributed to the composition and percentage of the matrix present. Siliceous matrix increases the seismic velocities, whereas the micaceous matrix reduces it. It has also been observed textural properties and recrystallisation and presence of certain minerals affect the various physical, elastic and mechanical properties of rocks.

PROJECT

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

(Pradeep Srivastava)

The work in the DST sponsored project was focused to develop the understanding on (1) deformation pattern in Alaknanda valley using Ground Penetrating Radar (GPR) (2) Sedimentation pattern in a glaciated (Mandakini) and a non-glaciated (Nayar) tributaries of Alaknanda. The detailed geomorphic and Ground Penetrating Radar (GPR) studies combined with Digital Elevation Model (DEM) studies in the lower Alaknanda Valley of Lesser Garhwal Himalaya have been found useful in understanding the Quaternary tectonic activity within the mountain prism. The study have confirmed the occurrence of an earlier inferred E-W lineament (Sati et al. 2007) and has helped in picking a new NS trending fault in the river bed below Horticulture Research Centre of the HNB Garhwal University. The other evidence of neotectonic activity observed in the area are; subsidence of about 8 m, E-W trending cracks of 2 to 3 cm wide and the vertical subsidence of about 15 cm over the metalled University road at Chauras. GPR survey along the E-W trending road clearly showed occurrence of a 6 m wide palaeochannel oriented along ~ N-S direction. The luminescence chronology indicates that this fault was active ~25–10 ka and has been responsible for the formation of the terraces around Srinagar. The sedimentation pattern in Mandakini and Nayar rivers was studied in the exposed sections. The study suggested that the sedimentary sequences in the glaciated catchment of Mandakini are dominated well sorted imbricated gravels represented channel filling via aggradation on the channel bars. On the contrary the aggradation in the non-glaciated catchment of Nayar was more controlled by debris flows and landslide events as represented by the dominance of poorly sorted sub-angular gravelly lithofacies.

PROJECT

"Earthquake risk reduction in the Himalaya" as a part of Indo-Norwegian collaboration with NORSAR

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

This study report sites investigations in the Himalayan foothills where different methods have been applied and

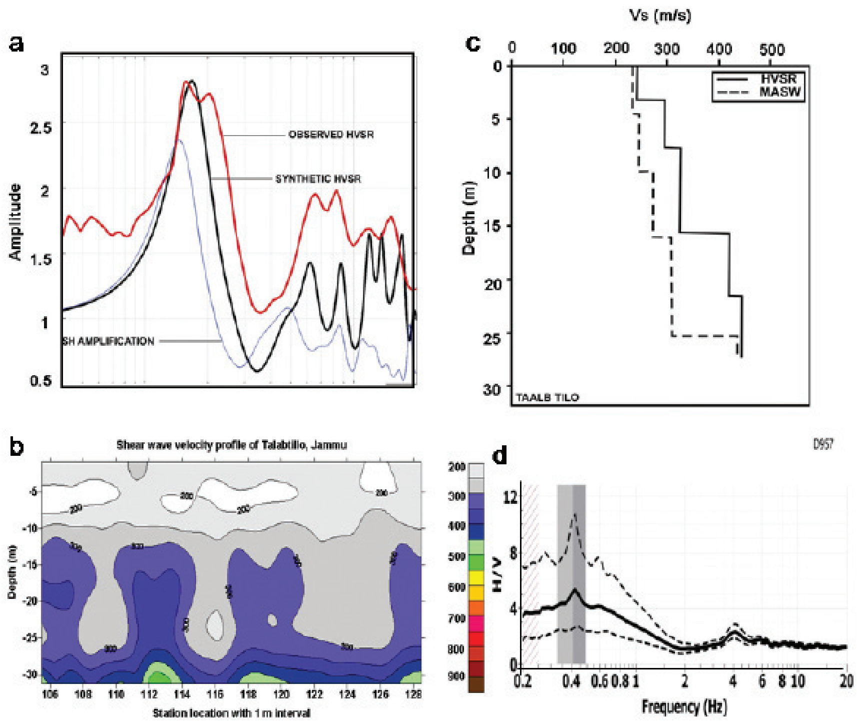


Fig.35. Comparison of the dispersion curves obtained through different methods: active MASW, passive remote MASW (with two circular array of 25 and 50 m of aperture, respectively), f-k analysis, and the combination of active MASW and passive remote MASW. The results are shown for the three sites: **a**) Dhanuri, **b**) Roshnabad, and **c**) NGA.

compared. The accuracy of the Multichannel Analysis of Surface Waves (active method), the frequency–wave number spectrum (f-k) and the ReMi passive methods vis-a vis their depth penetration and respective resolution in determining shear wave velocity has been analyzed. We carried out seismic reflection using a linear array (active MASW), Refraction Micro-tremor (ReMi) a circular array (passive array) and short-period micro-tremor measurements of a circular shaped array at three different sites. The locations of sites were chosen w.r.t. the Himalayan Frontal Thrust (HFT) for characterization of the sedimentary cover derived either from fan deposits or river deposits. Using these techniques, we measured phase velocities for frequencies between 2.3 Hz and 15 Hz and compared the results derived from all three methods. As a result of the study, we conclude that the active MASW method has better resolution for the shallow part i.e. down to 20-30 m than the f-k and (ReMi) methods for determining the Rayleigh-wave phase velocity from records. On the other hand, the ReMi and f-k methods proved to be very useful for obtaining better estimates below 30 m, especially in the sandy beds (Ganga sediments) where seismic waves penetrate poorly below 20 m depth due to the very low shear wave velocity. The dispersion curves estimated through the different methods shows very good coherence and the combination of the obtained results provided reliable information about the soil characteristics for these sites in terms of mean S-wave velocity, depth and resonance frequency of the sedimentary cover (Fig. 35).

PROJECT

Experimental investigations of shallow earth structures Using NIMFIS (Near surface Electromagnetic Frequency Induction Sounding) technology Under Integrated long term Programme (ILTP)

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

Under this project a joint field work has been carried out at three different sites using NEMFIS instrument. The penetration depth of the instrument was very less i.e. not more than 7 m which could be very useful for the archeological survey. Although the results derived up to 7 m meters with 3D profiles are good enough to understand any conducting material but not good for identifying the fault trace or differentiate different lithological units.

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Eocene Jaintia Group of Mikir Hills in Assam, Northeastern India. J. Pal. Soc. India (comm).

Technical Reports

Bartarya, S.K. & Asthana, A.K.L 2009. Geological report for the stabilization of Landslides along roads in Mussoorie Area, submitted to PWD, Dehradun

Dobhal, D.P. 2008. Interpretation of Observed data on Himalayan Glaciers (Chapter-4), Assessment Report on Himalayan Glaciers, submitted to Study group on Himalayan Glaciers constituted by Principal Scientific advisor to Govt. of India.

Gupta, Vikram & Asthana, A.K.L. 2008. Report on the Kangsali and Vallambitta Landslides on Motna - Madan Negi Motor Marg, New Tehri, Uttarakhand submitted to PWD, New Tehri, Borari with 11p. and 8 figs.

Gupta, Vikram & Asthana, A.K.L. 2009. Geological report on a part of the Lakhsyari – Ludhera – Kyari - Kachta Motor Marg and the Rani Gaon Link Road district Dehra Dun, Uttarakhand submitted to PWD, Sahiya (Kalsi) with 11p. and 8 figs.

Mazari, R.K. & Gupta, Vikram 2008. Report on the stabilization of Mansa Devi hill slope, Haridwar for Technical Committee, Government of Uttarakhand constituted for the study of Mansa Devi hill slope stabilisation.

Mazari, R.K., Gupta, Vikram & Bist, K.S. 2008. Report on the geological investigation of open channel section of Madhyamaheshwar Small Hydro Project, District Rudraprayag, Uttarakhand, submitted to Uttarakhand Jal Vidyut Nigam Ltd (UJVNL) with 11p. and 9 figs.

Mazari, R.K., Sah M.P. & Bhakuni, S.S. 2008. Geological Feasibility of the Jadh Ganga and Karmoli Hydro Electric Projects, District Uttarkashi Uttarakhand submitted to THDC, Rishikesh with 9p. and 5 figs.

Negi, P.S. 2008. Feasibility report pertaining to Forest Work Plan of Ramnagar forest division, District Nainital, Uttrakhand for the year 2008-09 to 2017-18.

Sah, M.P. & Bhakuni, S.S. 2008. Geological Feasibility report for the proposed reconstruction of residential blocks of Uttam Investment Pvt. Ltd, Tulimate Estate, Mussoorie.

Sah, M.P. & Bhakuni, S.S. 2008. Geological Feasibility Report of Proposed Alignment of Nainital By-Pass Road, Uttarakhand submitted to PWD Nainital with 10p. and 7 figs.

Sah, M.P., Bist, K.S. & Gupta, Vikram 2008. Geological Feasibility of Rambara Hydroelectric Project (RHEP) submitted to Additional Secretary (Energy), Department of Energy, Govt. of Uttarakhand

Sah, M.P. & Vikram Gupta 2008. Geological Feasibility of a site for the proposed residential house at Chaman Estate, Mussoorie.

Siddaiah, N.S. 2008. DST Project Report on "Mineralogical and Geochemical studies of sediments from the Kakara-Subathu Succession (Paleocene-middle Eocene), NW Himalayan Foothills" submitted to DST, New Delhi.

SEMINAR/SYMPOSIA/WORKSHOPS ORGANISED

International Symposium on "Mountain Building and Climate-Tectonic Interaction – (MBCT-2008)

An international symposium on "Mountain Building and Climate-Tectonic Interaction – MBCT-2008" was held in the Institute on October 23-25, 2008. Dr. A.K. Singhvi, Sr. Professor, Physical Research Laboratory, Ahmedabad was the Chief-Guest on the occasion, and Dr. V.K. Dadhwal, Dean, Indian Institute of Remote Sensing, Dehradun presided over the function. The seminar coincided with the Founder's Day of the Institute and also a special year in the completion of its 40 years.

In this International Symposium eight technical sessions were conducted to address seven themes like "Orogenesis and Model", "Erosion and orogeny", "Mountain to Delta: Erosion, Sedimentation and Global change", "Climate and Tectonic expressions in Hinterland- foreland", "Tracking Palaeoclimate through proxy records", Regional and Intraplate tectonism" and "Ancient Records" under the shadow of MBCT. The symposium provided common platform to the eminent geoscientists and research delegates from both national and international geoscientific institutions and universities like Universidade do Porto, Portugal, University of Rochester, University of California, Vanderbilt University, University of Cincinnati, Brigham Young University, Central Washington University; Oregon State University in USA; National Taiwan University, Taiwan; Physical Research Laboratory, Delhi University, Birbal Sahani Institute of Palaeobotany, Lucknow University, Banaras Hindu University, Calcutta University, Kurukshetra University, HNB Garhwal University, Wadia Institute of Himalayan Geology etc for sharing their views on the mentioned themes on climate-tectonic interaction through oral or poster presentations during these sessions. In total 44 posters and 49 papers were orally presented during these eight technical sessions.

Chief Guest Prof. A.K. Singhvi along with Dr. V.K. Dadhwal, Dr. B.R. Arora and Dr. A.K. Dubey sharing the dias during the inauguration function of International Symposium on Mountain Building and Climate Tectonic Interaction.

VISITS ABROAD

- Dr. R.K.Mazari visited Kathmandu, Nepal to attend the UNDP Sponsored meeting on Glacial Lake Burst Flood regional project held on April 17-18, 2008
- Dr. P.S.Negi visited Dhaka, Bangladesh to attend Third South Asia Water Research Conference, on May 24-26, 2008
- Dr. B.R. Arora, Dr A.K. Mahajan and Dr A.K. Mundepi visited Norway under International joint collaborative programme NORSAR, in June 2008.
- Dr. V.M.Choubey visited Geological Survey of Israel, Israel, in connection with point data processing from June 16-29, 2008.
- Dr. P.P. Khanna visited Singapore to attend the Abu Dhabi Group's Knowledge Forum organized by ICIMOD, Nepal, on June 25-27, 2008.
- Dr. P.S.Negi visited Italy (Torino University) for Post graduate course in Mountain Environment & Global Climate Change, under international fellowship programme sponsored by UNESCO, FAO from 23 July to 06 August 2008.
- Dr. M.P. Sah visited Kathmandu, Nepal to attend the Workshop on Glacial Lake Outburst floods and flashflood risk assessment in Hindu Kush-Himalaya, organized by ICIMOD on 30 July to 1 August, 2008
- Dr. V.C.Tewari visited University of California, Los Angeles, USA, to attend World Summit on Ancient Microscopic Fossils on 27th July to 2nd August, 2008.
- Dr. V.C. Tewari visited Oslo, Norway to attend 33rd International Geological Congress on August 6- 14 2008.
- Dr. P.K. Mukherjee and A.K. Mahajan visited Oslo, Norway to attend 33rd International Geological Congress on August 6- 14 2008.
- Sh. Naresh Kumar visited St. Louis and San Diego, U.S.A to attend Training Program on Superconducting Gravimeter (SG), on August 11 – 31, 2008
- Dr. Kishor Kumar visited Royal Belgian Institute of Natural Sciences, Brussels, Belgium to attend a Discussion meeting on Late Paleocene-Early Eocene terrestrial mammal faunas of India, on August 30-September 7, 2008.
- Dr. V.C. Tewari visited International Centre for Theoretical Physics, Trieste, Italy, as Senior Associate of the ICTP on September 10, 2008.
- Sh. Naresh Kumar visited ICTP, Trieste Italy, to participate in Workshop on 3D Modelling of Seismic waves Generation, Propagation and their Inversion, September 22 – October 4, 2008
- Dr. A.K.Mahajan and Dr. Ajay Paul visited National Center for Research on Earthquake Engineering, Taipei, Taiwan to attend International Training Program for Seismic Design of Structures and Hazard Mitigation on October 20-24, 2008.
- Dr. G. Philip and Dr. Suresh. N. visited Active Fault Research Centre, Geological Survey of Japan, and Tsukuba Japan, under Indo-Japan co-operative science programme on Nov.5-27, 2008.
- Dr. R.K. Mazari visited Paro, Bhutan to attend "Regional Workshop on Glacial Lake Outburst Flood (GLOF) Risk Mitigation" on 20-21 January 2009.
- Dr. Swapnamita Choudhury visited Kathmandu, Nepal to attend the Regional Consultative Workshop on "Remote Sensing of the Cryosphere - Assessment and Monitoring of Snow and Ice in the HKH Region" held at International Centre for Integrated Mountain Development (ICIMOD) from March 31st to April 2nd, 2009.

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEES

Name of the Scientist	Status	Prestigious Committee/s outside WIHG
B.R. Arora	Member	Editorial Board of Current Science
	Member	Sectional Committee for Earth and Planetary Science, Indian Academy of Sciences, Bangalore.
G. Philip	Member, Executive Council	Indian Society of Remote Sensing, Dehra Dun Chapter
R.K. Mazari	Member, Executive Council	Indian Society of Remote Sensing, Dehra Dun Chapter
V.C. Tewari	Life Member	Indian Geologial Congress, Roorkee
Rajesh Sharma	Member, Scientific Committee	International Applied Geology Congress, April 2010, Mashad, Iran
	Member, Scientific Committee	Asian Current Research on Fluid inclusions, IIT Kharagpur
D.R. Rao	Member	Working Group of IGCP-510: A-type Granite
T. N. Jowhar	Executive Member	Council of the Indian Geological Congress, Roorkee for the year 2008-2009.
	Member	Computer Society of India, Dehradun
D.P. Dobhal	Member	Geometrics and Impact of Climate Change with Special reference to Mountain Ecosystem Uttarakhand
P.S. Negi	Member	International Programme on Research and Training on Sustainable Management of Mountain Area, managed by UNESCO, FAO
Barun K Mukherjee	Member	Life member, Indian Science Congress, Roorkee, INDIA
	Member	Life member, Japan Society for the Promotion of Sciences, JAPAN

AWARDS AND HONOURS

- Dr. V.M. Choubey was honoured with National Mineral Award for the year 2007, conferred by Ministry of Steel and Mines, Govt. of India for his excellence in research in the field of Geo-Environmental studies.
- Geological Society of India on its Golden Jubilee Celebration facilitated Dr. B.R. Arora for his contribution to Geosciences.
- Indian Geophysical Union bestowed Electrotek and Geometrics Endowment Award on Dr. B.R. Arora.
- Dr. P.S. Negi is a recipient of Schlich Prize -2006 award for best research paper published in The Indian Forester (award conferred during 2008).

Ph.D. THESIS

Name	Supervisor	Title of the Theses	University	Awarded/ Submitted
Shri Vivek Retwij Bhardwaj	Dr. R. Islam Prof. M. Raza	Geochemistry of Mesoproterozoic metasediments of Khetri Copper Belt, NE Rajasthan and its implication on provenance characteristics and tectonic setting.	AMU, Aligarh	Submitted
Upasana Devrani	Dr. A.K.Dubey Dr. P. C. Bahukhandi	Structural evolution of the Garhwal Synform: Field and anisotropy of magnetic susceptibility studies.	HNB Garhwal University, Srinagar	Submitted
Vivekananda Pathak	Prof. C.C.Pant Dr. Ajay Paul	Seismotectonics of the Dwarahat-Dhaulchhina area with special reference to neotectonics	Kumaun University, Nainital	Submitted
Gopal Singh Darmwal	Prof. C.C.Pant Dr. Ajay Paul	:Seismotectonics of the Dharchula, Munsiari and Berinag area with special reference to neotectonics	Kumaun University, Nainital	Submitted
Jyoti Shah	Prof. D. C. Srivastava Dr. P.K.Mukherjee	New Methods of strain Analysis and deformational Style of Kumaun Lesser Himalaya	IIT, Roorkee	Awarded
V Kumaravel	Dr. N. Siva Siddaiah Dr. S.J. Sangode	Rock magnetic and Geochemical Characterization of Plio-Pleistocene Paleosols from the Siwalik group of the Himalayan Foreland Basin, NW Himalaya	HNB Garhwal University, Srinagar	Awarded

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOPS/ TRAINING COURSES

Seminar/Symposia/Workshop

- Workshop on "Understanding the Planet Earth : Challenges Ahead" held at Survey of India, April 2008
  Participant: B.R. Arora

- Workshop on "Understanding planet Earth: Challenge Ahead, organized by geodetic and research branch Survey of India, Dehra Dun, 10-11, April 2008.
  Participant: M.P. Sah, P.S. Negi and A.K.L. Asthana

- Regional Glacial Lake Outburst Flood Project Meeting sponsored by UNDP, Kathmandu, Nepal, April 17-18, 2008.
  Participant: R.K. Mazari

- Meeting on 'Impact of Climate Change on Water Resources' Organised by GSI, Northern Region, at Lucknow, 21-22, April 2008.
  Participant: M.P. Sah

- Workshop on 'Role of Space Technology in the Development, Management and Conservation of Natural Resources' organized by USAC at Gopeshwar, Uttarakhand, 22, May 2008.
  Participant: G. Philip and A.K.L. Asthana

- Third South Asia Water Research Conference organized by Third South Asia Water Research Consortium and others at Dhaka, Bangladesh, 24-26 May, 2008.
  Participant: P.S. Negi

- Uttrakhand Sustainable Development Summit (USDS) organized by The Energy and Resource Institute, New Delhi, at Dehra Dun, 19-20 June, 2008.
  Participant: P.S. Negi

- Abu Dhabi Group's Knowledge Forum, held at Singapore from 25-27 June 2008
  Participant: P.P. Khanna

- World Summit on Ancient Microscopic Fossils, University of California, Los Angeles, USA 27 July to 2 August, 2008.
  Participant: V.C. Tewari

- Workshop on Glacial Lake Outburst floods and flashflood risk assessment in Hindu Kush-Himalaya, ICIMOD, Kathmandu, Nepal, 30 July to 1 August, 2008.
  Participant: M.P. Sah

- Training programme on Leadership Development Programme for Middle and Junior Level Scientists held at Lal Bahadur National Academy of Administration (LBSNA), Mussoorie 4-8 August 2008.
  Participant: Vikram Gupta

- 33rd International Geological Congress held at Oslo, Norway, 6- 14 August, 2008
  Participant: V.C. Tewari

- 33rd International Geological Congress held at Oslo, Norway, 6- 14 August, 2008
  Participant: P.K. Mukherjee and A.K. Mahajan

- National workshop on Ophiolites held at Calcutta University, Kolkata, 29, August, 2008
  Participant: A.K. Singh

- National Seminar and Workshop on Application of Remote Sensing and GIS in the Natural Resource Management, Sustainability and uses at H.N.B. Garhwal University, Srinagar Garhwal, 11-13 September 2009.
  Participants: A.K. Dubey and D.P. Dobhal

- International Symposium on Mountain Building and Climate-Tectonic Interaction" organized by Wadia Institute of Himalayan Geology Dehradun from September 23-25, 2008
  Participants: B.R. Arora, R.K. Mazari, R.J. Azmi, V.C. Tewari, Rohtash Kumar, S.K. Ghosh, D.K. Misra, K. Kumar, N.S. Siddaiah, Rajesh Sharma, B.N. Tiwari, G. Philip, R.S. Rawat, S.K. Bartarya, H.K. Sachan, Sushil Kumar, Pradeep Srivastava, Suresh. N, D.P. Dobhal, A.K. Mahajan, P.S. Negi, S. Rajesh, S. K. Rai, Barun K Mukherjee, S.S. Bhakhuni, K. Luirei, Narendra Kumar Meena, Koushik Sen and Chabak, S.K.

- 9th Workshop on 3D Modelling of Seismic waves Generation, Propagation and their Inversion: ICTP, Trieste, Italy, September 22, October 4, 2008
  Participant: Naresh Kumar

- Geological Society Golden Jubilee celebration, Bangalore, 11-13 October, 2008.
  Participant: B.R. Arora

- Geological society Golden Jubilee celebration and mobilizes students from different arts of NW Himalayan school in order to have interaction of students with scientist of the nations at Bangalore,11-13 October, 2008.
  Participant: A.K.Mahajan

- Intensive training course (Praveen), Central Hindi Training Institute, Ministry of Home Affairs, Govt. of India, New Delhi, October 7 to November 6, 2008.
  Participant: Kapesa Lokho

- 45th Annual Convention of the IGU and Meeting on Seismic Hazard and Crustal Earthquakes: Indian Scenario held at Banaras Hindu University, Varanasi on Novemeber 5-7, 2008.
  Participant: B.R. Arora

- 10th International Conference Power India 2008, organized by INDIA-TECH Foundation, at Mumbai 6-8 Nov 2008.
  Participant: S.K. Bartarya

- International Conference: Biotic and climatic changes in the Indo-China region held at BSIP, Lucknow, 8 – 13 Nov. 2008.
  Participants: B.R. Arora and N.R. Phadtare

- 2nd meeting of Asian current research on Fluid inclusion (ACROFI) at Deptt. of Geology & Geophysics, IIT Kharagpur, 12-14 Nov 2008.
  Participants: Rajesh Sharma and H.K. Sachan

- Brainstorming Session on Out of India Biotic Dispersal held at INSA, New Delhi, 22-23 Nov., 2008.
  Participant: B.N. Tiwari

- 7th General Assembly of Asian Seismological Commission, held at Tsukuba, Japan 24-27, November 2008, Participants: G. Philip and N. Suresh

- Seminar on "Indo-Myanmar Ranges in the Tectonic Framework of the Himalaya and Southeast Asia" at Department of Earth Sciences, Manipur University, Canchipur, Imphal, Manipur, 27-29 Nov. 2008.
  Participant : S.S. Bhakuni

- International Seminar on "Role of Plant Taxonomy in Biodiversity Management and Human Welfare" organized by Forest Research Institute and Association of Plant Taxonomy at DehraDun, 1-3, December 2008.
  Participant: P.S. Negi

- Workshop on Landslide inventory, Hazard and Risk Management under Asian Programme for Regional Capacity Enhancement for Landslide impact Mitigation (RECLAIM-II)" at IIRS, Dehradun 10-11 January, 2008.
  Participant: A.K. Mahajan

- Meeting of Directors and Scientists of autonomous Institutes of DST held at ARCI, Hyderabad, 17-18 January, 2009.
  Participants: B.R. Arora, Meera Tiwari and S.K. Rai

- Workshop on Glacial Lake Outburst Floods: A Risk Reduction Initiative in the Himalaya, Paro, Bhutan, 20-21, January 2009.
  Participant: R.K. Mazari

- National Conference on Geometrics and Impact of Climate Change with Special reference to Mountain Ecosystem Organised by Indian Society of Geomatics at Uttaranchal Space Application Centre, Dehra Dun 4-6, Feb 2009
  Participants: B.R. Arora, R.K. Mazari, M.P. Sah, G. Philip and D.P. Dobhal

- 7th International conference on advances in metrology (AdMet-2009), held at New Delhi, 18-20 February, 2009
  Participant: N.K. Saini

- 2nd International Conference on Precambrian Continental Growth and Tectonism, held at Department of Geology , Bundelkhand University , Jhansi, 24- 28 February, 2009
  Participant: V.C. Tewari

- Indo–Russian Workshop on Mitigation and Human Induced Disasters held at Indian National Science Academy (INSA), New Delhi, 4-5, March 2009.
  Participants: B.R. Arora and Vikram Gupta

- 3rd Meeting of the Expert Committee on 'Integrated Program on Dynamics of Glaciers in the Himalayas' held at School of Environmental Sciences, Jawaharlal Nehru University, New Delhi on March 17-18, 2009.
  Participant: B.R. Arora

- Workshop on "Groundwater Scenario and Water Quality in Uttarakhand organized by Central Ground Water Board, Uttarakhand Region, Dehra Dun 19 -20 March, 2009.
  Participant: S.K. Bartarya

LECTURES BY VISITING SCIENTISTS

Name and address	Date	Topic
Prof. Gajander Singh Former Vice-Chancellor Doon University, Dehradun	11.05.08	Technological Advancement in Uttarakhand: Mission of Doon University
Prof. M. Jayananda Dept.of Geology, Bangalore University, Bangalore	11.06.08	Formation and Cratonization of Archaean Continental Crust in Southern India
Dr. R. Chidambaram Principal Scientific Advisor, Government of India	29.06.08	Nuclear Energy and Climate Change
Prof. Krishna Sappal Curtin University, Perth, Australia	24.11.08	Colie Coal and Clean Coal Technologies
Prof. Daryl P. Domning Howard University, Washington, D.C	01.08.08	Sirenians and Seagrasses: An Ecomorphological Perspective
Dr. Alexander Webb Louisiana State University, USA	28.08.08	Structural and Geochronological Observations in Himachal Pradesh leads to a new Himalayan Tectonic Model
Dr. V.K. Jha Scientist (retd), IIRS, Dehradun	15.09.08	Hamari Rajbhasha Kaisi Ho
Dr. (Smt). Suman K Agrawal Deputy Secretary, DST, New Delhi	25.09.08	Karyashetra mein Abhiprerna: Kuch Vichar
Dr. M. Ramakrishna Bangalore	23.10.08	Mountain building and climate tectonic interaction
Dr. Frank Köhler, Australian Museum and College, St. Sydney, NSW 2010, Australia	26.11.08	Testing the relevance of the 'out of India' scenario for selected groups of freshwater snails
Prof. Takehiko Yagi Institute for Solid State Physics, University of Tokyo, Kashiwa, Japan	13.01.09	Approach to the mineralogy of the lower mantle: an experimental study
Dr. S.N. Bhattacharya Scientist, IMD, New Delhi	20.02.09	Computational Seismology
Dr Conrad Lindholm Scientist, NORSAR, Norway	25.02.09	Global Earthquake Modeling Programme: An international collaborative efforts

Name and address	Date	Topic
Prof. Girijesh Pant Vice-Chancellor Doon University, Dehradun	28.02.09	Globalization and Knowledge Regime: Making the right choice
Prof. Koji Okumura Hiroshima University, Japan	04.03.09	Recent development of research on active tectonics in Japan as a key for seismic hazard assessment and safety for nuclear facilities
Dr. Yuichi Sugiyama Director, AFRC, Geological Survey of Japan, Japan	06.03.09	Introduction to earthquake-related research in Geological Survey of Japan and recent study on an 80-km long active fault system in Tokyo Megalopolis

LECTURES BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
A. K. Dubey	Geological Survey of India, Dehradun	22.04.08	(i) Structural evolution of the Himalaya, and (ii) Initiation and development of faults.
Sushil Kumar	WIHG, Dehradun	22.04.08	Understanding of seismic waves
Swapnamita Coudhury	WIHG, Dehradun	20.06.08	Transient Thermal Earthquake Precursors- Detected by Satellite Sensors
Vikram Gupta	Administrative Training Institute (ATI), Nainital	25.06.08	Landslide and Mitigative Measures
Barun K Mukherjee	WIHG, Dehradun	11.07.08	Seeing a continent-continent collision through single grain
R. Islam	WIHG, Dehradun	18.07.08	Granite magmatism in the Himalaya through space and time: Geochemical and Geodynamic evolution
Rajesh Sharma	Geological Survey of India Training Institute, Zawar, Udaipur	03.09.08	Fluid inclusions and ore forming fluids
Rajesh Sharma	WIHG, Dehradun	12.09.08	Use and Misuse of fluid inclusion data
A.K. Dubey	Garhwal University, Srinagar	11.09.08	Structural evolution in the Himalaya
A.K. Dubey	WIHG, Dehradun	25.09.08	Pragati ke Chalis Varsh
T. N. Jowhar	WIHG, Dehradun	19.09.08	An insight into the estimation of Pressure-Temperature in Rocks.
Narendra K. Meena	WIHG, Dehradun	03.10.08	Application of Environmental magnetism as paleoclimate/ paleomonsoon proxy
D.P. Dobhal	Uttarakhand State Council of Science and Technology, Dehradun	14.10.08	Climate change; Evidence from Rapid glaciers recession- An Over view in Himalayan Context.
V.C. Tewari	WIHG, Dehradun	07.11.08	Global Cretaceous – Tertiary Boundary : Mass Extinction and Bolide Impact.
D.R. Rao	WIHG, Dehradun	05.12.08	Electron Probe Micro Analyzer: Instrument Technique and its Application
Suresh. N	WIHG, Dehradun	12.12.08	Evolution of Late Quaternary deposits in Soan Dun, NW Sub-Himalaya
R. Islam	Indira Gandhi Forest Research Academy, Dehradun	23.12.08	Rock types and their mineral constituents

Name of Scientist	Venue	Date	Topic
S.K. Rai	Indira Gandhi Forest Research Academy, Dehradun	23.12.08	Weathering, parent material and soil types
A.K. Dubey	Indira Gandhi Forest Research Academy, Dehradun	26.12.08	Geologic structures and their surface manifestations.
G. Philip	Indira Gandhi Forest Research Academy, Dehradun	29.12.08	Tectonic Landforms
P.K. Mukherjee	Indira Gandhi Forest Research Academy, Dehradun		Introduction to Geology and Dynamic Earth
Ajay Paul	Indira Gandhi Forest Research Academy, Dehradun	30.12.08	Seismic zonation and Mitigation
H.K. Sachan	Geological Society of India, Bangalore	31.12.08	Role of Forbidden metamorphism in Himalayan orogen.
S.K. Bartarya	Indira Gandhi Forest Research Academy, Dehradun	31.12.08	(i) Characterization, Control and Conservation of Himalayan Springs, and (ii) Introduction to Hydrogeology
M.P. Sah	Indira Gandhi Forest Research Academy, Dehradun	02.01.09	Landslide and their geological control
V.C. Tewari	Northe Eastern Hill University, Shillong, Meghalaya.	07.01.09	Cretaceous - Tertiary Boundary (K/T B) global events of palaeoclimate and tectonics in the Shillong Plateau, Meghalaya and Indo – Myanmar region
P.S. Negi	Asian School, Dehradun	21.01.09	Slope instability and Bioengineering in Himalaya: An innovative approach
A.K. Singh	D.M.College of Science, Imphal	27.01.09	Evolution of the Himalaya
D.P. Dobhal	Welham School, Dehradun	18.02.09	Shrinking glaciers of the Himalaya-Consequences and adaptations
V.C. Tewari	Bundelkhand University, Jhansi	25.02.09	Neoproterozoic Snowball Earth and the Sedimentological evolution of the Lesser Himalaya
R.S. Rawat	WIHG, Dehradun	27.03.09	Sulphide mineralization in the Uttarakhand Lesser Himalaya and some possible sites for their exploitation in future
S.K. Bartarya	IIRS, Dehradun	07.03.09	Hydrogeology of mountainous terrain with special reference to Himalaya
Rajesh Sharma	Kumaun University, Nainital	25.03.09	Fabric of the ore minerals

TECHNICAL SERVICES

Analytical Services

Central Facility Laboratories

The activities of Central Facility Laboratories (CFL) are divided into three main categories: Analytical services: management/instrument operation and maintenance activities, New Addition/up-gradation of existing facilities, and Practical training to the users/students.

Analytical Services

During the reporting year, analytical services were provided to more than 45 users out of which 55% were from out side research organizations, universities and industries. A total number of three thousand eight hundred fifty three samples were analyzed using different techniques available in the laboratories. The samples analyzed were variety of geological materials (soils, rocks, sediments, and surface and ground water samples), synthetic materials, plant and archeological samples. During the reporting period only one of the instruments- ICPMS was under AMC with outside servicing agency and the rest were maintained by the staff. There was very little hindrance due to instrument failure. All equipments were operational through out the year. Following is the detail of samples analyzed by different laboratories.

LABORATORY	WIHG USERS	OUTSIDE USERS	TOTAL
XRF	837	584	1421
XRD	395	356	751
SEM	454	225	679
ICP-MS	549	453	1002
EPMA	66	101	167
TOTAL SAMPLES ANALYSED			**4020**

New Addition / Up-gradation of the Facilities:

- During this year one major sample preparation facility: sample fusion unit was added to the existing facilities. It was installed and standardized during the reporting year. This enhanced the analytical capability for analysis of major elements with improved quality of analysis data. The facility will be used mostly for XRF analysis. However, sample fusion technique can also be used conveniently for making solutions of several rock types for further analysis by wet chemical methods like ICP-MS.
- Another important analytical facility: Laser Ablation system was added to the existing ICP-MS. Using this advanced analytical technique solid samples can also be analyzed by ICP-MS avoiding sample digestion which requires use of hazardous acids and other costly chemical reagents. Moreover, it can also be used for microanalysis.
- CL detector and Age quanta software were added to the existing EPMA facility.

Practical training to the users and students:

- Practical training was provided to the users (particularly to research scholars) on various analytical instruments. Nine M.Sc. dissertations from Gurukul Kangri University, Hardwar, Banasthali Vidyapeeth and NIT Kurukshetra were supervised during this period. Considerable efforts have been made towards development of analytical techniques for the determination of platinum group of elements and analysis of non-geological matrices like bones, plants, food products and archeological samples.

Photography Section

During the reporting year around 3000 snaps were clicked using digital cameras, and 05 colour films were exposed to cover the various functions, including Foundation Day, Founders day, National Science Day, National Technology Day, New Years Day, Seminars/symposia, and superannuation farewells etc. organized in the Institute. Portraits of Institute staff for use in the new identity cards were all clicked within the Institute. Apart from this around 1000 snaps were clicked for rock and fossil specimens. The developing and processing of around 10 films was arranged with a total of about 500 prints (digital and regular) of assorted sizes.

Drawing Section

The drawing section catered to the cartographic needs of the scientists of the Institute including the sponsored projects. During the year drawing section has provided 84 geological/ structural/geo-morphological maps to the scientists of the Institute. The staff of the drawing section has also prepared charts, identity- cards, addition and alteration in maps / diagrams, Litho-logs and geological cross sections.

Sample Processing Lab.

The Sample Processing Lab provided thin/polished sections to the requirements of the Institute scientists. During the year the laboratory provided 1819 thin and polished sections to various users for carrying out microscopic, fluid inclusion and EPMA studies. 1613 rock samples were powdered for carrying out mineral identification, major, trace and REE analysis by XRD, XRF and ICPMS.

S.P. NAUTIYAL MUSEUM

The Museum is a major axis of education and continues to generate awareness among the students and public not only from the distant corners of India but also from overseas. Museum as usual remained the main centre of attraction for the national and international visitors. Students from different schools, Universities, colleges and from other Institutions visited the museum, guided tours provided to them. This year more than 3,000 people visited the Museum from different parts of country. On the National Science Day 28th May, 2009 more than 2,000 students from various schools, colleges, paramedical as well as from the engineering colleges of the Doon Valley visited the Museum.

Museum observed four Open days viz National Technology Day (11th May, 2009). Foundation Day (29th June, 2008), Founders Day (23rd Oct. 2008) and National Science Day (28th Feb., 2009). Like preceding years, enormous number of students and public visited the museum on these open days. The print media gave a wide coverage of the function. Science quiz and Hindi essay competitions organized on the eve of Science week celebrations. Various schools of Doon Valley and of the surrounding areas participated in the quiz competition and the prizes were distributed to the students who stood first, second and third in the merit both in quiz and essay competition. Two consolation prizes, each were also given for Hindi essay and for science quiz competition.

The activities of the museum are according to the needs and the interests of the students. A large number of students continue to visit the museum for their respective school projects. The visitors from England, U.K, France, Turkey, Japan, Russia, U.S.A., Italy, Nepal, Switzerland, Canada, Australia and Germany also visited the Museum.

One of the major and effective additions was the display of a Geological clock at the entrance wall of the museum. It is 10 feet x 7 feet three-dimensional model that depicts the life through ages. It shows the distribution of life in the different epochs. The fossils shown in the model were prepared by the fiberglass. This exhibit is the centre of attraction and is highly appreciated by the scientific community as well as by the students and by the public.

Database of the rock and fossil specimens is almost complete and museum at present is actively planning for repository section of National Level. In order to give a general awareness to the public and to the students regarding the Institute and Museum activities and regarding the personal protection in earthquakes brochures both in Hindi and in English are given free of cost.

LIBRARY

The Library of the Wadia Institute of Himalayan Geology is one of the advanced libraries in the field of Earth Sciences in terms of its collection and services. It is a medium size specialized Library consisting of books, monographs, journals and seminar/conference proceedings on Earth Sciences with special reference to Himalayan Geology. A large number of National and International scientific journals in the field of earth sciences are subscribed in the Library which are not available in any other Library in the northern part of the country. The Library serves to the scientific, technical and administrative staff of the institute as well as to the scientist, academicians and researchers of sister organizations situated at Dehra Dun and various universities.

The most important event in the history of DST Institutions' was formation of the DST Libraries consortium by efforts of the honorable DST Secretary. The DST Libraries consortium has joined CSIR e-Journals consortium. Now WIHG Library has access to various Science and Technology packages of 24 different major publishers. Some of them are Cambridge and Oxford University Press, Springer, Wiley, Taylor and Francis, Sage and different databases like Sci-Finder, INSPEC, Indian

Standards etc.. The DST has provided funds for online access to each institutional Library to Web of Science (WOS), Science and Nature weeklies with other NPG Publications depending on the requirement. The consortia will grow further in terms of number of publishers.

The Library subscribed to 79 foreign and 44 Indian Journals in Print format. The main thrust was given to provide full text online access of journals to the users on Intranet. Presently library has full text online access to more than 250 titles pertaining to various disciplines of thrust areas of the Institute. Since the Elsevier is not participating in the consortia the WIHG Library has subscribed to Elsevier's Earth & Planetary Collection consisting of 110 titles on science direct platform.

The enhance access with 10 years back files with Print subscription of Blackwell Journals (9 titles) Springer (6 titles), John-Wiley (10) and Sage (1) titles from each was acquired. The online access was subscribed for current year for the AGU (3 titles) and Geological Society of America (2 titles). The 28 title which are subscribed in print only by Library are having free full text online access with varying access period from current year to full archive.

During the period of this report Library acquired a total number of 176 books. Out of these 63 books/ reference books were purchased while 05 books are received as gratis. In addition to this, 108 books in Hindi were purchased for Hindi collection. The Library has a good collection of Hindi books to promote the usage Hindi Language in staff of the Institute. The Library acquired a total number of 500 reprints of publications of various scientists.

The Library incorporates a reprographic cell which serves as a central facility for photocopying. During the period of this report the Library provided a large number of photocopies of articles from journals, books and monographs to the scientists of the Institute and projects. The photocopying facility was also provided to administrative and technical sections of the Institute.

In line of development of new infrastructural facilities, the Library has been renovated to facilitate the library for the users, especially the young scholars to provide them most advanced library and information system.

PUBLICATION & DOCUMENTATION

The Publication and Documentation Section is involved in bringing out the journal of Himalayan Geology and publishing Hindi magazine Ashmika, Annual Report in Hindi and English. During the year, the Section published Himalayan Geology vols. 29(2) 2008, 29(3) 2008 and 30(1) 2009, Hindi magazine Ashmika volume 14 and Annual Report of the Institute for the year 2007-08 both in Hindi and English. Abstract volume for the workshop on International Symposium on "Mountain Building and Climate-Tectonic Interaction – (MBCT-2008)" was also brought out by the Section. Apart from this, various jobs such as printing of Lecture, Circular for the above-mentioned workshop, invitation cards for the seminars/ workshops, certificates for celebration of Foundation Day and National Science Day were also brought out by the Section. Additionally, services for scanning and color printing of maps, diagrams and figures as requisitioned by Institute scientists were provided by the Section.

FOUNDATION DAY CELEBRATIONS

The 40th Foundation Day of the Institute was celebrated on June 29, 2008. Dr. R. Chidambaram, Principal Scientific Advisor, Government of India was the Chief Guest and Dr. T. Ramasami, Secretary, Department of Science and Technology, Government of India presided over the function. Dr. R. Chidambaram delivered the Foundation Day Lecture on "Nuclear Energy and Climate Change". On this occasion, Himalayan Geology Volume 29(2), Hindi Magazine 'Ashmika' Volume 14 and vision document of the Institute reflecting the application of emerging knowledge about the Earth process for fostering sustainable development and secure living in the Himalayan region was also release by the Chief Guest. On this day, distribution of awards for best research papers published by the Scientists in various fields were also given by the Chief Guest. The awards were given to Dr. V.C. Tewari for his paper on "Neoproterozoic-Early Cambrian isotopic variation and chemostratigraphy of the Lesser Himalaya India, Eastern Gondwana" published in Chemical Geology, and to Dr. H.K. Sachan & Dr. B.K.Mukherjee for their paper on "Preservation of methane generated during serpentinization of upper mantle rocks : evidence from fluid inclusions in the Nidar ophiolite, Indus Suture Zone, Ladakh" published in the journal of Earth Planetary Science Letters. Best worker awards were given to Shri C.B. Sharma, Jr. Engineer, Dr. Jitendra Bhatt, Tech. Asstt, Shri N.B.Tiwari, Assistant, Shri Rambir Kaushik, Tech. Asstt, Shri A.K.Gupta, Lab. Asstt, and Shri Chandra Pal, Section Cutter for good work carried out by them during the year 2007-2008.

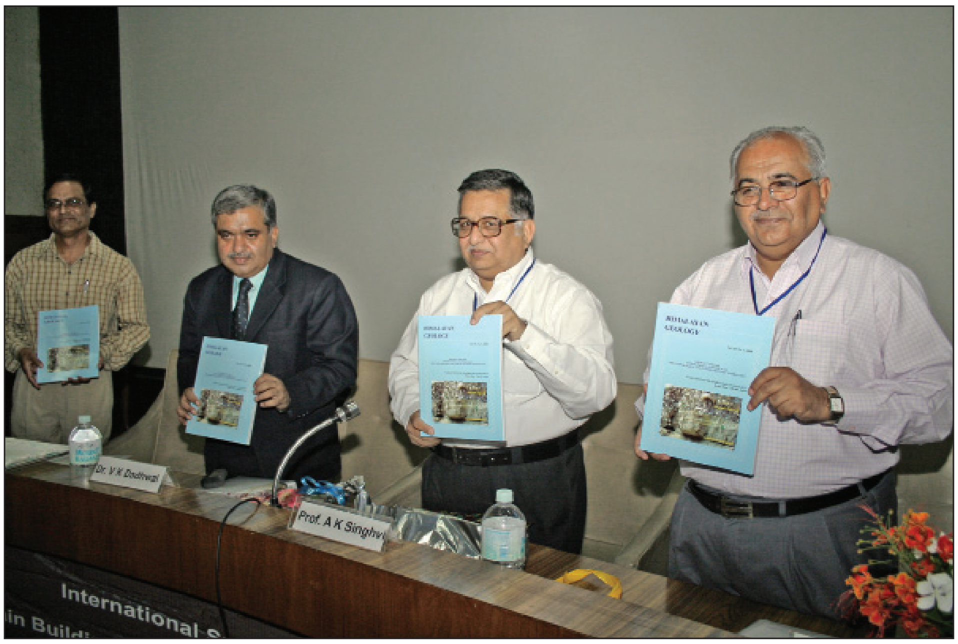
Chief Guest Dr. R. Chidambaram, Principal Scientific Advisor, Government of India along with Dr. T. Ramasami, Secretary, DST and Dr. B.R. Arora releasing the Vision Document of the Institute during the Foundation Day Celebration.

NATIONAL TECHNOLOGY DAY

The Tenth National Technology Day was observed on 11th May, 2008, on this day Museum and other laboratories were kept open for general public and for school and college students. A large number of people also visited the institute museum and other laboratories. On this occasion, Prof. Gajendra Singh Vice-Chancellor Doon University, Dehradun delivered Technology Day lecture on "Technology Advancement in Uttarakhand Mission of Doon University". The lecture was attended by students, general public and by the institute staff.

FOUNDER'S DAY

The Institute celebrated its Founder's Day on 23 October 2008 in honour of Prof. D.N. Wadia. On this occasion, an international symposium on "Mountain Building and Climate-Tectonic Interaction – MBCT-2008" was held in the Institute on October 23-25, 2008. Dr. A.K. Singhvi, Sr. Professor, Physical Research Laboratory, Ahmedabad was the Chief-Guest and Dr. V.K. Dadhwal, Dean, Indian Institute of Remote Sensing, Dehradun presided over the function on this occasion. An abstract volume of Himalayan Geology (Journal) was also released by the Chief Guest. The seminar coincided with the Founder Day's of the Institute as a special year in the completion of its 40 years.



Chief Guest Prof. A.K. Singhvi along with Dr. V.K. Dadhwal, Dr. B.R. Arora and Dr. A.K. Dubey sharing the dias during the Founder's Day and inauguration function of International Symposium on Mountain Building and Climate Tectonic Interaction and also releasing the Himalayan Geology, Abstract Volume, 29(3) 2008.

NATIONAL SCIENCE DAY CELEBRATIONS

The National Science Day-2009 was organized in the Institute by a week long activities, beginning with a Science Quiz Competition. The theme selected for said competition was "Expanding horizons of Science". The various educational institutions of the Dehradun participated in the Science Quiz and Hindi Essay Competition. In spite of Annual Board Exams, a total of 34 educational institutions participated in Hindi Essay and quiz competition.

On this day all the laboratories were kept open to students and general public. In total nearly 36 educational institutions with more than 2,000 school children and a large number of general public visited the Institute Museum and various laboratories. New exhibits on the Uttaranchal Himalaya and the Impacts of Human activities on Environment were displayed along with various other exhibits depicting Himalayan glaciers, Earthquakes, Landslides, Origin of Life, Volcanoes, Rocks Minerals, etc. The scientists along with technical staff and research scholars explained to the students and general public, the functioning of the various scientific instruments and their use. Like previous year this year, a joint exhibition along with Indian Society of Remote Sensing Dehradun was organized and the documentary on the Chandrayan was shown to public and students.

In the evening an invited special science lecture was delivered on "Globalization and knowledge regime making the right choice" by a Distinguished Scientist Prof. Girjesh Pant, Vice Chancellor Doon University, Dehradun. This was attendant by Scientists of the Institute and by a large number of general public and the students of different schools.

School Children visiting Institute during the National Science Day Celebration.

DISTINGUISHED VISITORS TO THE INSTITUTE

- Dr. R. Chidambaram, Principal Scientific Advisor, Govt. of India
- Dr. T. Ramasami, Secretary, Dept. of Science and Technology, Govt. of India
- Dr. Suman K. Aggarwal, Dy. Secretary, Dept. of Science and Technology, Govt. of India
- Dr. A.K. Singhvi, Physical Research Laboratory, Ahmedabad
- Dr. M. Ramakrishna, Bangalore
- Dr. V.K. Dadhwal, Dean, Indian Institute of Remote Sensing, Dehradun
- Prof. M. Jayananda, Dept. of Geology, Bangalore University, Bangalore.
- Mr. Mikhail V. Shaldubin, Russia
- Dr. Susana Barbosa, University of Porto, Portugal
- Dr. Lewis A. Owen, Dept. of Geology, University of Cincinnati, Cincinnati, Ohio
- Dr. Steven Goodbred, Earth & Environmental Sciences, Vanderbilt University, Nashville, Tennessee
- Dr. Michael Brookfield, Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan Republic of China
- Dr. Beth Pratt Sitaula, Geological Sciences Dept., Central Washington University, 400 E University Way Ellensburg
- Dr. Arjun M. Heimsath, School of Earth and Space Exploration, Arizona State University, USA
- Prof. Asish R. Basu, Department of Earth and Environmental Sciences, University of Rochester, Rochester, New York
- Prof. Roberts Yeats, Oregon State University, Oregon, USA
- Prof. Steven G. Wesnousky, Centre for Neotectonics, University of Reno, Nevada, USA.
- Prof. Ron Harris, Brigham Young University, Utah, USA
- Dr. Lee Zoo, University of Texas,
- Dr. Sarah Dickison, USA,
- Mrs. Paramita M. Biswas, Indian Revenue Services Income tax commissioner, Dehradun,
- Prof. Girijesh Pant Vice-Chancellor, Doon University, Dehradun
- Prof. Yuichi Sugiyama, Geological Survey of Japan, Tsukuba, Japan
- Prof. Koji Okumura, Hiroshima University, Japan
- Prof. Gajander Singh, ex-V.C. Doon University, Dehradun.
- Prof. Krish Sappal, Cyurtin University , Perth, Australia

Dr. R. Chidambaram, Principal Scientific Advisor, Government of India along with Dr. T. Ramasami, Secretary, DST during one of their visit to Institute.

Prof. A.K. Singhvi, PRL, Ahmedabad along with Dr. V.K. Dadhwal, Dean, IIRS, Dehradun in the Institute during one of their visit.

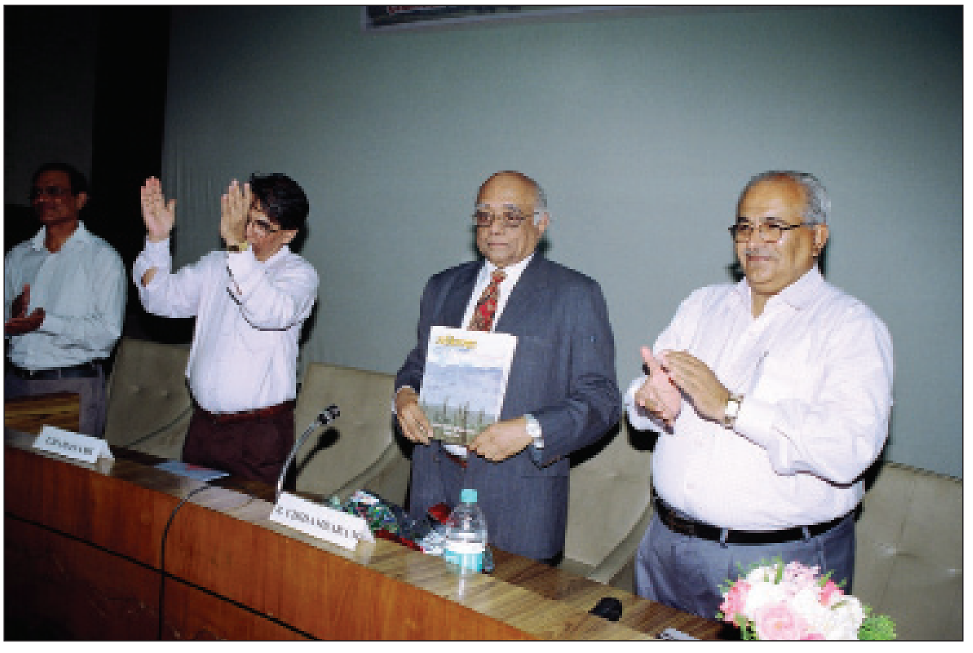
STATUS OF IMPLEMENTATION OF HINDI

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

On the occasion of the Foundation Day of the Institute on 29 June 2008, the Hindi magazine 'Ashmika' volume 14 was released.

Hindi fortnight was celebrated from 14 to 28 September 2008 during which various competitions like poetry, essay and debate were organized. To inspire the staff for progressive use of Hindi in their work Rajbhasha lecture was also arranged.

The Annual Report of the Institute for the year 2007-2008 was translated in Hindi and published in bilingual form. On the occasion of the National Science Day week, a Hindi essay competition was organized for the students of various schools of Dehra Dun.



Dr. R. Chidambaram, Principal Scientific Advisor, Government of India along with Dr. T. Ramasami, Secretary, DST releasing the Hindi Magazine "Ashmika" during the Foundation Day Celebration.

MISCELLANEOUS ITEMS

1. Reservation/Concessions for SC/ST employees

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

2. Monitoring of personnel matters

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

3. Mechanism for redressal of employees grievances

There is a Grievance Committee consisting of four Senior Scientists/Officers for redressal of employee's grievances. No request regarding grievance of any of the employee was received during the year by the Grievance Committee.

4. Welfare measures

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

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

To inquire into the complaints of sexual harassment of women employees at work places in the Institute, a separate Committee has been constituted. The Committee consists of six members. The Chairman and two other members of the Committee are female officers, which includes a female officer from the Geological Survey of India. No complaint of sexual harassment of women employees at work places was received by the Committee during the year 2008-2009.

6. Status of Vigilance Cases

No vigilance case was either pending or was contemplated against any of the employee of the Institute during the year, 2008-2009.

7. Information on the RTI cases

No applications for seeking information or appeals thereof under the Right to Information Act, 2005 were carried forward from the previous year 2007-2008.

The details of information on the RTI cases during the year 2008-2009 are as under:-

Details	Opening balance as on 01.04.2008	Received during the year 2008-2009	Number of cases transferred to other public authorities	Decisions where requests/ appeals were rejected	Decisions where requests/ appeals accepted
1	2	3	4	5	6
Requests for information	Nil	11	Nil	Nil	11
First appeals	Nil	1	Nil	1	Nil

No application or appeal under the Right to Information Act, 2005 was carried forward to the next financial year 2009-2010.

8. Sanctioned Staff strength (category wise)

Group/ Category	Scientific	Technical	Adminis-trative	Ancillary	Total
A	63	-	2	-	65
B	-	2	6	-	8
C	-	37	30	14	81
D	-	28	-	26	54
				Total	208

9. Sanctioned and released budget grant for the year 2008-2009

Plan : Rs. 1472.00 lakhs

Non-Plan : Rs. 90.00 lakhs

Total : Rs. 1472.00+90.00 = 1562.00 lakhs

10. XIth Plan approved outlay

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

BLOOD DONATION CAMP AT WIHG, DEHRADUN

STAFF OF THE INSTITUTE

A) Scientific Staff

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

(B) Technical Staff

1.	Shri V.P. Singh	Sr.Pub.&Doc.Officer Gr.III(5)
2.	Shri Saeed Ahmad	Sr.Librarian Gr.III (5)
3.	Shri J.J. Sharma	Sr.Tech.Officer Gr.III(5)
4.	Shri M.M.S. Rawat	Sr.Tech.Officer Gr.III (5)
5.	Shri B.B. Sharma	Sr.Tech.Officer Gr.III (5)
6.	Shri A.K.Pandit	Artist-cum-Modellor Gr.III (4)
7.	Shri Sanjeev Kumar Dabral	Tech.Officer Gr.III (4)
8.	Dr. R.K.Sehgal	Tech.Officer Gr.III (4)
9.	Shri Chandra Shekhar	Tech.Officer Gr.III (4)
10.	Shri V.P. Gupta	Tech.Officer Gr.III (4)
11.	Shri Samay Singh	Tech.Officer Gr.III (4)
12.	Shri Rakesh Kumar	Jr.Tech.Officer Gr.III(3)
13.	Shri Ravindra Singh	Jr.Tech.Officer Gr.III(3)
14.	Shri H.C. Pandey	Jr.Tech.Officer Gr.III(3)
15.	Shri S.C. Kothiyal	Sr.Lab.Asstt.Gr.II(5)
16.	Shri N.K. Juyal	Sr.Tech.Asstt.Gr.III(2)
17.	Shri T.K. Ahuja	Sr.Tech.Asstt.Gr. III(2)
18.	Shri C.B. Sharma	Jr.Engineer Gr.III(2)
19.	Shri S.S. Bhandari	Tech.Asstt.Gr.III(1)
20.	Shri Rambir Kaushik	Tech.Asstt.Gr.III(1)
21.	Dr. Jitendra Bhatt	Tech.Asstt.(EDP) Gr.III(1)
22.	Shri Bharat Singh Rana	Tech.Asstt.Gr.III(1)
23.	Shri Pankaj Chauhan	Tech.Asstt.Gr.III 1)
24.	Shri V.K.Kala	Draftsman Gr.II(5)
25.	Shri G.S. Khattri	Draftsman Gr.II(5)
26.	Shri Navneet Kumar	Draftsman Gr.II(5)
27.	Shri B.B.Saran	Draftsman Gr.II(3)
28.	Shri Chandra Pal	Section Cutter Gr.II(5)
29.	Shri Shekhranandan	Section Cutter Gr.II(5)
30.	Shri Pushkar Singh	Section Cutter Gr.II(5)
31.	Shri Satya Prakash	Section Cutter Gr.II(5)
32.	Shri Santu Das	Section Cutter Gr.II(3)
33.	Shri Nand Ram	Elect.cum-Pump.Optr.Gr. II(5)
34.	Shri Lokeshwar Vashistha	S.L.T.Gr.II(3)
35.	Dr. S.K. Chabak	S.L.T.Gr.II(3)
36.	Shri R.M. Sharma	S.L.T.Gr.II(3)
37.	Shri C.P. Dabral	S.L.T.Gr.II(3)
38.	Shri Satish Pd.Bahuguna	Lab.Asstt.Gr. II(5)
39.	Shri S.K. Thapliyal	Lab.Asstt.Gr. II(5)

40.	Shri Shiv Pd. Bahuguna	Lab.Asstt.Gr. II(5)
41.	Shri Sashidhar Pd.Balodi	Lab.Asstt.Gr. II(5)
42.	Shri Rajendra Prakash	Lab.Asstt.Gr. II(5)
43.	Shri A.K. Gupta	Lab.Asstt.Gr. II(5)
44.	Shri Tirath Raj	Lab.Asstt(Photo)Gr.II(3)
45.	Shri Balram Singh	Elect-cum-Pump Opt.Gr.II(3)
46.	Shri Anoop Singh	F.C.L.A.Gr. I(4)
47.	Shri Pratap Singh	F.C.L.A.Gr. I(4)
48.	Shri Ram Kishor	F.C.L.A.Gr. I(3)
49.	Shri Ansuya Prasad	F.C.L.A.Gr. I(4)
50.	Shri Puran Singh	F.C.L.A.Gr. I(3)
51	Shri Ram Khilawan	F.C.L.A.Gr. I(3)
52.	Shri Madhu Sudan	F.C.L.A.Gr. I(3)
53.	Shri Hari Singh	F.C.L.A.Gr. I(3)
54.	Shri Ravi Lal	F.C.L.A.Gr. I (3)
55.	Shri Preetam Singh	F.C.L.A.Gr. I(3)
56.	Shri Vivekanand Khanduri	F.C.L.A.Gr.I(1)
57.	Shri Subodh Kumar Barthwal	Lab.Assistant
58.	Shri Nain Das	Lab.Assistant
59.	Mrs.Rama Pant	Field Attendant
60.	Shri R.S.Negi	Field Attendant
61.	Shri Ramesh Chandra	Field Attendant
62.	Shri Khusi Ram	Field Attendant
63.	Shri Tikam Singh	Field Attendant
64.	Shri Bharosa Nand	Field Attendant
65.	Shri B.B.Panthri	Field Attendant
66.	Shri M.S.Rawat	Field Attendant

(C) Administrative Staff

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

(D) Ancillary Staff

1.	Shri Dewan Singh	Driver
2.	Shri Sohan Singh	Driver
3.	Sri Ganga Ram	Driver
4.	Shri Chander Pal	Driver
5.	Shri Naresh Kumar	Driver
6.	Shri Shyam Singh	Driver
7.	Shri R.S. Yadav	Driver
8.	Shri Surjan Singh	Driver
9.	Shri Girish Chander Singh	Guest House Attdt.cum Cook
10.	Sh. Dinesh Parsad Saklani	Guest House Attdt.cum Cook
11.	Shri Bhagat Singh	Bearer
12.	Mrs. Kamla Devi	Bearer
13.	Mrs. Deveshawari Rawat	Bearer
14.	Shri Shyam Lal	Bearer
15.	Shri S.K. Gupta	Bearer
16.	Shri Chait Ram	Bearer
17.	Mrs. Omwati	Bearer
18.	Shri Jeevan Lal	Bearer
19.	Shri Surendra Singh	Bearer
20.	Shri Vijai Ram Bhatt	Bearer
21	Shri Lal Bahadur	Chowkidar
22.	Shri Har Prasad	Chowkidar
23.	Shri Mahendra Singh	Chowkidar
24.	Shri Rohlu Ram	Chowkidar
25.	Shri H.S. Manral	Chowkidar
26.	Shri G.D. Sharma	Chowkidar
27.	Shri Swaroop Singh	Mali
28.	Shri Ashok Kumar	Mali
29.	Shri Satya Narayan	Mali
30.	Smt. Dukhni Devi	Mali
31.	Shri Ramesh	Safaiwala
32.	Shri Hari Kishan	Safaiwala

(E) Security Staff (on contract)

1.	Shri Om Prakash Thapa	Security Guard
2.	Shri Mohan Singh Rawat	Security Guard
3.	Shri Kirti Dutt	Security Guard

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

Governing Body (w.e.f. 1.12.2006)

Sl.No.	Name	Address	Status
1.	Dr. T. Ramasami	Secretary, Dept. of Science & Technology Technology Bhavan, New Mehrauli Road, New Delhi 110016	Chairman
2.	Shri K.P. Pandian	Joint Secretary & Financial Adviser, Dept. of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member
3.	Dr. N.C. Mehrotra	Director, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007	Member
4.	Dr. V.P. Dimri	Director, National Geophysical Research Institute, Uppal Road, Hyderabad 500 007	Member
5.	Dr. S. Krishnaswami	INSA - Senior Scientist, Physical Research Laboratory, Navrangpura, Ahmedabad 380 009	Member
6.	Prof. M.P. Singh	Dean, Faculty of Science and Head, Geology Department, Lucknow University, Lucknow 226 007	Member
7.	Prof. G.S. Roonwal	C-520, SFS, Sheikh Sarai I, New Delhi 110 017	Member
8.	Dr. M. Ramakrishnan	Flat No.8, Mani Pallavam 29, Balakrishna Road Valmiki Nagar, Thiruvanmiyur, Chennai 600 041	Member

9.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary
10.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Non-Member Asstt. Secretary

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

Sl.No.	Name	Address	Status
1.	Dr. M. Ramakrishnan	Flat No.8, Mani Pallavam, 29, Balakrishna Road, Valmiki Nagar, Thiruvanmiyur, Chennai 600 041	Chairman
2.	Prof. L.S. Chamyal	Geology Department, M.S. University, Baroda	Member
3.	Prof. Abhijit Bhattacharya	Department of Earth Sciences, Indian Institute of Technology, Kharagpur 721 302	Member
4.	Dr. S. Sinha Roy	(Ex-Sr. Deputy D.G., GSI), Birla Institute of Scientific Research, Statue Circle, Jaipur 302 001	Member
5.	Prof. G.V. R. Prasad	Geology Department, Jammu University, Jammu 180 004	Member
6.	Shri V.K. Raina	(Ex- Deputy, D.G., GSI), 258, Sector 17, Panchkula 134 109 (Haryana)	Member
7.	Dr. Rasik Ravindra	Director, Antarctic Research Institute, Goa - 403 804	Member
8.	Dr. R.K. Chadha	Scientist 'F', National Geophysical Research Institute, Uppal Road, Hyderabad 500 007	Member
9.	Dr. M. Prithviraj	Scientist 'F'/Director, Earth System Science Division, Dept. of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member

10.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
11.	Dr. A.K. Dubey	Scientist 'G', Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

Finance Committee (w.e.f. 01.12.2006)

Sl.No.	Name	Address	Status
1.	Prof. M.P. Singh	Dean, Faculty of Science & Head Geology Department, Lucknow Univesity, Lucknow 226 007	Chairman
2.	Joint Secretary & Financial Adviser or his authorized nominee	Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member
3.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
4.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
5.	Shri Harish Chandra	Finance & Accounts Officer, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

Building Committee (w.e.f. 1.12.2006)

Sl.No.	Name	Address	Status
1.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Chairman
2.	Dr. A.K. Dubey	Scientist 'G', Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
3.	Joint Secretary & Financial Adviser or his outhorized representative	Dept. of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member

4.	Shri Rajesh Agarwal	Chief Engineer (Civil), Dept. of Civil Engineering, Oil and Natural Gas Corporation, Shed No. 32, Dehra Dun 248 001	Member
5.	Shri C.R. Srivastava	Executive Engineer, Indian Institute of Petroleum, Mokhampur, Dehra Dun 248 001	Member
6.	Shri Shashi Kant Tyagi	Supdt. Engineer', Dehradun Central Cirecle, CPWD Nirman Bhavan, 20 Subhash Road, Dehra Dun 248 001	Member
7.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

STATEMENT OF ACCOUNTS

CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

21/2, Pleasant Valley
Rajpur Road, Rajpur P.O. Dehradun-248009
Phone: (0135) 2724622, 2735974
E-mail: chandrabhangoel@yahoo.co.in

AUDITOR'S REPORT

We have examined the attached Balance Sheet of **Wadia Institute of Himalayan Geology, Dehradun,** as at 31st March 2009 and the annexed Income & Expenditure Account and Receipt and Payment Account for the year ended on that date. These Financial statements are the responsibility of the Institute's management. Our responsibility is to express an opinion on these financial statements based on our audit.

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

In our opinion and to the best of our information and according to the explanations given to us the said accounts, gives the information in the manner so required and give a true and fair view: -

1) In the case of the Balance Sheet of the state of affairs as at 31st March 2009.

2) In the case of Income & Expenditure Account of the deficit for the year ended on 31st March 2009.

3) In the case of Receipt & Payment Account of the receipts and payments for the year ended on 31st March 2009.

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/-
(CHANDRA BHAN GOEL)
FCA

DATED: 09.07.2009
PLACE: DEHRADUN

CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

21/2, Pleasant Valley
Rajpur Road, Rajpur P.O. Dehradun-248009
Phone: (0135) 2724622, 2735974
E-mail: chandrabhangoel@yahoo.co.in

SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS FOR THE YEAR ENDING 31.03.2009

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) Expenses Payable

B. FIXED ASSETS

i) Fixed Assets are stated at cost of acquisition or cost of construction plus the related expenditure. As per the decision of management from the current year depreciation has been charged on the Fixed Assets at the rates specified in the Income Tax Act.

ii) Full depreciation has been charged on the additions to all Fixed Assets made during the year.

iii) Vehicle purchases prior to 01.04.98 have been debited to Equipment account.

C. CLASSIFICATION

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

CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

21/2, Pleasant Valley
Rajpur Road, Rajpur P.O. Dehradun-248009
Phone: (0135) 2724622, 2735974
E-mail: chandrabhangoel@yahoo.co.in

NOTES TO ACCOUNTS

MAIN ACCOUNT OF WIHG

- Schedule '1' to '11' forms part of the Balance Sheet, '12' to '36' forms part of the Income & Expenditure and Receipts & Payments Account as on 31.03.09.
- Balance of Debtors and Creditors as on 31.03.09 subject to confirmation.
- Separate Balance Sheet have been prepared for :
  - Contributory Provident Fund/ General Provident Fund.
  - Pension Fund.
  - Projects.
  - New Pension scheme.

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/-
(CHANDRA BHAN GOEL)
FCA

DATED: 09.07.2009
PLACE: DEHRADUN

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
BALANCE SHEET
(AS AT 31ST MARCH 2009)

(Amount in Rupees)

PARTICULARS	SCHEDULE	CURRENT YEAR	PREVIOUS YEAR
LIABILITIES			
Corpus/ Capital Fund	1	303,988,088	319,874,792
Reserves and Surplus	2	-	-
Earmaked/ Endowment Fund	3	954,366	937,466
Secured Loans & Borrowings	4	-	-
Unsecured Loans & Borrowings	5	-	-
Deferred Credit Liabilities	6	-	-
Current Liabilities & Provisions	7	1,958,721	918,937
TOTAL		**306,901,175**	**321,731,195**
ASSETS			
Fixed Assets	8	269,449,589	272,231,634
Investments from Earmaked/ Endowment Funds	9	24,759	22,935
Investment- others	10	-	-
Current Assets, Loans & Advances	11	37,426,827	49,476,626
Miscellaneous Expenditure			
TOTAL		**306,901,175**	**321,731,195**
Significant Accounting Policies	37		
Contingent Liabilities and Notes on Accounts	38		

AUDITOR'S REPORT

"As per our separate report of even date"

For CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

Sd/-
CHANDRA BHAN GOEL
FCA

Sd/-	**Sd/-**	**Sd/-**
(HARISH CHANDRA)	**(DINESH CHANDRA)**	**(B.R. ARORA)**
FINANCE & ACCOUNTS OFFICER	REGISTRAR	DIRECTOR

DATE : 9.07.2009
PLACE : DEHRADUN

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
INCOME & EXPENDITURE ACCOUNT
(FOR THE PERIOD ENDED 31ST MARCH 2009)

(Amount in Rupees)

PARTICULARS	SCHEDULE	CURRENT YEAR	PREVIOUS YEAR
A INCOME			
Income from sales/ services	12	-	-
Grants/ Subsidies	13	120,670,000	105,840,000
Fees/Subscription	14	33,435	14,000
Income from Investments (Income on Invest from Earmarked/ Endowment - Fund)	15	548,238	207,156
Income from Royalty, Publication etc.	16	55,055	49,025
Interest earned	17	2,825,539	3,444,143
Other Income	18	1,757,809	1,794,645
Adjustment for Rounding Off		1	-
TOTAL (A)		**125,890,077**	**111,348,969**
B EXPENDITURE			
Establishment Expenses	20	106,628,784	68,036,728
Other Research & Administrative Expenses	21	33,249,995	23,636,184
Expenditure on Grant/ Subsidies etc.	22	-	-
Interest/ Bank Charges	23	5,929	13,894
Depreciation Account	8	44,319,323	43,051,055
Increase/ Decrease in stock of Finished goods, WIP& Stock of Publication		16,616	38,117
TOTAL (B)		**184,220,647**	**134,775,978**
Surplus/ (Deficit) being excess of Income over Expenditure (A - B)		(58,330,570)	(23,427,009)
Transfer to Special Reserve (Specify each)		-	-
Transfer to / from General Reserve		-	-
BALANCE BEING SURPLUS /(DEFICIT) CARRIED TO CORPUS FUND		**(58,330,570)**	**(23,427,009)**

AUDITOR'S REPORT

"As per our separate report of even date"

For CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

Sd/-
CHANDRA BHAN GOEL
FCA

Sd/-	Sd/-	Sd/-
(HARISH CHANDRA)	**(DINESH CHANDRA)**	**(B.R. ARORA)**
FINANCE & ACCOUNTS OFFICER	REGISTRAR	DIRECTOR

DATE : 9.07.2009
PLACE : DEHRADUN

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
RECEIPTS & PAYMENTS ACCOUNT
(FOR THE PERIOD ENDED 31ST MARCH 2009)

(Amount in Rupees)

PARTICULARS	SCHEDULE	CURRENT YEAR	PREVIOUS YEAR
RECEIPTS			
Opening Balance	24	6,838,252	13,528,050
Grants - in - Aids	26	156,200,000	146,100,000
Grants - in - Aids/Other Receipts (Ear Marked)	27	713,080	839,820
Loan & Advances	28	50,153,527	37,967,129
Loan & Advances (Ear Marked)	31	52,560	60,000
Fees/Subscription	14	33,435	14,000
Income from Investments	15	548,238	207,156
Income from Royalty, Publication etc.	16	55,055	49,025
Interest earned on Loan to Staff	17	2,825,539	3,444,143
Other Income	18	1,757,809	1,794,645
Investment (L/C Margin Money)	34	27,500,000	19,350,000
		246,677,495	**223,353,968**
PAYMENTS			
Establishment Expenses	20	106,628,784	68,036,728
Other Administrative Expenses	21	33,249,995	23,636,184
Interest/ Bank Charges	23	5,929	13,894
Loans & Advances	29	47,419,325	37,187,677
Loans & Advances (Ear Marked)	32	52,570	61,842
Investment (L/C Margin Money)	35	17,500,000	27,500,000
Fixed Assets	36	34,623,411	59,610,073
Ear Marked Fund Expenses	33	697,994	399,952
Grant - in - Aid (Ear Marked) Refunded	30	-	69,366
Closing Balance	25	6,499,487	6,838,252
		246,677,495	**223,353,968**
Significant Accounting Policies	37		
Contingent Liabilities and Notes on Accounts	38		

AUDITOR'S REPORT

"As per our separate report of even date"

For CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

Sd/-
CHANDRA BHAN GOEL
FCA

Sd/-	Sd/-	Sd/-
(HARISH CHANDRA)	**(DINESH CHANDRA)**	**(B.R. ARORA)**
FINANCE & ACCOUNTS OFFICER	REGISTRAR	DIRECTOR

DATE : 9.07.2009
PLACE : DEHRADUN

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
PUBLICATIONS AVAILABLE FOR SALE

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OTHER PUBLICATIONS

Geology of Kumaun Lesser Himalaya, 1980 by K.S. Valdiya US $ 50.00	Rs. 180.00
Geology of Indus Suture Zone of Ladakh, 1983 Eds. V.C.Thakur & K.K. Sharma	Rs. 205.00 US $ 40.00
Bibliography on Himalayan Geology, 1975-85 (A comprehensive bibliography-include 3284 references)	Rs. 100.00 US $ 30.00
Geological Map of Western Himalaya, 1992 by V.C. Thakur & B.S. Rawat	Rs. 200.00 US $ 15.00
Excursion Guide :The Siwalik Foreland Basin (Dehra Dun - Nahan Sector), (WIHG Spl. Publ. 1,1991) Rohtash Kumar and Others	Rs. 45.00 US $ 8.00 by
Excursion Guide : The Himalayan Foreland Basin (Jammu-Kalakot-Udhampur Sector) (WIHG Spl Publ.2, 1999) by A.C. Nanda & Kishor Kumar)	Rs. 180.00 US $ 15.00
Atlas of Early Palaeogene Invertebrate fossils of the Himalayan foothills belt (WIHG Monograph Series, No. 1, 2000) by N.S. Mathur & K.P. Juyal (Available from M/s Bishen Singh Mahendra Pal Singh 23-A New Connaught Place, Dehradun - 248 001, India)	Rs. 1450.00 US $ 50.00

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