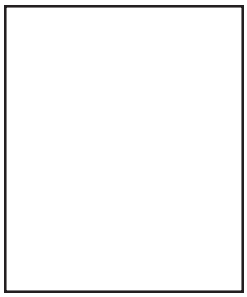
EXECUTIVE SUMMARY



Dr. N.S. Virdi, Director

Wadia Institute of Himalayan Geology is an autonomous Research Institute devoted to basic and applied scientific research on various aspects of geology, resources, environment and natural disasters in the Himalaya and its surroundings. The research activities pursued through long and short-term projects of the Institute along with sponsored research projects have yielded interesting results. Some of the highlights of scientific and other activities are presented in the sequel. This year being the first year of the X- Plan, work has been initiated in the new projects, and also the work on the on going projects is being completed.

Geodynamics and Crustal Evolution

The Tso-Morari eclogites, presently occurring as lenses in the host gneisses, probably represent fragmented dykes related to the N-MORB - OIB type magmatism of the Neo-Tethyan ocean that have traversed through the northern margin of the Indian plate then represented by the Tso Morari crystalline rocks. The whole rock epsilon Nd values (t = 0) for eclogite rocks from the Tso-Morari, Ladakh vary from +3.3 to +8.3, indicating derivation from depleted mantle sources. The Phe volcanics on the other hand with its ε_{Nd} (t = 0) are very different, it varies from -2.7 to -7.8, indicating their derivation from highly enriched sources.

The obduction of Island Arc on to the Indian plate exhibit two different orientations. The early obduction of Island Arc and ophiliotic mélange trends WNW-ESE to the west of Rumtse, while later obducted Island Arc (Nidar Ophiolitic Complex) on to the Indian plate to the south and the Asian plate to the north form a pop-up structure and trend NW-SE. These two suture zones are separated by a transfer fault.

Major fluid types have been identified by using petrography and microthermometry studies of the eclogitic rocks of Tso-Morari, Ladakh. The mono-phase CH_4 inclusions at room temperature with characteristic negative crystal shape occurring in the form of cluster or as isolated ones are observed in quartz of coesite bearing eclogite. The initial melting temperature of such inclusions is in between –182 to-179°C indicating methane rich inclusions with some amount of nitrogen. These methane rich inclusions are homogenized in the range of –120 to -100°C.

New mineralized zones in the Almora-Dudatoli-Ramgarh-Chail rocks have been observed. Highly deformed mineralized zone in the calcareous schistose rocks of the Ramgarh crystallines is about 100 meter wide. In the Almora crystallines the tin bearing quartz veins are brownish while non mineralized veins are white. Similarly the tungsten bearing veins in the calc silicates near the granitic bodies are quite big

In the Raunag Nala area of Tawaghat (Kumaun), occurrence of polymetallic sulphide mineralisation in quartz veins associated with crystalline rocks has been noticed for the first time. The preliminary ore petrography of the samples of Raunag Nala area indicate chalcopyrite, pyrite, galena, sphalerite, covellite, and malachite.

Experiments were performed on clay models to understand the evolution of the Leopargial Horst in Satluj Valley, H.P. The results of the experiments suggest that, the area of higher elevation had suffered shortening during the initial stages of deformation but once it has crossed the height of the compressing blades, the shortening was minimum. A larger number of thrust faults in the model may lead to formation of extension faults at higher elevations (i.e. above the compressing blades) and simultaneous thrusting at the lower elevations (i.e. below the compressing blades).

The paleoseismological studies in a trench between Ram nagar and Chour galia section along the HFT, along the Rawasan Nadi (near Laldhang) suggest a possible earthquake related feature. The studies suggest that, the dates from the youngest black carbonaceous matter from both the hanging wall and footwall unit and the overlying laminated sequence of fine to medium sand silt should bracket the age of the earthquake.

Basin Evolution

The oxygen-based model of the trace fossil distribution in the Kunzum La-Takche, Pin and Parahio sections revealed that with the increase of oxygen concentration in interstitial sediment water shows a parallel transition from fodinichnial-pascichnial to fodichinial trace fossils in association.

The measured lithostratigraphic column along with fossilferous horizons in the Tangzee Kogma areas of the Suru valley of the Zanskar region have yielded fauna which contain some Middle Cambrain trilobites.

In addition to the discovery earliest Cambrian protoconodonts from the Upper Gangolihat Formation reported last year, this year too numerous agglutinated foraminifera and oncolites have been recorded. It now appears that the Precambrian/Cambrian boundary event also exists in the Inner Carbonate belt of the Kumaun Lesser Himalaya, similar to the Krol-Tal transition beds of the Outer Lesser Himalaya.

The carbon isotope chemostratigraphy of the Meso-Neoproterozoic Gangolihat Dolomite in Pithoragarh area, Kumaun Lesser Himalaya has been proposed. The study of carbonates and stromatolitic – magnesite – dolomite association show a shift in $d^{13}C$ from positive or negative. This may reflect a change in the benthic microbial community which helped in the formation of magnesite in the Gangolihat Dolomite.

Chert nodules and chert bands from the Gangolihat Dolomite contain well preserved prokaryotic and eukaryotic origin walled microfossils as well as muticellular microfossils. The assemblage comprises cyanobacterial filaments, coccoides, acritarchs and sponge spicules of Vendian age. Presence of microbiota from Infrakrol Formation, Upper Krol Formation and Gangolihat Dolomite strengthen the point that Late Proterozoic microfossils are very well preserved in Outer and Inner Lesser Himalaya.

The study of lithounits viz., Mandhali, Chandpur and Nagthat formations, suggests an overall shallow marine depositional set up. The preliminary geochemical analysis carried out from these detrital sediments display compositional variation from typical shale to quartzite.

The study of Eocene vertebrate fossils from the Subathu Group of Kalakot, J & K, have resulted in a very exciting find – a molar tooth of a small primate. The discovery is quite significant as it represents the first pre-Siwalik primate from India.

The presence of calcareous nodules in the paleosols of the Siwalik Foreland Basin indicates evaporative conditions. Majority of the paleosols have very strongly developed B-horizons. Brief development of cryogenic gelic features (0.5 cm diameter) within the B-horizon are observed, suggesting short events of cooler and dryer conditions within the warmer phase.

Natural Hazards

The local seismicity behaviour in and around Uttarkashi region of Garhwal Himalaya during a swarm activity in Jan-Feb. 2003, showed the magnitude range of the earthquakes was 1-3 (coda magnitude). More than 300 events were recorded during one month of intense seismic activity. The swarm seems to be triggered by the local events of 3rd and 4th January, 2003.

The data collected during a six month seismicity monitoring programme in the Chamoli-Joshimath region of Garhwal Himalaya, showed that the seismicity is confined to a small zone around Indo-Nepal border between MCT and MBT. These events align themselves along a lineament approximately 10 km SE of the river Kali in Nepal parallel to the river.

The deep teleseismic events recorded are inverted for the 1-d crustal structure and found that, a low velocity layer around 18 Km is prominently visible below the Kothi and Itanagar stations, which could be the top of the thrust plane. The Moho at Kothi is diffused in the depth range of 42 to 52 km. while at Itanagar it is sharp at 40 km.

Processing of repeat measurements over the GPS network revealed nearly 15 mm/yr shortening taking place within a 100 km narrow, arc-parallel zone, confined between the MBT and MCT.

Glaciology, Natural Resources, Paleoclimate and Environment

Analysis of suspended sediment data from three stations of Dokrani Glacier, between Snout-Gujjar Hut, Gujjar Hut and Tela stations, suggest that, the suspended sediment concentration of Himalayan rivers is significantly controlled by the sediment transfer from glacier in the headwater regions. These results are contrary to the present line of thinking that the monsoonal rains play the dominant role in higher sediment transfer from the headwater of Himalayan rivers.

The mass balance, ablation accumulation and snout recession studies by EDM survey of Dokriani glacier showed that, the total recession of the snout at center was 19.25 m where as on the left and right flank it has receded about 10 m and 12 m respectively.

Distribution patterns of the elemental abundance of active stream and river sediments from part of the main Alaknanda catchment and that of Bhagirathi-Bhilangana valley show intrinsic relationship with the lithology and tectonics of the area. The stretching and elongation pattern of contours along some of the thrusts and anomaly pattern around the intersection of the thrusts and faults are some of the strong evidences illustrating the influence and role played by the structure and tectonic fabric of the area in controlling the dispersion of elements.

The longest peat sequence so far known from the Higher Himalaya is reported from the upper tree-line area in Din Gad valley of NW Garhwal Himalaya. Multi-proxy paleoclimate data from this peat profile have revealed full Holocene climate and monsoon history of the Garhwal Higher Himalaya.

Northeast Himalaya

In Roing-Anini section of Dibang river sections, eastern Arunachal Pradesh, four major tectonic units have been identified separated by major thrust planes. The geochemical studies further carried out on the trondhjemites of the region seems to have many of the characteristics which indicate their derivation from the melting of subducted oceanic slab (basaltic), leaving residues of 10% garnet amphibolite or eclogite.

Eight major tectonostratigraphic units have been demarcated during the detailed traverse mapping along the Pasight-Geku-Yinkiong-Tuting section from south to north in Siang valley of Eastern Arunachal Pradesh. Considerable neotectonic movements have taken place along the 'boundary thrusts' that define the boundaries of lithotectonic terranes and along many 'tear faults' cutting the terrain transversely. A major 10 km long transverse N-S trending active fault namely Pasighat Fault has been recognised. This fault has uplifted the gravelly fluvial terrace (T1) by 50 meters just west of the Degree College Pasighat. The uplift is observed to have taken place in three pulses.

A prolific growth and diversification of Mesoproterozoic to Terminal Proterozoic microbialites (stromatolites) have been recorded for the first time from the Buxa Dolomite of the eastern Lesser Himalaya. The carbon and oxygen isotope chemostratigraphy of the Buxa Dolomite in the Western and Eastern Arunachal Lesser Himalaya are globally comparable with the Lower Permian Gondwana sedimentation in the Western and Eastern Gondwanaland.

Implementation of Hindi

In order to promote Hindi in day-to-day work, general orders, circulars, notices, etc. were issued both in Hindi and English. The Hindi version of the Annual Report of the Institute was published and circulated. Hindi fortnight was celebrated from 14th to 28th September, 2002 and during this period various programmes in Hindi were organized.

Miscellaneous

- 58 papers and 10 popular articles were published, 97 papers are in press/ communicated and 20 technical/consultancy reports were submitted.
- 29 sponsored projects are in progress dealing with various aspects.
- 43 invited lectures delivered by Institute's scientists
- 6 scientists visited abroad.
- Five new scientists were recruited in the Institute, two among them are deputed to NE Itanagar unit.
- Library is now being fully computerized. The back log of journals has been cleared.
- The Central Facility of the Institute is being upgraded by the purchase of New ICP-MS instrument to carryout geochemical analysis. The Water Chemistry lab and Paleomagnetic lab are also being upgraded.
- The Institute has gone for Local Area Network (LAN) and internet lines have been provided to all scientists & main sections/labs.
- An in house training course on 'Fundamentals of Soil Mechanics and its applications to Landslide investigations' was organized for Institute scientists from 15th March 2001 to 2nd June 2002.
- Organized the field excursion for trainees of DST sponsored short-course on 'Paleoseismology and Earthquake Geology' jointly with C.A.S. Punjab University, Chandigarh, to the western Doon valley.
- On the request of I.G. of ITBP Uttaranchal & Himachal regions, the Institute organized two one day Interaction Workshops on Natural Disasters and their Management, with special reference to H.P. and Uttaranchal.
- The Central Ground Water Board Uttaranchal Region, Dehradun, Ministry of Water Resources hold 'Training Programme on Artificial Recharge of Ground Water' on 12th March, 2003 in Wadia Institute.
- Public awareness programme on Seismic Hazards was organized in our North-East Centre at Itanagar on 28th February 2003.

- The Institute has brought out "Himalayan Geology" vols. 23 (1 & 2) and 24(1), Ashmika vol. 8 (Hindi magazine) and Annual Report for the year 2001-2002 (both in English and Hindi). It also brought out S.P. Nautiyal Memorial Lecture delivered by Dr. R.K. Bhandari.
- Institute celebrated National Science Day, Technology Day, Foundation Day and Founder's Day with the usual enthusiasm.
- Prof. K.K. Sharma, Scientist 'G', Dr. N.S. Mathur, Scientist 'F' and Dr. Hakim Rai, Scientist 'F' superannuated on 30.4.2002, 31.12.2002 and 31.7.2002 respectively after serving the Institute for long and productive years.
- Sh. G.R.K. Nair, Registrar retired on 30.11.2002 after serving the Institute for over 15 years. Sh. Dinesh Chandra, S.P.O., was appointed as new Registrar, w.e.f. 30.11.2002.
- Prof. V.S. Ramamurthy, Secretary, DST, visited our Institute on 9th February, 2003 and laid down the foundation stone of the Institute's guest house cum hostel. He also went around various labs, and interacted with the scientists.
- The Institute also received two distinguished visitors during the year, Shri. Bachi Singh Rawat, Hon'ble Minister of State for Science and Technology, Govt. of India, and Sh. Y.S. Rajan. Exec. Director, TIFAC & Scientific Secretary to the Govt. of India.

N. S. VIRDI
DIRECTOR

PROGRESS IN RESEARCH PROJECTS

1. THRUST AREA

GEODYNAMICS AND CRUSTAL EVOLUTION

1.1 SUB PROJECT

Crustal Evolution in the Trans-Himalayan region of Tso-Morari, Indus and Shyok Suture Zones
(T. Ahmad, S.K. Paul, H.K. Sachan, D.R. Rao)

T.Ahmad studied the eclogitic rocks occurring as lenses within the Puga gneisses of the Tso-Morari Crystalline Complex. The rocks display restricted variation in SiO_2 abundances (~ 45 to 48 wt %) indicating basaltic composition. Total alkali versus silica (TAS classification) indicates their transitional nature between alkaline and tholeiitic basalt. Rare earth element patterns of these rocks display enriched characteristics with fractionated patterns $(La/Yb)_N$ = ~ 2 to 6. Some of the patterns display slight depletion of La and Ce with respect to Nd; $(Ce/Nd)_N$ varies between ~ 0.75 to 1.2. The $^{87}Sr/^{86}Sr$ ratios for the eclogitic rocks vary widely between 0.70884 and 0.73721 probably indicating interaction with host granitic gneiss with $^{87}Sr/^{86}Sr$ ratio of 0.92547. Multi-element display enriched trace element characteristics somewhat resembling those of the OIB – E-MORB, although large ion lithophile elements (LILE: Rb, Ba, K) display erratic behavior. La, Ce, LILE and $^{87}Sr/^{86}Sr$ ratio appear to have been perturbed by secondary processes.

Whole rock epsilon Nd values (t = 0) vary from + 3.3 to + 8.3, indicating derivation from depleted mantle sources. Trace element and Nd-isotopic characteristics of these eclogites resemble those of the adjoining N-MORB - OIB rocks of the Zildat ophiolitic melange, but the $^{87}Sr/^{86}Sr$ ratios for the Tso-Morari eclogites is much higher than the ophiolitic rocks (Fig. 1). The latter have under gone blue schist facies metamorphism. However, our view regarding protolith for these eclogites differs from the widely held view (based on tectonic consideration and major and trace element characteristics) that these eclogites may be the equivalent of rift related Permian Panjal volcanics and their extension (Phe volcanics) in eastern Ladakh.

Although major and trace element and to some extent $^{87}Sr/^{86}Sr$ characteristics of the Phe volcanics do resemble with the Tso-Morari eclogites, the ε_{Nd} (t = 0) are very different, and varies from - 2.7 to - 7.8, indicating their derivation from highly enriched sources. Preliminary Ar-Ar data on the separated white mica from one of the samples gives three dates: 72.1±1.1 Ma; 85.2±0.6 Ma and 100.8±0.9 Ma, significance of these ages, however, is not yet clear. We suggest that Tso-Morari eclogites, presently occurring as lenses in the host gneisses, probably represent fragmented dykes related to the N-MORB - OIB type magmatism of the Neo-Tethyan ocean that have traversed through the northern margin of the Indian plate then represented by the Tso-Morari crystalline rocks.

S. K. Paul carried out field work along Mahe-Sumdo-Tso Kar section, Rumse-Tiri section and Nor Nis – Shergol section in the Indus Suture Zone and observed that, in the northwestern Himalaya the collision began in the mid-Cretaceous with the suturing of the Island arc to the Asian plate and proceeded during Cenozoic, with the obduction of Island Arc on to the Indian plate. The obduction of Island Arc exhibits two different orientations. The early obduction of Island Arc and ophiolitic mélange trend WNW-ESE to the west of Rumse while latter abducted Island Arc (Nidar Ophiolitic Complex) on to the Indian plate to the south and the Asian plate to the north form a pop-up structure and trend NW-SE. These two suture zones are separated by a transverse fault. Northwestern extension of the Nidar Ophiolitic Complex merges with southern margin of the Indus Suture Zone observed to the north of Tanglang La and has cross-cut angular relationship with the rocks of Indus Formation, indicating anticlockwise rotation and reorientation of the Indus Suture Zone to the SE of Tanglang La.

He also carried out field work around Durbuk, Tangtse and Pangong Tso, and observed that, the rocks exposed between Durbuk and Tangtse belong to the Shyok Suture Zone in eastern Ladakh. A dyke shaped gabbroic body with large feldspars exposed to the north of Durbuk, has oblique relationship with the Tangtse mylonitic granite. The contact between gabbroic body and mylonitic granite is faulted and designated as Karakoram Fault and it shows dextral strike slip movement. Metasediments comprising of shale, siltstone, phyllite, chert and quartzite exposed to the north of Tangtse mylonitic granite at Durbuk and Tangtse reached upto garnet grade and are intruded by leucocratic granite. The northern part of the Karakoram meta sediments exhibit cyclic deposition of chert and quartzite. Tectonic deformation caused by subsequent oblique collision, also affected the rocks of the Asian plate. The leftover leucocratic granitic melt of the Karakoram granitic complex invaded the metamorphic rocks exposed to the north of Durbuk and Tangtse. The metamorphic rocks

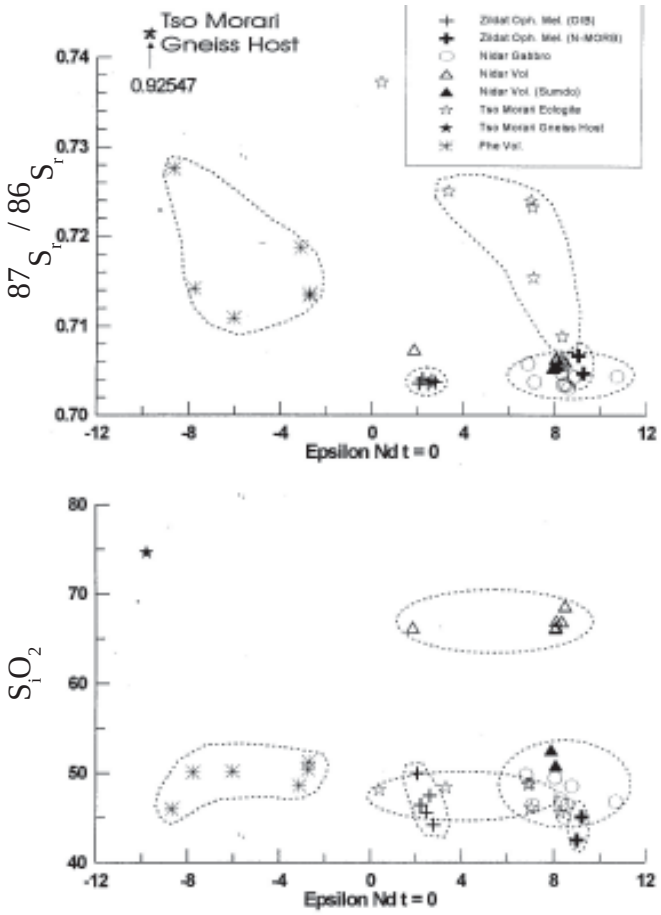


Fig. 1 : (a) Plot showing positive ε_{Nd} values for most of the plotted rocks indicating derivation from depleted mantle sources. Phe volcanics with negative ε_{Nd} values indicate derivation from enriched mantle sources. Variable and elevated Sr ratios for the Tso Morari eclogites and Phe volcanics may partly be due to alteration effects. (b) Plot shows absence of any co-relation with considerable variation in ε_{Nd} for restricted SiO_2 variation, indicating little influence of crustal contamination in the plotted rocks.

comprised of metapelites, minor calc silicate, amphibolite and migmatitic orthogneiss. These leucogranite veins are intensely and intricately intruded into the low pressure site such as the foliation, fold hinge lines, axial plane surfaces and fracture planes. The dextral strike slip movement on the rocks of Shyok Suture Zone trending NW-SE, form the southern Karakoram Fault and the northern strand of Karakoram Fault trending NNW-SSE are mainly responsible for the transgressional movement, and led to pop-up of Pangong migmatite and granodiorite into which the Karakoram granite were intrude.

H.K. Sachan carried out metamorphic and fluid inclusions studies on eclogite rocks of Tso-Morari region. He observed three phases of inclusions in omphacite. The inclusions are having halite cubes besides the vapor bubble and liquid. The fluid inclusions in omphacite occur as tubes that are oriented parallel to the c-axes of host grain. The bi-phase aqueous inclusions are also observed in the core of garnet grain in the form of clusters which suggest a primary origin of such inclusions. Many single gas rich inclusions are also observed in the omphacite, garnet and quartz. Besides these early inclusions, some secondary trail bound inclusions also occur. These inclusions are mostly bi-phase in nature. Secondary inclusions are concentrated mostly in the quartz grains hosted in garnet and omphacite.

Major fluid types have been identified by using petrography and microthermometry studies. The $N_2/CO_2/CH_4$ inclusions are found to be much less abundant than aqueous one by volume. The pure N_2 inclusions found in coesite bearing eclogite, whose homogenization to liquid temperatures (Th) range between –165 to -147°C. These inclusions are isolated and clustered often occurring in close vicinity of high saline aqueous inclusion. The CO_2 inclusions are mono-phase at room temperature with a final melting temperature (Tm) close to pure CO_2 triple point (-56.6° C). Homogenization of these inclusions occurs in the rage of -7 to -1°C with a clear maxima at -2°C .

The CH_4 inclusions are mono-phase at room temperature with characteristic negative crystal shape occurring in the form of clusters or as isolated ones. The initial melting temperature of such inclusions is in between –182 to-179°C indicating methane rich inclusion with some amount of nitrogen. These inclusions are observed in quartz of coesite bearing eclogite. These methane rich inclusions are homogenized in the range of –120 to -100°C. Aqueous inclusions are by far the most abundant in all samples. They show wide range of salinities from almost pure water to high saline fluid. The final melting temperature of aqueous inclusions range from –18 to –1.2°C.In halite bearing inclusions, the total homogenization took place by halite disappearance. In most of the inclusions, the vapor bubble disappears a few ten degrees below final halite dissolution which occur between 250-300°C. In many cases, the dissolution temperature could not be measured due to decrepitation.

D. R. Rao carried out geochemical and geochronological studies of granitoids from the southern slope of the Karakoram batholith between Sasoma-Saser-Brangsa regions. The studies suggest that the granitoids are metaluminous to peraluminous (mol. A/CNK value is ~1.0), have Sr_i ratio of ~0.709, show volcanic arc affinity and suggest emplacement age of ~124 Ma. It is proposed that they represent the reworking of lower crustal calc-alkaline parental rocks.

1.2 SUB PROJECT

Mineralization and metallogeny in space and time in context of diagenesis, magmatism, meta-morphism and tectonism: special emphasis on the role of complex fluids in the genesis and evolution of host rocks and ores.
(R..S. Rawat, T.N. Jowhar, Rajesh Sharma, D. R. Rao)

R. S. Rawat & T. N. Jowhar carried out field work in Garhwal and Kumaun Himalaya (Uttaranchal) during March 2003. Field work in Lansdowne -Amritpur-Ramgarh-Padampuri-Champhy-Ghingrani-Bhowali-Almora- Ranikhet- Chaukhutiya-Deghat-Karanprayag-Mohankhal-Pokhari-Rudraprayag was carried out to understand the mineralization associated with acidic and basic rocks of these areas. During this field work the investigators have studied the nature of field relationship of different granitic bodies having a distribution in space and time - of 1800, 1300, 1000 and 500 Ma granitic bodies occurring in different tectonic setup. New mineralized zones in the Almora-Dudatoli-Ramgarh-Chail rocks have been observed (Figs. 2 A to D). Highly deformed mineralized zone in the calcareous schistose rocks of the Ramgarh crystallines is about 100 meter wide (Fig. 2 D). The calcareous quartzite in the Ramgarh group has a highly mineralized zone – about 20m wide quite conspicuously shown by malachite and the alteration of other sulphides (Fig. 2 C). The mineralized zone shows atleast three generations of deformations. In the Almora crystallines, tin bearing quartz veins are brownish while non mineralized veins are white (Fig.2 A). Similarly the tungsten bearing veins in the calc silicates near the granitic bodies are quite big (Fig. 2B).

R.S.Rawat was also involved in the preparation of ultra pure starting materials for the homogenization and cation exchange studies in the Experimental Petrological Lab at the Institute. The ultra pure starting materials for XRD and High P-T studies were first separated by isodynamic magnetic separator followed by heavy liquid (Bromoform-NN Dimethynmide mixture of 2.60 density) and also by use of Sodium polytungstate methods. These methods were followed by staining techniques to get 99.9% pure samples and finally by repeated handpicking of the stained grains to get ultra pure samples for further studies. On the basis of starting materials prepared, he carried out eight homogenization and cation exchange studies at 1050°C and 850°C from different granitic bodies to get their melting temperature as per the methods developed by Rawat and Prabha, 1988 (*N. Jb. Miner. Jg.*, 9, 417-425), and Rawat and Nagar, 2000 (*In: S & T of High Pressure, eds. Murali et al.*, Honolulu, Hawaii, USA, 2, 625-628).

T. N. Jowhar continued work on geothermobarometric studies on granites and crystallines. Petrographic and mineralogical studies were carried out on Almora crystallines. P-T computations were done using GPT software. Structural state studies on alkali feldspars from granite and gneisses of Almora crystallines were also carried out. The distribution of aluminum in tetrahedral sites have been quantitatively estimated by X-ray diffraction. The alkali feldspars are intermediate to maximum microcline with Al occupancy of 0.703 to 0.985 in T_1O tetrahedral site.

Rajesh Sharma & D.R Rao carried out field work in Champawat, Didihat, Askot and Tawaghat areas. Traverses were taken in Banlekh-Punabe-shisti, Dunaghat-Devidhura, Chandak, Askot-Barigaon and Dharchula-Tawaghat areas. Control of sulphide mineralization and host- ore relations have been studied at Askot, Tawaghat, Chandak and Berinag areas.

Rajesh Sharma studied the field features of the sulphide minerals that commonly occur in vein forms or disseminated in the host crystalline rocks near Askot and Rounag Nala areas. The variations in ore assemblage and ore-host relation are also observed around polymetallic sulphide deposit of Askot. Main ore minerals associated with schistose host rocks are chalcopyrite, galena, sphalerite, pyrite, arsenopyrite, covellite and malachite. These sulphides vary from coarse crystalline to fine grained complex assemblage. In the Raunag Nala area of Tawaghat, occurrence of polymetallic sulphide mineralisation in quartz veins associated with crystalline rocks has been noticed for the first time. Here malachite encrustations and chalcopyrite specks are also seen in the host crystallines. From the field characters and mineral assemblage, it appears to be similar to the Askot sulphide mineralization.

He carried out preliminary ore petrography of the samples of Raunag Nala area. The main ore minerals present in the studied samples are chalcopyrite, pyrite, galena, sphalerite, covellite, and malachite whereas quartz is main gangue mineral. Chalcopyrite forms the dominating primary sulphide. Mutual boundary relations between sphalerite-galena and chalcopyrite-sphalerite are observed. Sphalerite is also found replacing chalcopyrite whereas pyrite-chalcopyrite shows complex relations replacing each other.

He also carried out fluid inclusion and petrographic studies on the magnesite and talc deposits of Jhirouli, Rema and Kanda areas of Kumaun Lesser Himalaya as a part of the collaborative work with Dr. P.D. Pant/Ms Prabha Pandey of Kumaun University. A mineral map of the Uttaranchal state has also been prepared.

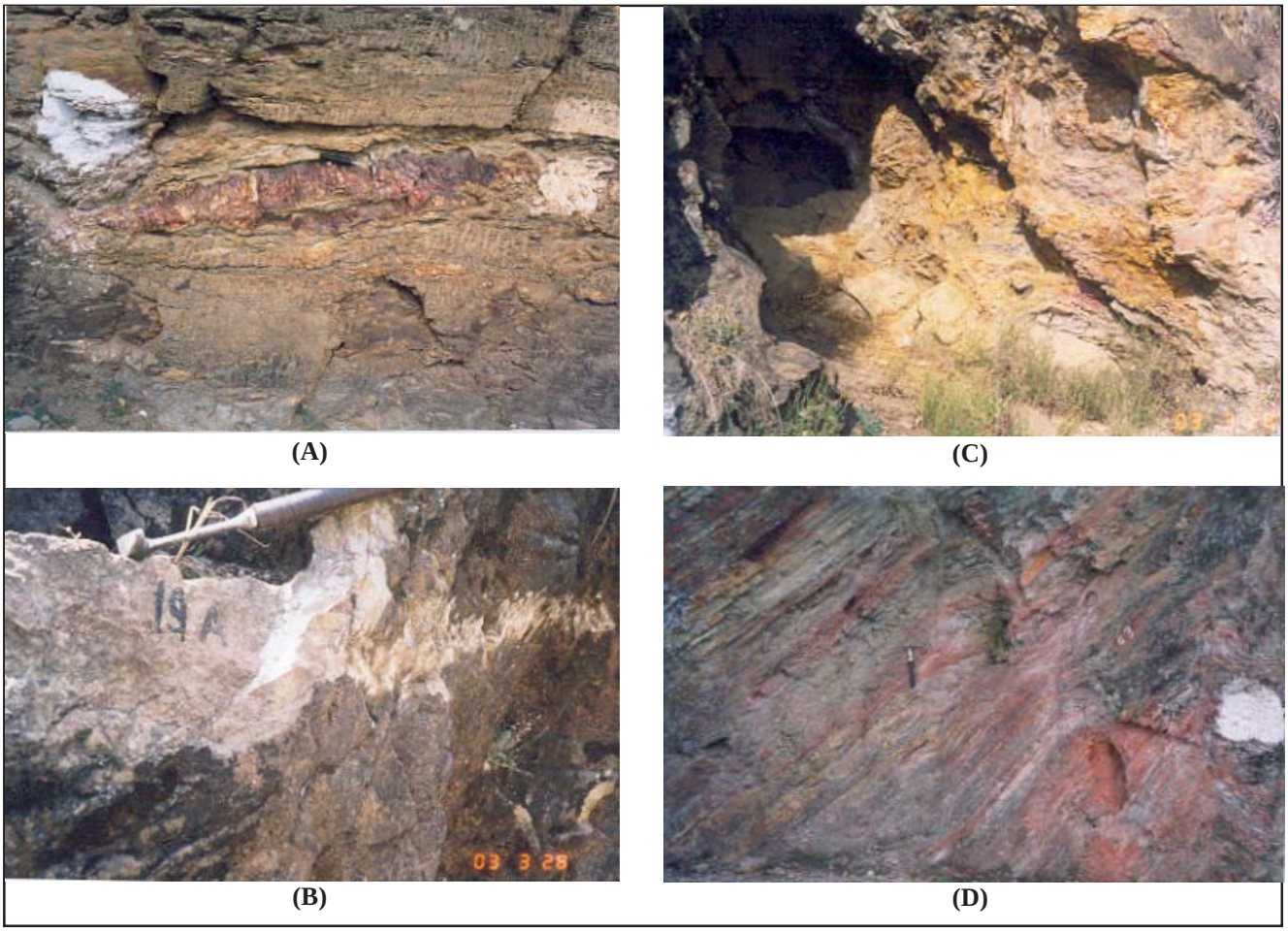


Fig. 2 : Field photographs showing (A) Cassiterite in the vein of Almora Crystallines, (B) Scheelite in the calc silicate rocks of Dudhatoli Crystallines, (C) Polymetallic sulphides in the Ramgarh Crystallines, and (D) Polymetallic suphides in the Chail rocks.

D. R. Rao studied the granitoid rocks between Sandev-Chobarti, which form a part of doubly plunging synformal belt of Askot Crystallines of Kumaun Himalaya. The studies show that the rocks are biotite dominating, medium to coarse grained with equigranular texture, and sometimes also showing porphyritic texture. Quartz occurs in two generations and occasionally shows triple junctions, suggesting high equilibrium temperature at the time of their formation. Perthites, and orthoclase showing Carlsbad twinning has been noticed. Plagioclase generally shows albite twinning, but albite-carlsbad and albite pericline complex twinning are not uncommon. Biotite occurs in two forms, the massive biotite mimic's the shape of hornblende and shows two sets of parting planes intersecting at 120°. Mica flakes do curve around the porphyroblasts of feldspar, suggesting early crystallization of the porphyroblasts. Subhedral to euhedral zircons and apatite occur as inclusions within the quartz, K-feldspar, plagioclase and biotite. The euhedral shape indicates magmatic origin for these granites. Epidote, chlorite, sphene and sericite occur as products of retrogression in these rocks.

The geochemical studies carried out on these rocks suggest that, they have granodiorite to adamellite composition, with normative corundum > 1 and show peraluminous character. However, they have K_2O/Na_2O ratio < 1, Na_2O values generally >3.2, CaO values > 1.5 and show linear trends on binary plots of SiO_2 vs CaO, MgO, TiO_2, MnO, P_2O_5 etc. They also plot in igneous fields on binary variation diagrams suggesting their I-type nature. The petrographic studies as discussed above also show many characters supporting the igneous origin for these rocks.

From the fluid inclusion studies *Rajesh Sharma* indicated two types of fluids entrapped in these rocks, (i) monophase gas rich, and (ii) biphase liquid + gas fluid. The liquid-gas proportion in biphase inclusions varies

widely from 9:1 to 2:8. A few inclusions show liquid-liquid meniscus at room temperature (cf. 24^0 C) suggesting a composition of the trapped fluid as aqueous liquid + carbonic liquid + carbonic gas. This may also rules out possibility of high density of carbonic fluid. They occur in a distribution pattern that suggests syn to post metamorphic fluid history.

From the preliminary studies carried out on Sandev-Chobarti granitoids it is suggested that, the granitoid rocks have hybrid origin, involving two stages of development. An early stage represents igneous origin for these rocks, while during latter tectonic deformation stage the rocks were subjected to partial melting and assimilation of sedimentary country rock. The recrystallized rock has resulted in hybrid composition for the rocks understudy. Due to assimilation the normative abundance of biotite and quartz increased at the expense of K-feldspar. This as resulted in the decrease of K_2O and increase of Al_2O_3, and their by imparting peraluminous character for these rocks.

1.3. SUB PROJECT

Study of frontal and oblique ramps in the Western Himalaya

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

A.K. Dubey conducted experiments using a model to understand the evolution of the Leopargial Horst. The model consisted of gray modeling clay in a box with external dimensions of 15 x 11 x 7.5 cm. The top surface of the model was embossed by a grid pattern and every fifth line was marked by a black pen. The model was cut for frontal and oblique ramp geometries (Fig. 3 a). The leading and trailing ramps had dips of 25^0 and 35^0 respectively and they were oriented at angles of 90^0 and 70^0 respectively to the axis of maximum compression. The central oblique ramp was oriented at an angle of 30^0 to the axis of maximum compression. The model was deformed under the general strain boundary condition, i.e. it was allowed to extend in horizontal and vertical directions simultaneously (Hobbs *et al.,* 1976, *In: An outline of Structural Geology,* Wiley, New York, 571 p).

The onset of deformation was marked by thrusting along the leading ramp and right lateral oblique slip displacement along the central and trailing ramps. The displacement out of the tectonic transport plane was observed to be of greater magnitude at the trailing oblique ramp and it was concomitant with the anticlockwise rotation of the central and trailing ramps along a sub vertical axis. A right lateral strike slip fault developed in the footwall indicating a greater horizontal extension as compared to the hanging wall. At a later stage of deformation a strike slip fault developed in the hanging wall. The fault did not show a large displacement because extension along the vertical axis of the press led the model to extend beyond the compressing blades and consequent absence of horizontal compression in the upper part of the model. At this stage of deformation the horizontal extension was enhanced by reduction in thrust displacement due to steepening of the thrust. This led to initiation of an extension fault in the hanging wall parallel to the axis of maximum compression. The fault is a shallow structure and did not form near the trailing frontal ramp where the entire hanging wall was above the compressing blades due to low thickness. The inhomogeneous deformation because of extrusion of the model above the compressing blades became more prominent at 47% shortening (Fig. 3b) and the extension fault exhibited opening of the fault walls. A second extension fault also developed parallel to the first fault. Formation of these faults suggests that the horizontal compression was dominated by the horizontal extension of the model.

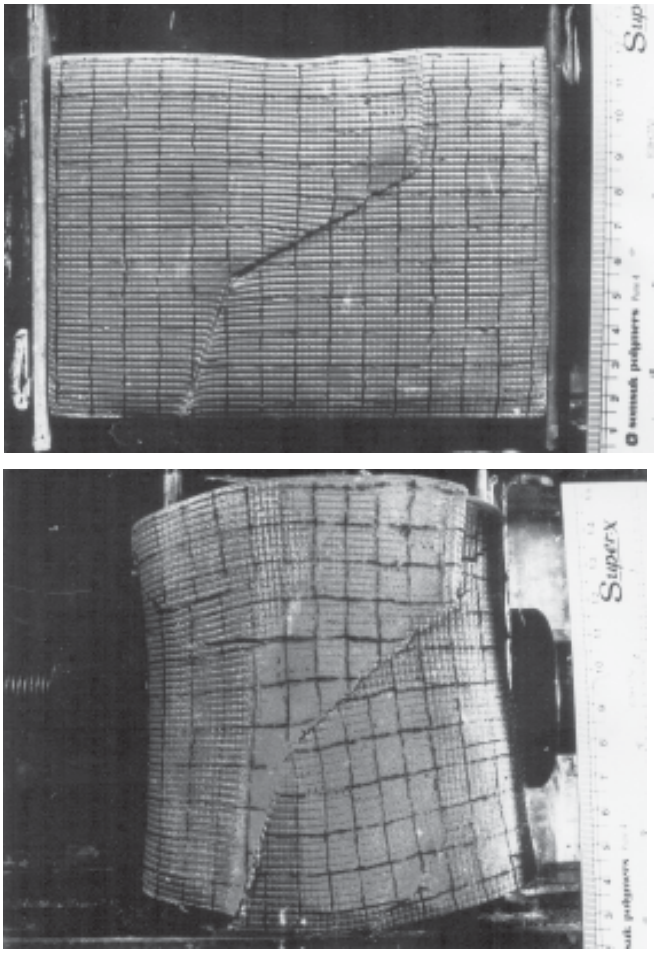


Fig. 3 : Two stages in the deformation of a modeling clay model characterized by oblique and frontal thrust ramp geometries, (a) 0 %, and (b) 47 % shortening.

The relationship between shortening and angle between the central and trailing ramps with the axis of maximum compression showed anticlockwise rotation of the ramps along a sub vertical axis. At the trailing ramp, the rotation rate was dropped after 4% shortening and the rotation ceased at 11% shortening. The central ramp did not rotate till 7% shortening but then it showed a rapid increase till 11% shortening followed by a decrease. The rotation was concomitant with oblique slip displacement along all the three ramps. The horizontal components of displacement measured from displacement of grid lines showed variable increase in strike slip displacement during the initial stages of deformation and only a minor increase after 21% shortening. The central oblique ramp showed initial non-uniform rapid increase till 22% shortening followed by decrease. The trailing ramp followed a similar pattern but the rate of displacement decreased after 6% shortening and the displacement ceased at 33% shortening. The maximum displacement was observed along the central ramp and the minimum displacement along the frontal ramp, which was orthogonal to the axis of maximum compression.

This is explicit from the experiment that the area of higher elevation had suffered shortening during the initial stages of deformation but once it has crossed the height of the compressing blades, the shortening was minimum. A larger number of thrust faults in the model may lead to formation of extension faults at higher elevations (i.e. above the compressing blades) and simultaneous thrusting at the lower elevations (i.e. below the compressing blades).

R.J.G. Perumal has carried out the paleoseismological studies between Ram Nagar and Chour Galia section along the HFT east of Hardwar. The scarp along the Rawasan Nadi (near Laldhang) suggesting a possible earthquake related feature was selected (Fig. 4 a), where a broad paired flat terrace that sits 13-15-m above the present river grade is truncated outboard the range front leaving a 13-m high clift. A trench was opened perpendicular to the NS trending scarp at Laldhang, to decipher the timing, size and repeat time of the earthquakes (Fig. 4 b). East West oriented trench of about 24-m long and 4-5-m deep was excavated with a backhoe. A one-meter by one-meter reference grid was established to transfer the trench stratigraphy into a scaled log.

On the eastern end of the trench the hanging wall exposed a sequence of debris flow deposit.

Unit 1 : It is light brown in colour represents high-energy depositional package characterized mainly of mixed clast shapes. The unit seems to have been tilted towards west and is truncated at about 8th meter grid from the eastern end of the trench.

Fig. 4 : (a) Shows a 13 m high scrap near Laldhang Forest Rest House. A Back-Hole is under the process of excavating the trench perpendicular to the scarp. Photograph is taken from the west. (b) Shows the trench exposed near Laldhang, the hanging wall gravels are tilted and truncated. The footwall sequence on fine sand-silt-clay is underthrusted along the fault plane. The pink flags represent the location of carbon samples collected from the stratigraphic units.

Unit 2 : Overlying the unit 1 is a light gray to light brown well-stratified pebble-cobble layer, which also represents depositional sequence of fluvial gravels nicely tilted showing inclination of clasts. The intervening cobble gravel layer is supported by sandy matrix and shows alignment of subangular to subrounded clasts. The unit is warped and tilted towards west and is truncated at about 10th meter grid from the eastern end of trench. At the basal portion of this unit, the clasts appear to have been warped along a flat plane that truncates this unit and the overlying unit-1.

Unit 3 : Overlying the unit-2 is a dark gray color clean sand that shows well stratified sequence of silt and coarse sand (Unit 3). This unit is loosely compacted and shows no soil development. Interbedded silty sand deposits in discontinuous lenses and beds characterize the unit. The silty sand unit is reddish brown in color. The entire unit is strongly stratified and poorly compacted. The clast range in size from few mm's to 2 cm in diameter (long axis). The clasts are sparsely disseminated and exhibit stratigraphy. This unit sits on top of the unit-2 is also tilted and warped along a plane that truncates the unit-1 and unit-2.

Unit 4 : Overlying the Unit 3 is a reddish brown in color is well-sorted hard, massive silty clay. The contact between the underlying unit – 3 and this unit is sharp and is also tilted and warped along the plane that shows shear fabric.

Unit 5 : Overlying unit-4 is a unit that is black in color when scrapped turns to light brownish black. The contact between the unit-4 and unit-5 is not sharp and quite interpretive and is also tilted and warped. Carbonaceous matter characterizes this unit. Pottery shards are observed in small bits. The contact between the underlying unit and this unit is gradational and quite interpretive, however, at some places the contact is sharp.

A similar suite of sequence is observed on the western end of the footwall and is in unconformable contact with the overlying hanging wall unit along a very shallow dipping plane that shows nice shear fabric.

Based on the above, along this plane the entire sequence of hanging wall unit is warped, truncated and displaced brittly for about 7 m. The faulted package of footwall is overlain by a thick poorly sorted pebble to cobbles subrounded gravel with choatic or massive texture. This unit is interpreted as colluvium derived from the slope process and is post-seismic (*Unit 6*). Carbon samples were collected from both the hangingwall and footwall unit. The dates from the youngest black carbonaceous matter from the both the hangingwall and footwall unit and the overlying laminated sequence of fine to medium sand silt (*Unit 7*) should bracket the age of the earthquake. However, the stratigraphic relation exposed in the trench show only evidence for a single event and hence need to identify trench site that could provide information of an older earthquake.

1.4. SUB PROJECT

Active tectonics in the NW Himalaya between Foredeep and Indus Suture Zone

(Surendar Kumar)

Collisions between continental plates have been a recurring event in geologic history. The most impressive collision today is in the Himalaya where Indian and Asian lithospheric plates collided during late Early Eocene (40 to 50 my ago). Along the entire Himalayan range, the western Himalaya section is among the most active. Continued northward migration of the Indian plate since that time at the rate of 5 cm/yr has resulted in approximately 2,000 km of closure between the two plates.

The frontal zone of the Himalaya is active at present. Active Faulting has been taking place along the Main Boundary Thrust (MBT), the Main Frontal Thrust (MFT) and associated faults. Displacements on imbricate north-over-south thrust on the MBT observed mainly in the western Himalaya are consistent with rapid uplift of the Himalaya. The change in dip of underthrusting slab and presence of sedimentary basins in front of the Himalaya is probably a result of the right angle compression of the underthrusting basement. The behaviour of faults with respect to the earthquakes can be utilized to determine the mechanism of earthquakes in this belt. A wealth of geophysical evidence demonstrates that south of the Himalaya, the top surface of India's basement rocks flexes and slides beneath the Himalaya-not steadily but in lurches during great earthquakes. This region also shows localized vertical movement, and small earthquakes are most common here.

The Seismic Hazards in the western Himalaya have been found to be due to associated major fault and thrust system in the region. The shallow subsurface geotechnical data combined with other surficial stratigraphy and geomorphology, record that the Frontal Folded Belt is an active 85-km long structure. From the style and rate of deformation of basement and constriction rate at the Himalayan Front is of about 15 ± 5 mm/yr. This rate provides a basis for estimating a rate of the entire western Himalayan region, which in turn will allow estimating time-average rate of slip in the underlying fault and thrusting planes. All this rate of slip, rupture of the underlying faults would give a nominal magnitude of earthquake in respect to time. The infrequent reoccurrence of >6 magnitude earthquake, its size and reoccurrence interval would be similar to the present day seismicity and could be estimated for source of destruction. The geometry of the source zone, the nature of the slip zone and kinematics derived from the data will also help constrain the interpretation of ongoing experimental geodetic surveying in the area. This all will help in better understanding of the Himalayan tectonics and associated Hazards in the mountainous region.

2. BASIN EVOLUTION

2.1. SUB PROJECT

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

(S.K. Parcha)

The field studies were carried out in the Zanskar area of Ladakh. The fauna collected from the Tangzee Yogma section includes some typical Late Middle Cambrian agnostids. The other studies carried out on the basis of trilobite and trace fossils of the Spiti area are briefly described below:-

Biometric Analysis of Trilobites

The multivariate statistical analysis and the image analysis of two ptychoparid trilobite species distinguished by Cranidium ornamentation was undertaken in joint collaboration with Prof. P. K. Saraswati of IIT, Mumbai. Twenty-six cranidial variables were measured. The data thus generated was processed. An analytical technique, called Classification and Regression Tree (CART), was used to analyze the data. The technique has been found to have wide-ranging applications. The literature survey indicates that this is the first application of CART in trilobite taxonomy.

Previous workers have debated about two Middle Cambrian trilobite genera *Hundwarella* and *Iranoleesia*. By using CART classification a tree is proposed in this study, this can assign an unknown specimen to one of the two genera. The CART has been further tested with 15 data sets of the two genera and it is observed that:

1. Except for one misclassification of deformed specimen of *Hundwarella* all other tested specimens of *Hundwarella* are correctly classified, and
2. The identification of *Iranoleesia* based on criteria of previous workers is found invalid and such specimens are classified under *Hundwarella* in the proposed classification tree

The statistical approach applied was found to be very useful for resolving particularly the taxonomic status and stratigraphic range of the different trilobite genera in the Cambrian sections of Zanskar and Spiti

Paleoenvironmental Implications of Trace fossils

A detailed synthesis of the palaeoenvironmental setting and the reconstruction of the paleoecological conditions of the Lower Cambrian successions of the Spiti region can be drawn on the basis of the trace fossil assemblages. The diverse assemblages of trace fossils range from the upper part of the bathyal zone to intertidal regime beyond shelf (Fig. 5). These trace fossils reflect a highly diverse palaeocommunity in shallow marine shelf environments. The most abundant ichnofaunal association of *Diplichnites-Rusophycus* is suggestive of shallow marine *Cruziana* ichnofacies.

Investigations of diverse assemblage of trace fossils suggests that the lower part of the Kunzum La Formation shows an upward shallowing succession of trace fossil assemblage, which ranges from basal neritic ichnofacies having trace fossils as *Planolites* worm and burrows which in higher successions, is represented by *Diplichnites* -

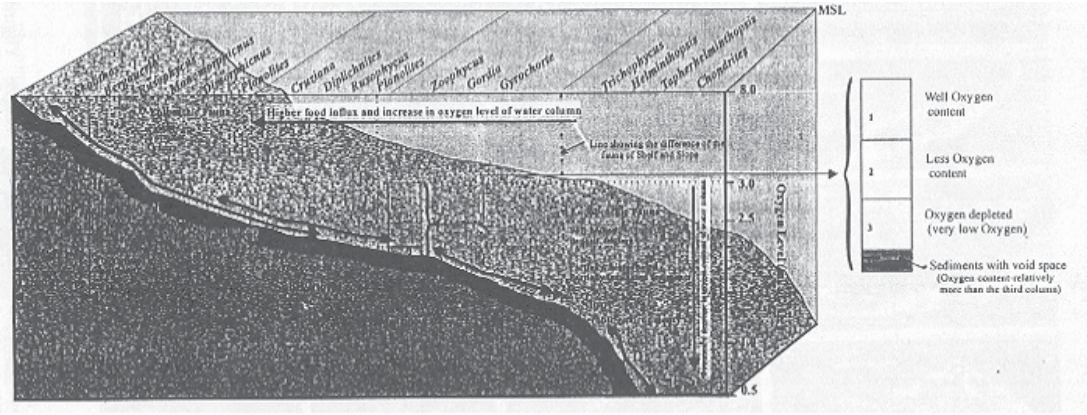


Fig. 5 : The Ichnofacies and inferred palaeoecologic setup based on trace fossil recorded from the early Cambrian succession in the Spiti area of Tethys Himalaya. Ichnofacies : A = Skolithos; B = Cruziana and Arenicolities; C = Cruziana and Zoophycus; and D = Nereites. (based Ekdale & Mason, 1988; Crimes, 1977; Savrda & Bottjer, 1989).

Rusophycus. The oxygen-based model of the trace fossil distribution in the Kunzum La-Takche, Pin and Parahio sections is illustrated in Fig. 5. It aptly describes the palaeoenvironmental conditions of variation in oxygen content of water column and interstitial sediment water along with diversity and transition of trace fauna from deep upper bathyal to shallow shelf to intertidal, which were prevailing during the deposition of the Lower Cambrian to early Middle Cambrian rocks. The palaeoenvironmental implications of these trace fossils of the Spiti region revealed the palaeoenvironment of low current velocities with low dysaerobic (oxygen deficient) to aerobic water columns and low interstitial water oxygen in sediments, which ensured the depositional conditions uninfluenced by currents.

The proposed model of oxygen-controlled trace fossils revealed that with the increase of oxygen concentration in interstitial sediment water shows a parallel transition from fodinichnial - pascichnial to fodichinial trace fossils in association. A high behavioral diversity from suspension to deposit feeders dominates the ichnocoenosis. The palaeoecological community habitating in oxygen deficient condition were well adopted for the turbulent setting, stability of substrates and nutrient influx.

Zanskar area of Ladakh Himalaya

The sections were measured in the Tangzee Kogma areas of the Suru valley of the Zanskar region. The measured lithostratigraphic column along with fossiliferous horizons are shown in Fig. 6. The identified fauna from this section indicates some Middle Cambrian trilobites. The detailed studies of the fauna are still under progress. The detailed GPS data was collected in order to prepare the detailed base map of the Lower Paleozoic successions of this region.

2.2. SUB PROJECT

Palaeobiology, Biostratigraphy and sedimentological characteristics of selected Proterozoic – Early Phanerozoic and Permian – Triassic boundary sections of the NW Himalaya

2.2 a SUB PROJECT

Biostratigraphy evaluation of selected PC/C and P/T boundary sections of NW Himalaya
(R.J. Azmi)

A reconnaissance field work for sampling of Deoban and Mandhali Formations and Dharagad Group of Inner Carbonate Belt of Chakrata Hills was carried out for biostratigraphic assessments. It was interesting to note that the micaceous siltstones of the Dharagad Group contain fairly well preserved *Planolites* and meandering

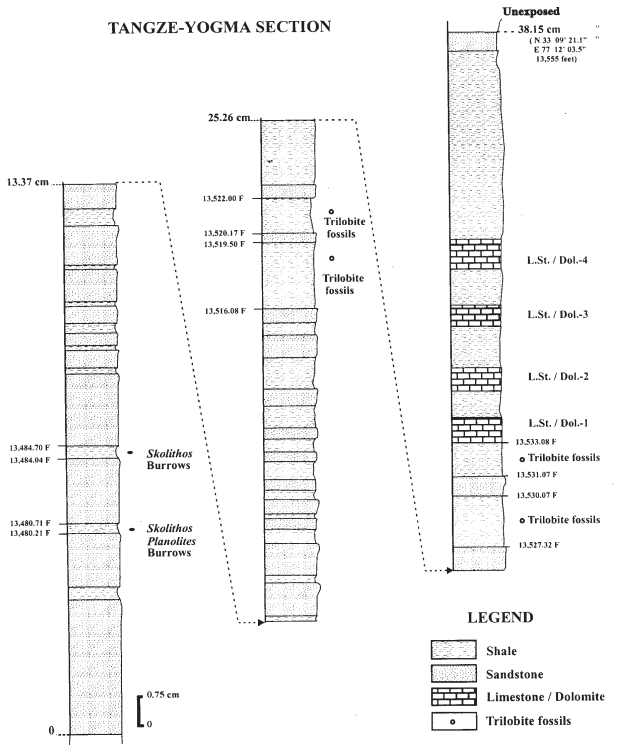


Fig. 6 : Lithostratigraphic column of the Tangze Yogma section, showing fossiliferous horizons in the Zanskar region of the Ladakh Himalaya. Longitude /Latitude and altitude measured by GPS.

trace fossils which substantiate the observations of Vibhuti Rai (1997, *Jour. Pal. Soc. India*, 42, 71-80) who had also recorded trace fossils from the Dharagad Group.

About 50 samples from Deoban, Gangolihat, Mandhali Formations and Dharagad Group from the Inner Cabonate Belt have been examined for microfossils recovery through processed residues and thin sections. In addition to numerous protoconodonts reported in last year's *WIHG Annual Report*, the uppermost Gangolihat Formation has also yielded numerous agglutinated foraminifera and oncolites (Figs. 7 a & b). Occurrence of *Platysolenites antiquissimus* and *Bathysiphon* sp. has been noted in the upper part of the Deoban Formation in the Chakrata area. SEM and thin section photomicrography of the above microfossils have been completed and their taxonomic work is in progress.

Preliminary micropaleontological results from the Inner Carbonate Belt (Gangolihat and Deoban Formations) suggest its correlation with the Krol Belt of the Lesser Himalaya which, in turn are correlatable with the Lower Vindhyans. It also appears based on the preliminary observations on trace fossils that the Dharagad Group may be equivalent to the Tal Formation, but its stratigraphic position below the Deoban Group may be due to tectonic reversal.

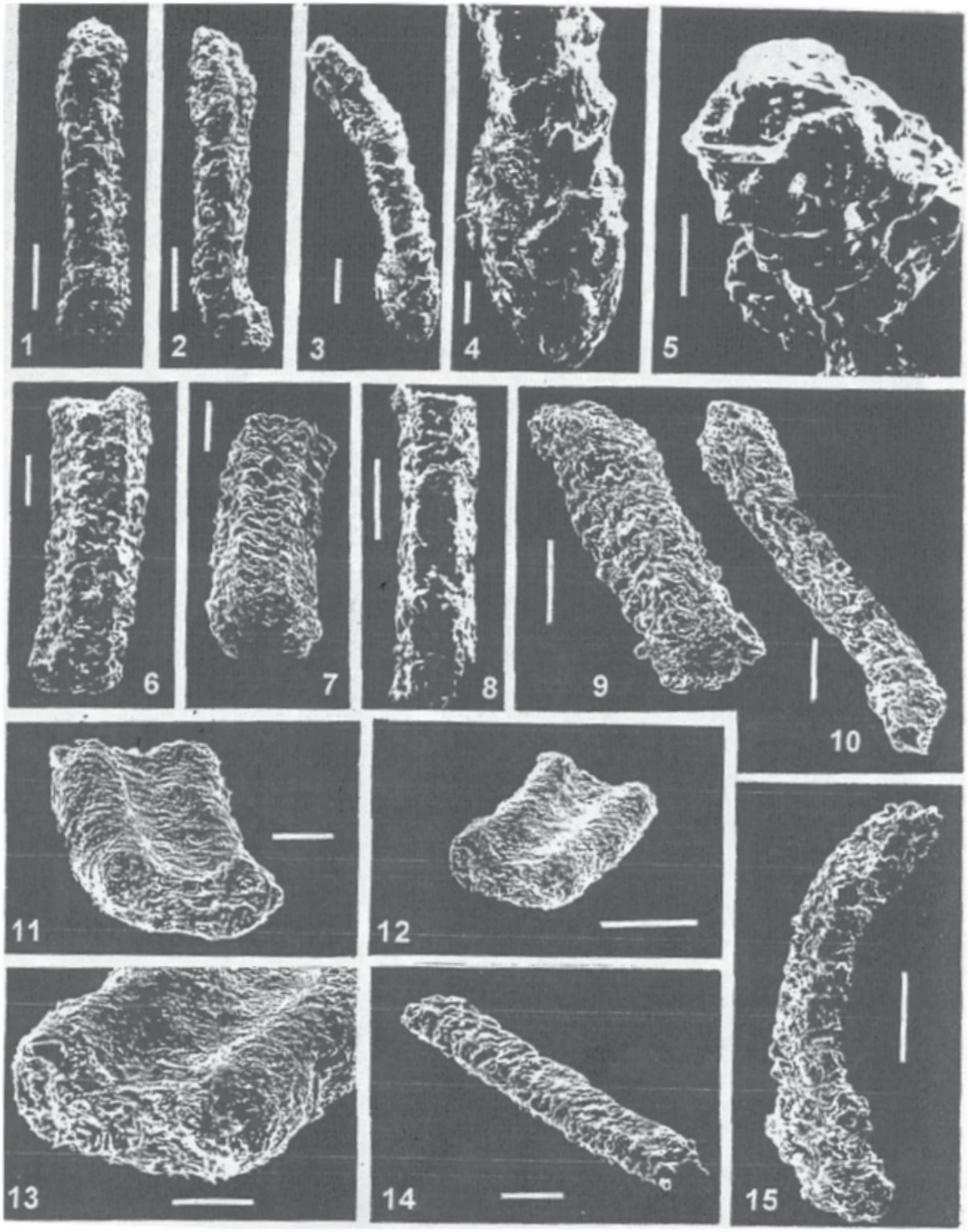


Fig. 7a : SEM photomicrogrphs of agglutinated foraminifera (1-5, 9 & 11-14), *Anabarites* (6-8) , and Protohertzina (10 & 15) from the Upper Gangolihat Dolomite of Jhirauli Magnesite Mine, Almora, Inner Lesser Himalaya. Scale bars of 1-3, 6-10, 12 & 15 represent 250 ìm, and that of 4, 5, 11-14 are of 100 ìm.

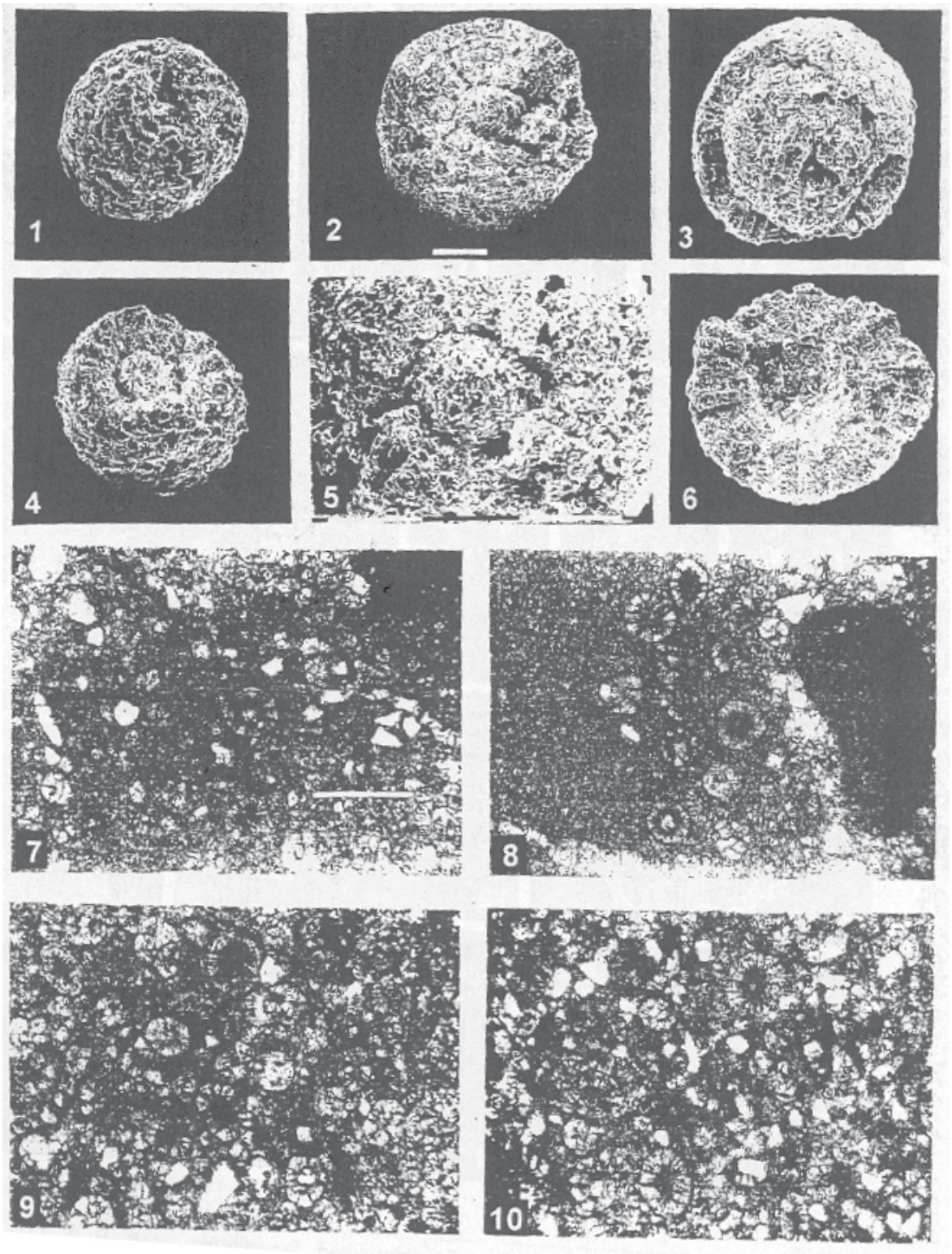


Fig. 7b : SEM photomicrogrphs of isolated oncolite individuals (1-6), and the same abundantly present in thin sections (7-10), from the Gangolihat Dolomite near village Chharchum, Pithoragarh district, Uttaranchal. Scale bar in 2 represents 100 mm for 1 –4 & 6 and that of 5 is of 100 mm. Scale bar in 7 represents 500 mm for 8-10.

2.2b SUB PROJECT

The Mesoproterozoic and Neoproterozoic microbial carbonate sedimentation and carbon isotope stratigraphy of the Bhagirathi valley, Uttaranchal Lesser Himalaya.
(V.C. Tewari)

The Proterozoic marine carbonates are characterized by a near zero per mill $\delta^{13}C$ value. The positive or negative shift in $\delta^{13}C$ are indicative of fresh water and evaporitic/ lagoonal environment. Stratigraphic variation in the carbon isotope ($\delta^{13}C$ Chemostratigraphy) value of Mesoproterozoic to early Cambrian marine carbonate and organic matter preserved within it is an important tool for palaeoclimatic interpretations and high resolution stratigraphic correlation of the Lesser Himalaya (Tewari, 1999, *Geosci. Jour.,* 20, 77-85; Tewari, 2001 *Geol. Surv. India Spl. Publ.*, 65, 49-56; Tewari, 2002, *Aspects of Geol. & Environ*., Nainital, 63-88).Significant variation in Carbonate $\delta^{13}C$ has been observed with major events in the stratigraphic boundaries, for example Neoproterozoic, glaciation event, Precambrian – Cambrian Boundary, Ordovician – Silurian glacial event and mass extinction, Permo – Triassic mass extinction events and Cretaceous – Tertiary mass extinction event worldwide including the Lesser and Tethys Himalayas.

The carbon isotope chemostratigraphy of the Meso-Neoproterozoic Gangolihat Dolomite in Pithoragarh area, Kumaon Lesser Himalaya has been established (Fig. 8). The Gangolihat Dolomite in the type area is subdivided into four members namely Chhera, Hiunpani, Chandaak and Dhari from base to top in stratigraphic order (Valdiya, 1962, *Jour. Geol. Soc. India*, 3, 27-48; Valdiya, 1980, *Geol. of Kumaun, Lesser Himalaya*, WIHG, 291 p.).

The $\delta^{13}C$ value of the basal Gangolihat Dolomite (Chhera Member) vary from + 0.83 to + 0.97 $^{o}/_{oo}$ (PDB) and indicate shallow marine (tidal flat) depositional environment. The Hiunpani Member is a cherty stromatolitic dolomite and the $\delta^{13}C$ value vary from + 0.91 to + 0.96 $^{o}/_{oo}$ (PDB). The positive near zero values indicate that the environment of deposition is shallow marine (subtidal – intertidal zone). The Chandaak Member of the Gangolihat Dolomite is characterized by prolific development of the microbialites (*Colonnella columnaris, Kussiella kussiensis, Baicalia nova* etc.) and well developed magnesite lenses within it. The $\delta^{13}C$ value of the stromatolitic – magnesite- dolomite association shows a negative shift in $\delta^{13}C$ (- 0.90 to – 1.19 $^{o}/_{oo}$ PDB). This negative shift in $\delta^{13}C$ is quite significant and indicate evaporitic/supratidal environment of deposition. This also suggests that there may be a change in the benthic microbial community which helped in the formation of magnesite in the Gangolihat Dolomite. The youngest member of the Gangolihat Dolomite (Dhari Member) is a cherty stromatolitic dolomite and the $\delta^{13}C$ value vary in a narrow range from - 0.90 to – 1.02 $^{o}/_{oo}$ (PDB). Therefore, the

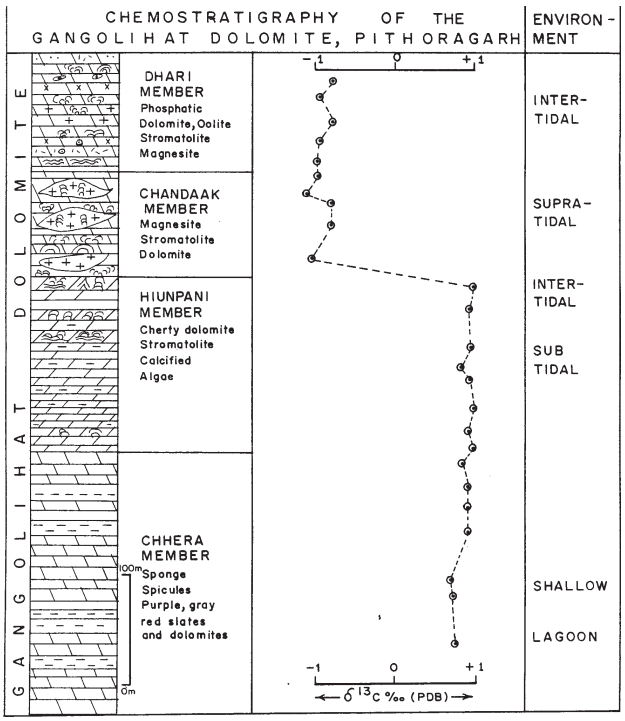


Fig. 8: Carbon isotope chemostratigraphic of the Gangolihat Dolomite, Pithoragarh area, Uttaranchal.

$\delta^{13}C$ value of Gangolihat Dolomite vary from - 1.19 to + 0.98 $^{o}/_{oo}$ (PDB) depicting only one main distinct signature of $\delta^{13}C$ minima (Fig. 8). The lower part of the Gangolihat Dolomite showing mostly positive trend (Fig. 8) of excursion and may be the result of increased rate of organic matter burial in a shallow carbonate platform. The recorded isotope data represent pristine isotopic signature.

The Uttarkashi – Dichli Dolomite in Bhagirathi and adjoining Valley of the Garhwal Lesser Himalaya is a part of the Deoban-Gangolihat belt. The carbon isotope chemostratigraphy of this part will be useful in regional correlation of the larger Deoban – Gangolihat basin of the Lesser Himalaya.

2.2c SUBPROJECT

Late Proterozoic – Early Cambrian Palaeobiology of Lesser Himalayan sequence of Himachal – Uttaranchal Himalaya with reference to evolution of life and its global relevance.
(Meera Tiwari)

Chert nodules from the black pyritiferous shale of the Infrakrol Formation contain exceptionally well preserved

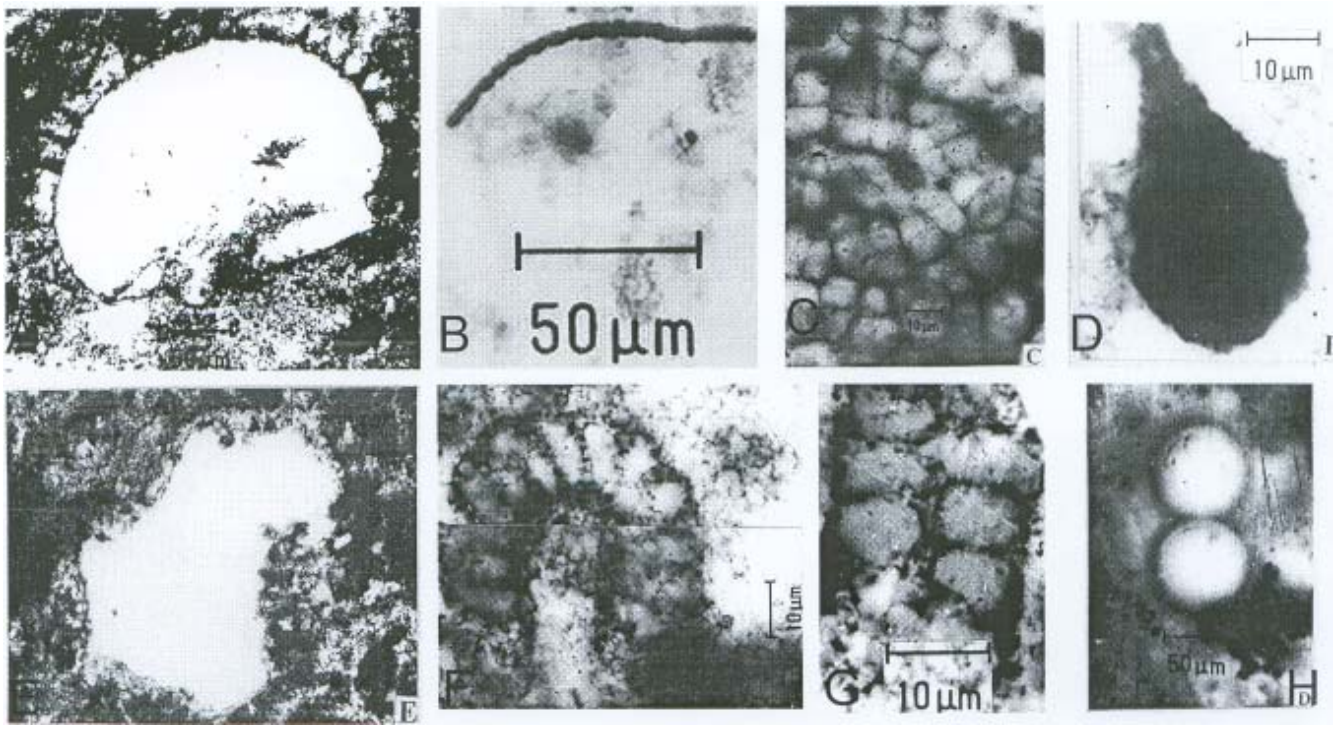


Fig. 9 : Microfossils from the chert nodules of the black pyritiferous shale of the Infrakrol Formation, Lesser Himalaya. The photomicrographs : (A, E) *Asterocapsoides sinensis*, (B) septate filamentous cyanobacteria filled with pyrite, (C) *Wengania globosa*, (D) vase shaped microfossil, (E) *Obruchevella parva* Reitlinger, (F) transverse section of *O. parva*, and (G) Myxococcoides sp.

prokaryotic and eukaryotic organic-walled microfossils as well as multicellular microfossils. The assemblage comprises cyanobacterial filaments, coccoides, acritarchs, thallophytic remains of red algae, sponge spicules-like structures and vase- shaped microfossils. Some of the forms are also identified as larvae of early animals (Fig. 9). The whole assemblage is getting more importance when beautifully preserved microbiotic remains were reported from Tal Formation. In addition to that well preserved microfossils were obtained from Cherty Dolomite of Krol Formation.

On the other hand thin sections of chert from Jhiroli Magnesite Mine also show presence of microbiota which is identified as: *Siphonophycus robustum*, *Siphonophycus inornatum, Siphonophycus* sp., *Oscillatoriopsis* sp., *Gunflintia* sp., *Nostochomorpha* sp., *Eupoikilofusa* sp., *Chlorogloecapsis contexta*, *Mixococcoides minor*, *Mixococcoides* major, *Trchyhystrichosphaeridium* sp., *Eomicrhystridium* sp., *Bavlinella faveolata* and *Cymatiosphaeridium* sp. Very well preserved cyanobacterial filaments, acritarchs and sponge spicules are found preserved in the Cherty Dolomite of Gangolihat Dolomite from Utrora section. Cyanobacterial filaments and Sponge spicules were first reported from this area by Tiwari *et al.*, 2000 (*Curr. Sci.,* 79 (5), 651-654). This time fresh samples were collected from the locality and proved the reproducibility of the microbiota. This further confirms that the microbiota belongs to an age which is younger than Upper Riphean. Presence of Microbiota from Infrakrol Formation, Gangolihat Dolomite and Cherty Dolomite of Krol Formation strengthen the point that Late Proterozoic microfossils are very well preserved in this part and represents an ideal section to study the early evolutionary history.

2.3. SUB PROJECT

Sedimentology of the inner carbonate belt and associated siliciclastic sequence in parts of Lesser Himalaya of Himachal and Uttaranchal Himalaya.

(T.N. Bagati, S.K. Ghosh, R. Islam)

S.K. Ghosh & R. Islam carried out field, petrography and geochemical studies of some important lithounits viz., Mandhali, Chandpur and Nagthat formations, to understand the provenance and paleo-weathering conditions. Field work was carried out in Mussoorie and Tons valley sections. Specific localities visited include Shanshai Ashram- Pathanghat- Maldeota, Kalsi-Chakrata road and Haripur-Chibro road. In these sections main

emphasis was given to find out suitable measurable section for sedimentologic data and systematic sampling for petrography and geochemical studies. From the above mentioned sections about 50 samples and preliminary sedimentological data were collected from Proterozoic-Mandhali, Chandpur and Nagthat formations. The Mandhali Formation, exposed along Kalsi-Chakrata and Haripur-Chibro road section consists mainly of a sequence of grey calcareous gritty shale and boulder slate/phyllite with abundant sub-angular to sub-rounded stretched pebbles cobbles and boulders of weathered limestone, grey and white quartzite and greyish slate, embedded in silty matrix. The succeeding argillo-calcareous lithounits consists of greenish-gray to gray, alterations of carbonaceous and calcareous phyllite and shaly limestone. The Chandpur Formation comprises greenish and greenish grey phyllites and alternation of grey, violet, green and purple fine-medium grained siliciclastics and argillites. The Nagthat formation, essentially comprises medium grained grey, white purple siliciclastics along with subordinate shale/ argillites. Preliminary sedimentologic observations suggest overall shallow marine depositional set up.

Petrographic study of siliciclastic samples from Mandhali, Chandpur and Nagthat formations was also carried out. The siliciclastic component of the Mandhali formation is represented by Bhadraj quartzite in the Tons valley section. These are medium to coarse grained and consists of sub-rounded to sub-angular mono-crystalline undulatory quartz and subordinate proportion of feldspar (KF>PF) and rock fragments of silty chert and meta-quartzite, argillite and low grade metamorphics. Cement is mainly siliceous and subordinate ferruginous and matrix is sericitic. The coarse siliciclastics (conglomerate) are mainly constituted by tectonised quartz aggregates, micro and silty chert argillite and rare limestone fragments embedded in silty clayey serictic-chloritic matrix. The interbedded slates/phyllite are composed of fine clusters of micaceous fibers interspersed with scattered detrital quartz. The siliciclastics of the Chandpur formation consists of fine- grained, poorly to moderately sorted, subangular unitary quartz, feldspar and rock fragments. The matrix component is mainly represented either by sericite and chlorite. The framework and texture hint towards quartz wacke nature of the Chandpur siliciclastics. The Nagthat siliciclastics are mostly medium-to fine-grained sublithic arenite to quartz wacke.

Preliminary geochemical (major and trace elements) analysis was also carried out on the Proterozoic Mandhali, Chandpur and Nagthat rocks of the above said sections. All these detrital sediments display compositional variation from that of typical shale to quartzite. To understand the behaviour of the individual elements, we have plotted all the major oxides and trace elements against SiO_2 and Al_2O_3. The correlation between SiO_2 and Al_2O_3 is negative, the correlation co-efficient (r) is as high as >0.9. Most of the major elements have an inverse relationship with SiO_2, but are positively correlated with Al_2O_3. The Al_2O_3 and K_2O relationship is very good, indicating clay mineral control on major oxide composition. Most of the trace elements show positive, linear to broad trends with Al_2O_3 and K_2O, also indicating clay mineral control on their contents. The majority of quartzitic samples show common presence of plagioclase, K- feldspar and clay minerals, but lack ferromagnesian minerals and therefore indicate minimal decomposition of feldspar and greater decomposition of ferromagnesian minerals. Cr is positively correlated with SiO_2, and may be due to increasing abundance of fuchsite with increasing SiO_2. Presence of higher amounts of mono-crystalline quartz than the polycrystalline quartz, characteristic major and trace element contents, indicate a granitic or granitic gneiss source. Major oxides are compared with Post Archean Australian Shale (PAAS) and North American shale Composite (NASC) which also suggest a prominent felsic provenance for these rock formations.

2.4. SUB PROJECT

Evolution of the Himalayan Foreland Basin.
(Rohtash Kumar, S.K. Ghosh, B.N. Tiwari, Kishor Kumar, N. Siva Siddaiah, R. Islam, S.J. Sangode)

Rohtash Kumar, S.K. Ghosh, R. Islam, & S.J. Sangode continuing their studies on various tectonic and climatic aspects of the evolution of the Himalayan Foreland Basin using sedimentological and magnetostratigraphic techniques identified some basic gaps in sedimentation (hiatuses). In this context, the phase of sedimentation which gave rise to the fluvial conditions in the Himalayan foreland and a ~ 15 Ma gap in sedimentation during Oligocene was targeted first during the current year.

In order to study the suitability of techniques those will be used at large were tested on pilot samples from the Lower Tertiaries. Compilation and review of previous work, additional field observations on the Lower Tertiary facies association, thin section petrography, mineral magnetism and geochemistry allowed us to decide the strategy and the area to be targeted. This allowed us to plan the target area in the Dehra Dun and Subathu Sub-basins of NW Himalaya where a subjugatory information is already available with us. By mineral magnetic studies it was observed that the lower Tertiary sites (mainly Dagshai and Kasauli and equivalents) are rich in the antiferromagnetic minerals (Goethite and hematite) with considerable amount of hard magnetites. Therefore the suitable treatment may be selected for further detailed palaeomagnetic analysis.

More detailed work on the rock magnetic approach to basin-source modeling made further development in producing more components suitable for the study.

Additional data on geochemistry and stable isotope was generated on the sediments of Kangra sub-basin.The studies suggest, two major events in sedimentation pattern and drainage organization at 10 and 5 Ma. The 10 Ma event records the dominance of thick, multi-storey, grey sheet sandstone deposits over mudstone-dominated succession having variable channel body proportion from Potwar Plateau in the west and Dehra Dun Sub-basin in the east (Fig. 10). The second 5 Ma event show as the presence of extensive and widespread thick conglomerate deposits with a change in paleoflow direction (Fig. 11). These two events are invariably related to the deformation along the Main Central Thrust and Main Boundary Thrust respectively. Fluvial architecture of both the events suggests large river network with high sediment flux and broad catchment area that could be provided by either tectonically raised high relief and/or high intensity rainfall (monsoon).

Integrated field, petrography and geochemical criteria was applied for the provenance and weathering history of the Siwalik clastic sediments (mudstone-sandstone) of the Kangra Sub-basin of the Himachal Pradesh spanning between 11 and 5.5 Ma. The chemical composition of these sediments is compared with upper crusts, PAAS (Post Archean Australian Shale) and NASC (North American Shale composite). The majority of the samples are silica rich than PAAS and NASC. SiO_2 and Al_2O_3 depict a strong linear array. Al_2O_3 and K_2O exhibit an excellent correlation which suggests clay minerals control

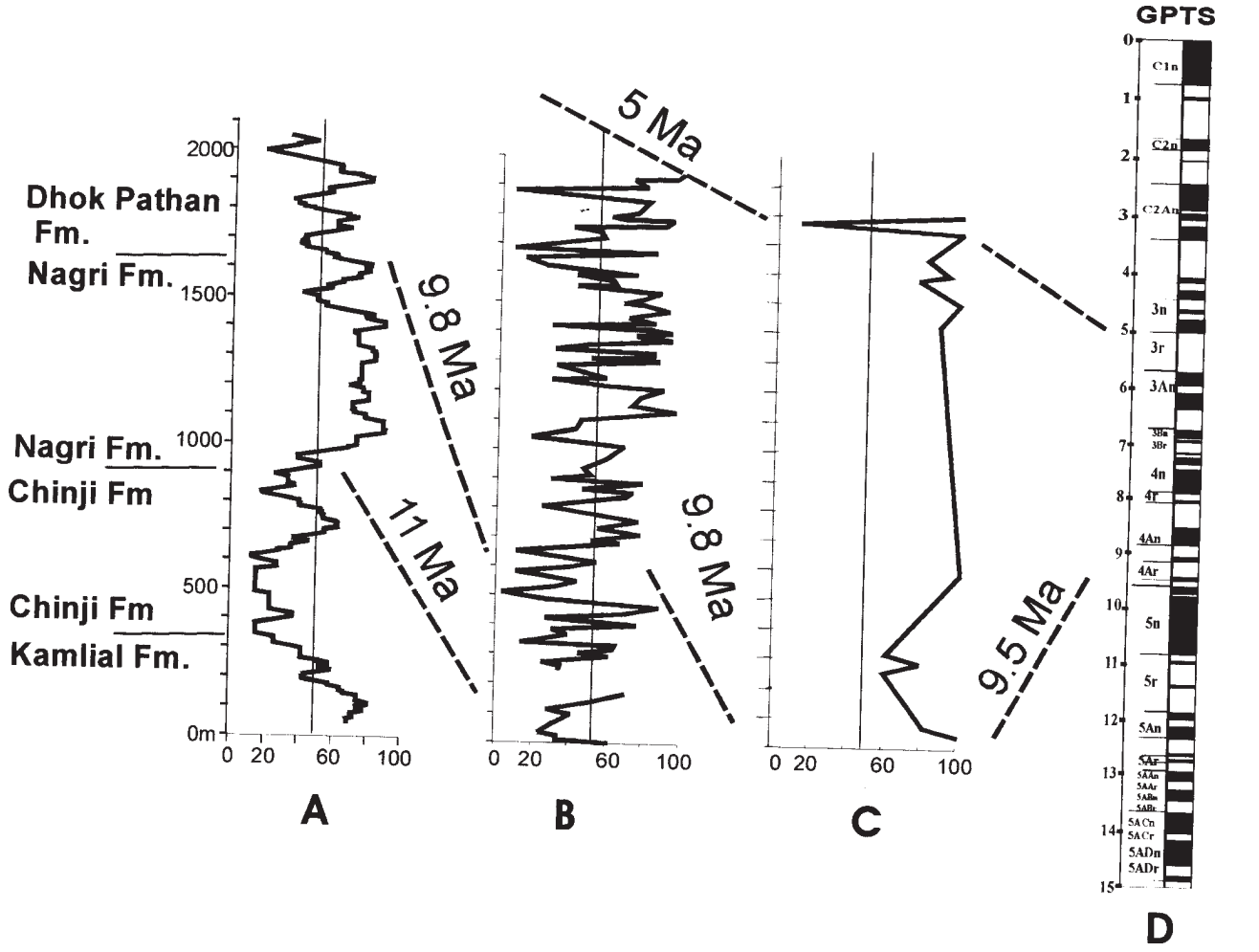
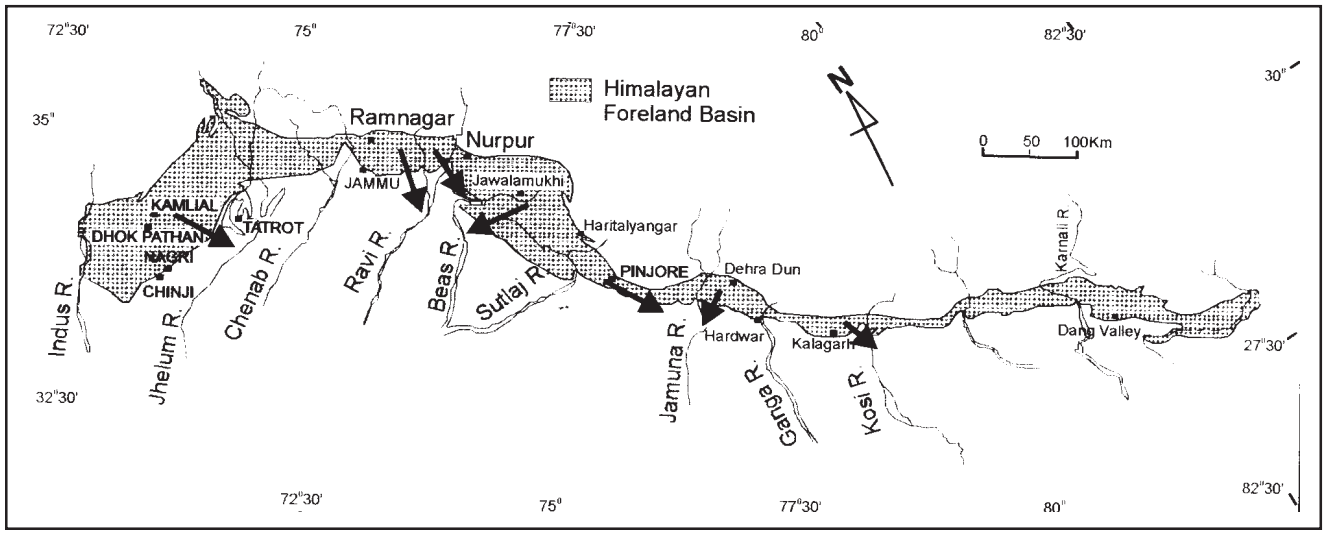


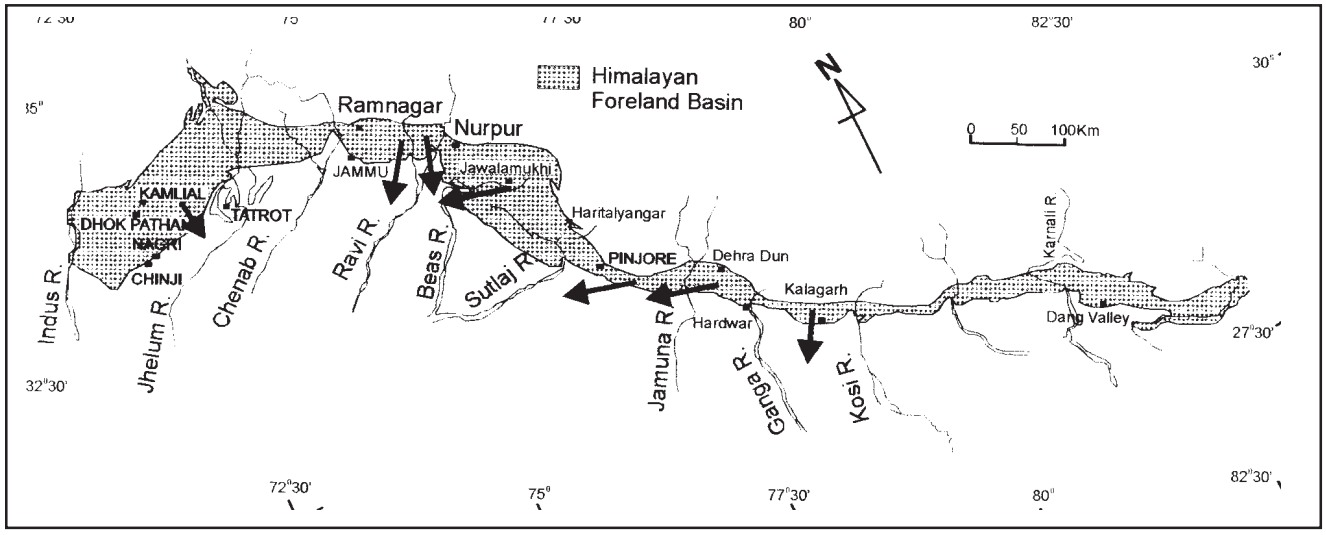
Fig. 10 : Upsection variation in the proportion of sandstone in relation to mudstone bodies. A - Potwar Plateau; B – Kangra sub-basin (KSB); C – Dehradun sub-basin (DSB); D – Global Polarity Time Scale. Note more than 50% channel body proportion between 11 and 9.8 Ma in Potwar Plateau whereas in KSB this proportion varies on the scale of 200 m. Similarly above 9.8 Ma, sandstone body proportion varies in Potwar Plateau and KSB, but more than 50% in DSB.

on the major elements composition that is diluted with increasing quartz content. The REE and HFSE (high field strength element) show depletion compared to PAAS infers depletion of mafic component. Th/Sc ratios are slightly higher than the PAAS indicate higher contribution of felsic components in the sediments. The CIA (chemical index of alteration) value (avg. 78.0) indicates intermediate weathering condition for these sediments. Relative closeness of the samples towards Al_2O_3 pole suggests a relatively high intensity of weathering corroborated by the presence of illite-illite smectite, which is very low in Ca.Therefore weathering reached a stage where alkali and alkaline earth elements have been substantially removed from the clay minerals. The geochemical consistency of the sediments from Kangra throughout the lower to upper Siwaliks indicate that the whole deposit is derived by weathering of the same or similar source rocks. Further, it is suggested that the highly acidic rocks are the source component than the basic rocks.

The stable carbon and oxygen isotopes of soil carbonate nodules and carbon isotopes of associated organic matter measured from the Siwalik succession between 11 and 1.77 Ma. The $\delta\ ^{13}C$ of soil carbonate shows that C_4 grass expansion ~6 Ma and $\delta\ ^{18}O$ shows intensification of monsoon with two peak ~10.5 Ma and



A. Paleoflow trend around 10 Ma



B. Paleoflow trend around 5 Ma

Fig. 11 : Paleoflow orienation in the Himalayan foreland basin. A - variability in paleoflow around 10 Ma, B - variability in paleoflow around 5 Ma. The change in paleoflow around 5 Ma is related to activity along MBT.

~ 6Ma. The $\delta^{18}O$ data suggests that, along with the change in precipitation pattern, expansion of C_4 grass can not be explained. Intensification of monsoon accompanied by low P_{CO_2} may be the main cause of expansion of C_4 grass. In addition, in a mixed C_3-C_4 environment the variation in the difference between the carbon isotope value of soil carbonate and organic matter can be use to understand the climatic variability.

B.N. Tewari observed that most of the Tertiary vertebrates from Himalayan foreland are known from predominantly marine Subathu Group and fresh-water Siwalik Group. Horizons of Murree and coevals, in-between Subathu below and Siwalik above have yielded sporadic early Miocene faunal elements.

Marine and non-marine vertebrates of Subathu make presence of terrestrial habitat in Himalayan foreland evident. Following withdrawal of Subathu Sea in middle Eocene, succeeding horizons represent late Eocene – Oligocene faunal gap. With initiation of thrust tectonics in early Miocene, vertebrates reappeared in non-marine sedimentary record of the foreland.

Withdrawal of the Subathu sea was the end of predominantly marine aggradational facies of sedimentation in the region. With consequent fall in sea level, progradational regime of sedimentation took over the foreland. During this period prevailing habitat in the area become unstable because of cannibalization of sedimentary cover; these recycled sediments were brought further down to be unevenly and thinly distributed on available freeboard. Scenario of incising streams without flood plains in the region with unstable sedimentary cover and consequent dwindling basic biomass presumably drove away vertebrate communities from the Himalayan foreland. This is appropriately portrayed in Subathu's succeeding non- marine horizons (=forced regressive deposits) as a gap in faunal record from late Eocene to Oligocene.

Initiation of thrusting in early Miocene (activation of MCT) marks the beginning of foreland basin on southern Himalayan flank. This tectonic event set level of fluvial erosion (= secondary base level) to a higher altitude presumably at par the earlier Subathu sea level in the region and thereby restored aggradational regime of sedimentation. Further, consequently this event stopped exclusive vertical incision by streams, started gradual expansion of flood plains, and allowed sedimentary cover supporting basic biomass to stabilize. These physical parameters induced by thrust tectonics re-established terrestrial vertebrate habitat in the region and allowed fossilization of vertebrate remains of the contemporary fauna in the sedimentary record. Local early Miocene faunas from the Himalayan foreland represent this phase of the sedimentation history.

Since early Miocene aggradational regime continues in the region with couple of relocations of base levels in the prograding Himalayan foreland basins; these basins namely, Siwalik and Indo-gangetic plains bear rather continuous record of evolving vertebrates in their sedimentary horizons.

Kishor Kumar's studies of Eocene vertebrate fossils from the Subathu Group of Kalakot (Jammu and Kashmir), have resulted in a very exciting find – a molar tooth of a small primate (Fig. 12). A diverse assemblage of continental Eocene mammals and other vetebrates has been known from the Subathu Group but so far no primate fossils were found. Therefore the discovery is quite significant as it represents the first pre-Siwalik primate from India. The Subathu primate is presently represented by a single upper molar tooth and in all probability it belongs to a new prosimian (non-anthropoid primate). It is considerably larger than Eocene primate teeth reported from the coeval beds of the Kuldana Formation in Pakistan. Its occurrence in Kalakot increases the known diversity, size range, and geographic range of Indo-Pakistan Eocene primates.

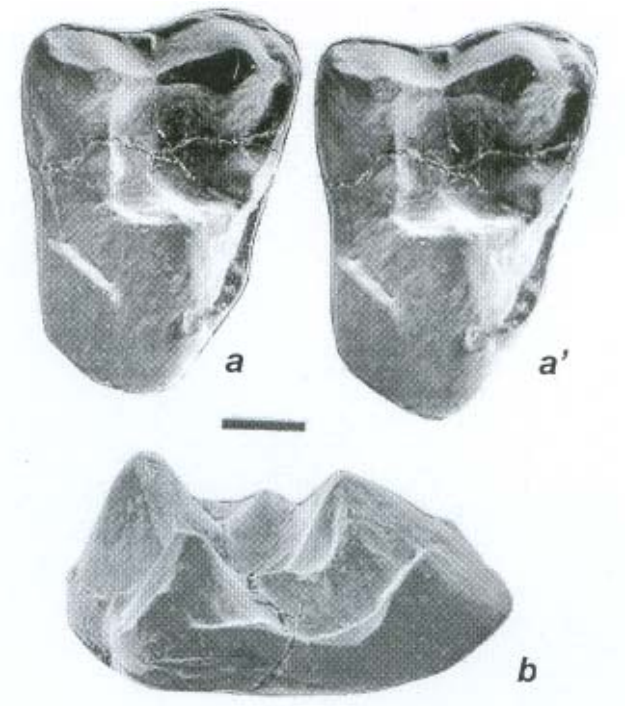


Fig. 12 : WIMF/A 1611, isolated tooth (RM2/) of Eocene primate in occlusal (a-a' stereo pair) and posterior (b) views; posterior view gives an idea of crown-height. Scale bar equals 1 mm.

The Kalakot primate tooth shows a number of primitive feature, viz., triangular outline, transversely elongated high crown, non-bunodont cusps, incomplete lingual cingulum, absence of hypocone, distinct paraconule and parastyle and a reduced metaconule, etc. These features distinguish it from teeth of primitive anthropoids, which are characterized by quadrangular outline, tetracuspate crown and complete lingual cingulum. Among the prosimians the Kalakot primate has similarities with adapids as well as momyids. However, it seems more akin to the former as its M2/ has slightly lingually bent buccal cusps, labially slanted protocone, and a much-reduced metaconule, and it lacks postmetaconule crista. The cusp and crest morphology and moderate crown height of M2/ point towards an omnivorous (insectivorous and frugivorous) dietary regime for the Kalakot primate. The body weight of Kalakot primate based on extrapolation from tooth dimensions of contemporary adapids is estimated to be around 1000 gm. This is the largest among the known Eocene primates from the Indo-Pakistan region. Owing to the insufficient material the generic naming has not been attempted but there is a strong probability that Kalakot primate tooth belongs to a new genus.

The Kalakot primate molar most closely resembles the teeth of European adapiforms like *Europolemur* and *Donrusselli*, and a *Europolemur* like unnamed species from China. Such relationship is consistent with the published faunal records – a European genus *Agerinia* is among the Eocene primates already known from the coeval deposits in Pakistan. Besides this, several other European elements, viz., dichobunid artiodactyls and helaletid perissodactyls are also represented in the Indo-Pakistan Eocene land mammal faunas. So the Kalakot primate may well be a European immigrant. It may have come to the Indo-Pakistan region from European via Asia sometime in early Eocene as also suggested by the presence of a *Europolemur*- like forms in China and several Eurasiatic elements in the Indo-Pakistan Eocene faunas.

The ganoid scales are common in many primitive actinopterygian fishes like Pholidoporidae, Polypteridae (*Polypterus*), Semionotidae (*Lepidotes* and *Lepidotyle*), and all known gar genera, viz., L*episosteus, Atractosteus, Paralepidosteus, Obaichthys* and *Oniichthys*, etc. They can not be identified generically by their external morphology. Therefore a detailed study of their histology and surface features using SEM was taken up for characterization of their familial and generic characters. The study showed that the ganoid scales of gars are (1) moderately thick and non overlapping as against thin and deeply overlapping or imbricated scales of pholidophorids, (2) two-layered with well developed canals of Williamson as against three layered scales of polypterids that characteristically lack canals of Williamson and instead show a typical orthogonal 'plywood' structure above the bony layer; apart from this, the ganoid tubercles of polypterid scales are smaller with larger inter-tubercle spaces than in known gars, and that (3) their bony layer is moderately thick and their ganoid tubercles are regularly disposed and discreet as against very thick bony layer and irregularly disposed and no so discreet tubercles in semionotids.

N.S.Siddaiah's field observations (conducted along with S.J. Sangode) combined with petrographic study on the paleosols of the Siwalik Foreland Basin suggest that they exhibit distinct colour (dark-red, reddish-brown, grayish, and yellowish-brown) horizon produced by the redistribution, differential concentration and hydroxylation and dehydroxylation of ferric iron in different parts of the paleosol profile. Randomly oriented pedogenic slickensides, downward branching root traces and variable sizes of mottling are the characteristic features of the Siwalik paleosols. Calcacreous nodules (1-2 cm in diameter) of massive nature are abundant and consist mainly of micritic calcite, clays, iron oxides and quartz with rounded grain boundaries. Hematite occurs in traces and is present only at the periphery of the nodule. Low magnesium calcite is the most common carbonate.

Microscopically, the calcareous nodules contain circum granular cracks and presumably record episodes of desiccation, shrinkage and cracking. These pedogenic carbonate nodules appear restricted solely to the portion of the paleosols characterized by abundant pedogenic slickensides and pods. Thus the presence of calcareous nodules indicates evaporitic conditions. Majority of the paleosols have very strongly developed B-horizons. Brief development of cryogenic gelic features (0.5 cm diameter) within the B-horizon are observed (Fig. 13), suggesting short events of cooler and dryer conditions within the warmer phase. In many instances the paleosol horizons were apparently truncated by an influx of sediment that itself eventually developed a paleosol due to compound pedogenesis. This may be due to high rate of sedimentation (episodic sedimentation) compared to the long period required for pedogenesis. The vivid red colour and strong ferruginization of these alluvial paleosols are evidence of an oxidizing atmosphere. This is corroborated by the poor occurrence/preservation of organic matter within these paleosols. It also assumes no waterlogging, which is compatible with the observed oxidation and ferruginization. Mottling is commonly associated with a fluctuating water table, such as could be driven by strong seasonality. Therefore, well developed macro-and micromorphological indicators (peds, mottling, iron-oxide coatings, and

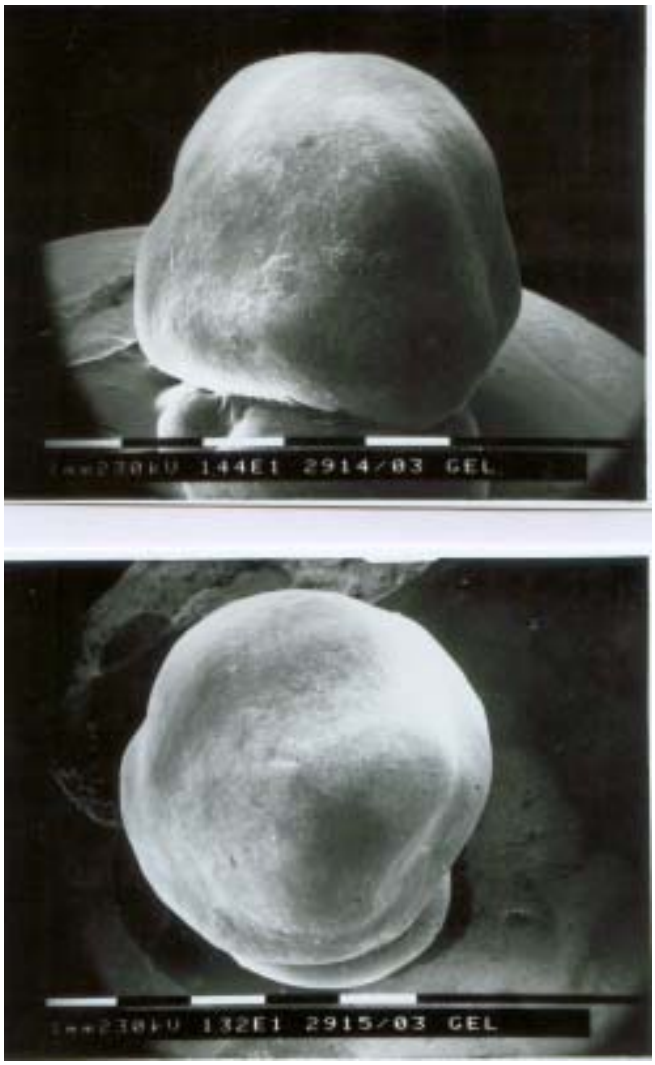


Fig. 13 : Development of Cryogenic Gelic features within the B-Horizon of the paleosols of the Siwalik Foreland Basin.

calcareous nodules) suggest a wealth of pedogenic processes.

2.5 SUB PROJECT

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

Standard Reference Sections

To finalise the Standard Reference Sections for the Siwalik Group, studies were confined to Lower Siwalik Subgroup of Ramnagar (J & K), Middle Siwalik Subgroup of Haritalyangar (Himachal Pradesh) and Upper Siwalik Subgroup of Chandigarh. Thirty five mammalian taxa are known from Ramnagar and these assign Astaracian age to the Ramnagar Local Fauna. This area is suggested as the Standard Reference Section for the type area of the Chinji Formation, which is in Potwar, Pakistan. Continuous section is exposed on Ramnagar - Dhar Road, but vertebrate fossils are abundant in the vicinity of Ramnagar. No published magnetostratigraphic date is available for this area, though this is required for better resolution. Rich Middle Siwalik faunas are only known in India from Haritalyangar area of Himachal Pradesh. The famous Hari Mandir scarp, which yielded the bulk of the both Nagri and Dhok Pathan faunas, is not yielding significant fauna. Thick vegetation has already been planted on the scarp and it is also being converted in to agricultural fields. However, in nearby region, excellent exposures comprising alternating beds of sandstone and mudstone are well exposed. Investigations reveal that Nagri Fauna of Haritalyangar is younger as compared to the type section of the Nagri in Potwar. Both the reference sections for the Nagri and Dhok Pathan are recognised in this area. Limited magnetostratigraphic date is available for these sections. Elsewhere in Indian Siwalik, the Middle Siwalik is mainly represented by multistoried sandstone bodies having mudstone beds or lenses in very subordinate position. The faunas at Haritalyangar represent more humid conditions as compared to Potwar. There are evidences that humidity increased eastward, which indicates better setting of the monsoon.

From the pre-Pinjor beds of Chandigarh - Saketi area, 29 marker taxa of the Tatrot Fauna were collected during the last forty years. Saketi area is recommended as Standard Reference Section for the Tatrot Formation. Magnetostratigraphic data is available only from adjoining regions of Saketi. For better resolution magneto-stratigraphic data of this section is required. The Upper Siwalik sections exposed in the vicinity of Parmandal-Utterbeni, Jammu can not be referred as Standard Reference Section for the Tatrot Formation as only three marker taxa (with few specimens) are known from that section. Patiali Rao section exposed west of the Pinjore township is suggested as the type section of the Pinjor Formation and ranges in age from about 2.58 to 0.63 Ma. During the last four decades, about fifty marker taxa have been collected from the Pinjor Formation of Chandigarh - Saketi area. Jammu region has yielded only eleven taxa and thus is not chosen as type section for the Pinjor Fauna. Excellent exposures of the Boulder Conglomerate Formation are known along the Panchkula-Morni Road and Kolsu Nala near Panchkula. Continuous excellent section of conglomerates is exposed along this Nala, but its base is not exposed. Section along Panchkula-Morni Road is recognised as the type section for the

Boulder Conglomerate Formation. The section contains thick succession of the boulder and cobble conglomerates with subordinate sandstone and mudstone interactions.

Upper Siwalik Subgroup / Post-Siwalik Faunas

Faunal lists for pre-Pinjor and Pinjor beds for Chandigarh and Jammu areas were modified and interpreted to know the migratory history. The faunal lists of the Pinjor Fauna of Nepal and Mynamar were modified and reinterpreted for better resolution. A composite list of the Pinjor Formation of last 250 years is under preparation.

Lists of the post-Siwalik faunas have been greatly modified. Now from the Middle Pleistocene and Upper Pleistocene of Peninsular India 18 and 29 taxa are known respectively. Twenty eight taxa are known from the Upper Pleistocene of Indo-Gangetic plain. Only 6 Pinjor taxa survived in post – Siwalik horizons of Peninsular India and Indo- Gangetic plain. This indicates the mass extinction of the Pinjor Fauna at species level. In addition, 16 Pinjor genera also survived in these deposits and these were modified and survived with different species.

Near Chandigarh Pinjor Fauna was very rich and from here it migrated to Potwar, intermotane deposits of Karewas of Kashmir and Kathmandu valley. By which route the Pinjor Fauna reached Irrawady Valley is not yet cleared. Whether it followed the present Yamuna River to reach Irrawady Valley, Mynamar? More data is required to know the nature of the route of migration to Mynamar. This problem is still under investigation. However there is distinct evidence that the post-Siwalik faunas followed the present day Yamuna River to migrate to various places in India.

3. NATURAL HAZARDS

3.1 SUB PROJECT

Landslide/mass movement and active fault studies in northwestern Himalaya
(M.P. Sah, R.K. Mazari)

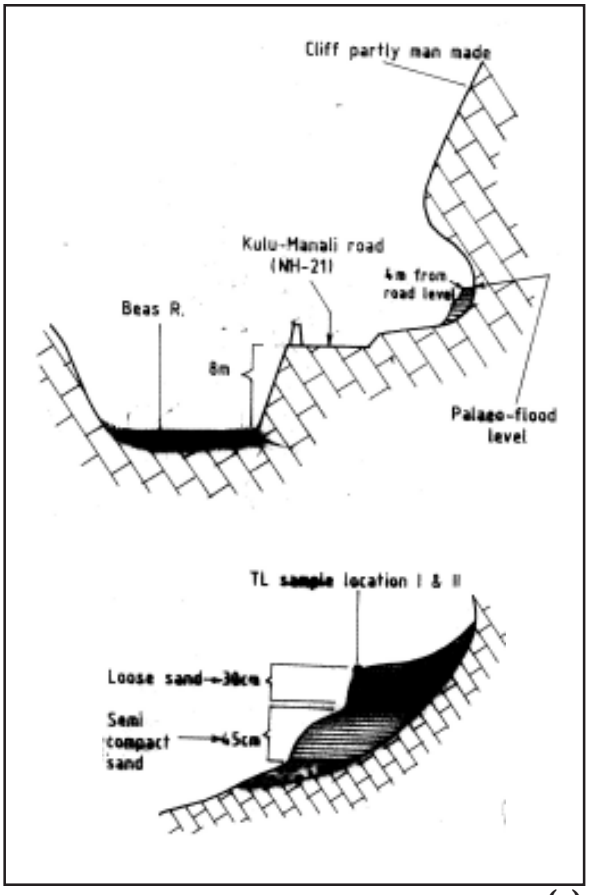
M.P. Sah & *R.K.* Mazari carried out work on the geoenvironmental status of the Kullu valley in Himachal Pradesh. Their preliminary studies show that geomorphically the Kullu valley is divisible into three zones, i.e., upper catchment, middle transfer zone and lower gorge section. The upper catchment is characterized by funnel-shaped valley having steep slopes and variable slope elements. This zone is under the influence of seasonal snow and has mass movement activity characteristic of the cold environment. Generally, in this zone, slopes are covered by relict glacial and periglacial deposits which are prone to mass movements. The middle transfer zone constitutes the major part of the Kullu valley and is characterized by wide open valley covered with large alluvial fans, fluvial terraces, relict slope deposits and flood plain sediments of the Quaternary period. It is this area which is subject to massive human activity like agriculture, horticulture and urban development. The gorge section starts from downstream of Hansu which is generally devoid of depositional landforms like fluvial terraces and fans which are common in the middle and upper sections. However, talus slopes, most of them in relict form are commonly observed in this section. Most of the perennial major streams join the main river (Beas) on its right bank. Except Parbati no perennial major stream flows on the left bank of the Beas river. Climatically, uppermost part of the Kullu valley experiences cold temperate conditions, whereas middle part of the valley enjoys temperate conditions and lower part of the valley bears subtropical conditions.

Geologically, the upper catchment comprises gneisses, granites and migmatites of the Vaikrita Group, locally designated as the Rohtang Gneissic Complex. Slate, garnetiferous mica schist, quartzite and limestone of the Jutogh Group and in pockets Shali limestone form the middle and gorge sections of the Kullu valley. Cover rocks are exposed in the form of Quaternary alluvial fans, fluvial terraces and relict periglacial slope deposits. Structurally, Kullu valley forms a part of a synclinorium with Beas river following a tear fault extending from upper catchment down to near Pandoh where it is terminated by a fault almost at right angles. Part of the area comprises the extensions of the Rampur and the Shali windows. Side valleys follow structurally guided alignments. Neotectonically, the area is active and its impact is visible in the form of uplifted river terraces, alluvial fans, raised pot holes, etc. At least three levels of fans area seen in the Kullu valley. Uplifted talus deposits on the hill slopes in the lower reaches of the valley particularly along the right side between Aut and Dalsin indicate a major vertical movement during the Quaternary. This is further supported by the presence of pot holes in rocky cliffs raised to a height of about 200 m from the river bed of Sarwari Khad at Sishamati near Kullu during a major phase of uplift in recent times.

Geoenvironmentally, two observations seam to be important for the Kullu valley. First, the area is stressed by ever-growing population pressure, thereby creating heavy demands on resources and infrastructure. Unplanned development in smaller townships like Bhuntar, Patlikuhal, Nagar, Manali and even Kullu proper has severely affected the geoenvironmental conditions of the Kullu valley. Secondly, due to declining hill aquifer portable water is in great scarcity. General recession of snowfields as a result

(a)

(b)



(c)

Fig. 14 : (a) Slope instability caused by lateral cutting of Beas river on the Quaternary fan deposit. The event occurred in August, 1995 damaging part of the NH-21 and disrupting the road communication between Kullu Manali. (b) Traces of palaeo-flood levels (1 & 2) preserved in a half cave in Shali limestone near Aut. Beas river (flowing from right to left) is at least 8 m below the Kullu-Manali road (NH-21). (c) Sketch diagram showing palaeo-flood levels in sand beds deposited in a half cave near Aut at the confluence of Tirthan river with Beas river.

of regional and global change has considerably reduced the discharge of the river systems in the area which has severely affected the sustained agricultural activity. Some springs discharge less water than before, while some others have disappeared altogether due to depleted recharge conditions. If traced back to late Quaternary times the rate of geoenvironmental change in this particular aspect is faster than ever before mainly due to onset of the present interglacial phase and rapid inhabitation by man in the hilly track. Thirdly, being the tourist attraction there are heavy demands on infrastructural facilities and water resources and there are limitations as the valley is constrained in its geomorphic set up**.** Preliminary studies show that hill slopes in the Kullu valley are stable by and large. No major slope failures have been observed in the field. In the majority of cases even relict periglacial slopes do not show signs of instability. The reasons for the overall hill slope stability in the Kullu valley are not yet clearly understood and demand an in-depth study. Investigations have shown that slope failures are largely confined to the Quaternary deposits, like alluvial fans, fluvial terraces, etc. This is mainly due to toe erosion by the Beas river during peak flows (example: 1993, 1995 floods), road building, house construction and other developmental activities, which disturb the natural equilibrium of these landforms and hence the slope failures. Presence of large boulders in the lower reaches of Kandi, Mahul, Sarwari and Phojal khads indicates events of major debris flows and gradual decrease of precipitation during the Quaternary period. In one section near Aut downstream of Kullu, palaeo-flood levels have been observed in a half cave carved out by the Beas river in an outcrop of Shali limestone at surprisingly higher level relative to the present day river bed (Fig. 14 a and b).

3.2 SUB PROJECT

Mass movements and their relationship with the MCT Zone, Lesser Himalaya.
(K.S. Bist, B.S. Rawat)

K.S. Bist & B.S. Rawat have carried out a reconnaissance survey for 44 days in the high strained M.C.T zone of Yamuna valley. They covered the hanging wall as well as the footwall between Jankichatti and Gangnani of Uttarkashi District. The investigation was mainly to map and collect the structural details and samples for geological and geotechnical study and to identify the potential zones of mass movement for further detailed studies. The various lithounits exposed in the area along with Holocene deposits (terrace and slope scree) were marked and mapped on 1:50,000 scale and some potential hazard zones of mass movement were identified. The lithologically of the foot wall zone is mainly made up of the low grade metamorphic rocks of the Garhwal Group which consists of quartzite, metabasics and phyllites which are tectonically overlain by the crystalline rocks mainly the granite gneiss, schist and granite with intercalated metabasics of the Higher Himalaya. The major regional tectonic contact (Main Central Thrust -MCT) dividing the domain into two litho-units is well observed at Wazri village south of Syana chatti.

The general attitude of the rocks is WNW - ESE dipping due NNE at moderate angle with oblique relationship to the regional slope facets. The study shows, the rocks exposed in the area are traversed by a number of minor shear zones which are almost parallel to the MCT. Fracture planes are southwesterly dipping with low to moderate angle (15°-35°) while shear planes are dipping due ENE with moderate (45°-50°) angle. The rocks of the hanging wall are less deformed in comparison to the foot wall. In general the rocks are highly fractured, jointed and moderately weathered. Three main representative sets of joints are quite prominent. The relationship of these joints with the slope orientation and regional bedding foliation shows that they play a major role in the rock slope failure i.e. wedge failure and toppling.

During the study emphasis was laid to understand the role of structural elements responsible for the mass movement and a preliminary geological cum geotechnical map has been prepared. Five active sites of mass movement were identified for the detailed study in forthcoming field program. These are located at Phool Chatti, Waria village, Gat gad (Syana Chatti), Khanera and Chaptari village. Among all these sites Phool Chatti, Waria and Gat gad are debris flows where as Khanera and Chaptari shows combination of debris flow and rock failure. The quantitative analysis of the rock and soil samples for geotechnical classification and characterization of the slope material has also been attempted.

Out of the 30 samples collected from the field 20 rock and 6 soil samples were analysed to characterize the nature of rock/soil material on slope under investigation. The results analysed in the Institute's geotechnical lab by Surya Prakash and P.B. Reddy are given in Table 1. The statistical analysis of the data shows the rock strength are weak to strong i.e. (1-2 mpa and 4-10 mpa), while very strong (10 mpa) character of the rock is also observed. Based on the grain size analysis of the 6 soil samples it is inferred that the soils are poorly graded sand, poorly graded silty sand - clayey sand to well graded sand and clayey sand which are presumably the produce of soliflouctin or fluvioglacial material.

Table 1: *Results of geotechnical testing on rock samples.*

Rock type / Sample reference	Point Load Strength Index (MN/m^2)	Water Absorption (%) W	Saturated Bulk unit Density (gm/cc) γ_b (sat)	Dry Unit Density (gm/cc) γ_d	Porosity (%) n	Void Ratio e	Sp. Gravity G.
Mylonite gneiss (YB-1)	6.12	.89	2.4	2.593	2.52	0.0258	2.660
Mylonite gneiss (YB-2)	0.18	1.14	2.39	2.570	1.83	0.0187	2.618
Granite gneiss (YB-3)	3.74	0.78	2.73	2.709	1.02	0.0103	2.737
Platy Quartzite (YB-10)	7.53	0.31	2.51	2.639	3.33	0.0345	2.730
Chlorite Schist (YB-11)	0.061	0.82	3.03	2.930	0.91	0.0092	2.957
Augen Gneoss (YN-12)	5.89	0.56	2.79	2.759	0.576	0.0058	2.775
Mica quartzite (YM-13)	7.14	0.52	2.53	2.522	6.24	0.0666	2.690
Gneissose granite (YB-14)	6.63	0.57	2.58	2.562	3.76	0.0394	2.663
Metabasic (YB-15)	10.46	0.59	3.44	2.950	2.93	0.0302	3.039
Leuco granit (YB-16)	4.095	0.67	2.43	2.615	2.32	0.0237	2.677
Schistose granite (YB-17)	1.565	0.92	2.85	2.562	5.39	0.0570	2.708
Grey Gneiss (YB-18a)	9.04	0.84	2.86	2.841	3.92	0.0408	2.957
Chlorite Schist (YB-18b)	3.71	1.05	2.60	2.575	8.10	0.0881	2.802
Meta basic (YB-19)	16.68	0.61	2.91	2.890	4.37	0.0457	3.022
Sheared granite (YB-20)	4.61	0.71	2.71	2.694	3.02	0.0312	2.778
Meta basic (YB-21)	2.5	0.82	2.78	2.763	8.33	0.0908	3.014
Meta basic (YB-22)	11.94	0.68	2.94	2.922	4.10	0.0428	3.047
Mylonitic quartzite (YB-23)	3.17	0.70	2.70	2.678	3.29	0.0340	2.769
Mylonitic gneiss (TH-1a)	7.15	0.65	2.63	2.608	1.32	0.0134	2.643
Mylonitic gneiss (TK-1b)	7.69	0.82	2.52	2.560	4.12	0.0430	2.670

(Data provided by Surya Prakash and P.B.Reddy, Getechnical Lab).

3.3 SUB PROJECT

Mapping of active faults using Remote-Sensing Techniques.
(G. Philip, N.S. Virdi)

The main objective of this project is to identify and map active faults and document Holocene surface deformation in selected segments of Doon valley and Yamuna valley along Yamunotri route to primarily address (i) what are the geomorphic signatures/surface manifestations of active faulting in this zone? and (ii) what is the recurrence interval of major earthquakes and estimation of hazard potential? In the reporting year the aerial photographs and high-resolution satellite data were studied to identify the surface expression of active faults in an area lying in the proximity of the MBT and the HFT. It has been observed that reactivated faults during the Quaternary have resulted in the dislocation of numerous landforms such as river terraces, alluvial fans, streams and ridges etc. and the creation of several other morpho-tectonic features. The aerospace data has been found to be useful in identifying such features and important lineaments and fault traces. In addition to many minor lineaments identified there are two major sets of lineaments observed in this area.To the north of the MBT the lineaments show a NW-SE trend, whereas to its south a NE-SW trend prevails.These lineaments are trending parallel to sub- parallel to the major structural features of this area. Study of topographic maps and satellite data to south of HFT has also brought to light numerous potential areas for the study of neotectonic activity and its influence on drainage changes and geomorphic evolution. Specifically the transverse linears, which have controlled the drainage and topographic features, are also very prominently seen on the images. The preliminary interpretation has shown certain expressions of tectonic landforms in this area, which is indicative of active faults. The study is in progress to identify specific sites for trench excavations across these active faults systems.

N.S. Virdi compiled and updated the map of lineaments and active faults along the Frontal belt between Kala Amb and Yamuna River. The lineaments have been classified and their relation to landforms being worked out. A few short excursions were undertaken for field check of active faults. The area between Rupar and Chandigarh is being studied on topographic sheets 1:50,000 and satellite images and base map is under preparation for plotting active faults and lineaments.

3.4 SUB PROJECT

Seismicity, seismotectonics and seismic hazard assessment of Northwest Himalaya.
(Kamal, Sushil Kumar, A.K. Mahajan, V. Sriram. A.K. Mundepi)

Kamal studied the local seismicity behaviour in and around Uttarkashi region of Garhwal Himalaya during a swarm activity in Jan-Feb. 2003. The magnitude range of these earthquakes was 1-3 (coda magnitude). More than 300 events were recorded during one month of intense seismic activity. The swarm seems to be triggered by the local events of 3-4 January, 2003. The temporal seismic behaviour is being analysed.

Kamal & Sushil Kumar analysed the data collected during a six month seismicity monitoring programme in the Chamoli-Joshimath region of Garhwal Himalaya with the assistance of *Ravinder Singh*. It was seen that the seismicity is confined to a small zone around Indo-Nepal border between MCT and MBT. The lineament, along which these events are concentrated, is transverse to the general trend of major Himalayan thrusts. These events align themselves along a lineament approximately 10 km SE of the river Kali in Nepal parallel to the river.

Sushil Kumar & A.K. Dubey for the first time provided evidence for superposed deformation in the Himalaya using Geophysical methods, for which, a total of 385 first P motion observations from 120 local earthquakes were analyzed. The P & S seismic wave speed model adopted for hypocentral locations comprised of two layers, one layer over the half space, with the upper layer having a thickness of 17 km (Sushil & Sato, 2003, *Him. Geol., 24*). About 85% of the earthquakes had focal depths of less than 16 km. Hence the observations were plotted on the Wulff Net with an assumption that the ray paths between the hypocenters and the stations were straight lines. The results are displayed through lower hemisphere projections.

The study demonstrates simultaneous development of thrust, strike slip, and normal faults in a small area covering-2000 sq. km. and the key to unlocking the problem of the peculiar tectonics of the region lies in its characteristic geology. The structural evolution of the area can be explained in the following stages.

The figure (Fig. 15 a) depicts a frontal ramp (FRI) bifurcating into oblique ramps (ORI and OR2) and finally acquiring the frontal ramp geometries (FR2 and FR3). In the profile section, the faults have listric geometry, i.e. steeper at surface becoming gradually gentler at depth. The maximum compression normal to the strike of the frontal ramps led to thrusting along the oblique ramps (Fig. 15 b). The oblique slip displacement was responsible for a component of strike slip displacement along the frontal ramps thereby producing displacement out of the tectonic transport plane (Apotria *et al*., 1991, *In: Thrust Tectonics, ed. K. McClay, Chapman & Hall, New York,* 141-154.)

that gradually decreases away from the oblique ramp. At a distance from the oblique ramps, the dip slip component becomes prominent.

A blind thrust shown by gray shale (Fig. 15 b) initiated as fault splay at a late stage of deformation. Since the earlier fault ramps had undergone clockwise rotation along a sub-horizontal axis (Dubey & Bhakuni, 1998, *Jour. Struc. Geol.*, 20, 517-527), the dip of the blind thrust was gentler. Displacement along the blind thrust led to formation of fault propagation folds in the hanging wall (i.e. Budha Kedar antiform) and the footwall (i.e. Uttarkashi antiform). After initiation, the folds propagated by forming a series of anticlines and synclines (i.e. transverse fold propagation) and by extending the length of the hinge lines with amplification (i.e. longitudinal fold propagation) (Dubey & Cobbold, 1977, *Tectonophys.*, 38, 223-239). However, this aspect has been ignored along with a few other aspects that do not affect the present conclusions significantly. These include; (i) formation of early folds as a result of displacements along FR1, FR2 and FR3, and (ii) rotation of the hanging wall block and consequent space problems (Ramsay & Huber, 1987, p.520-521; Dubey & Bhakuni, 1998, *Jour. Struc. Geol.*, 20, 517-527). Also, there is possibility that instead of a single blind thrust there are separate blind thrusts below the Uttarkashi and Budha Kedar antiforms. Notwithstanding the dilemma of one or two blind thrusts, it is emphasized that the blind thrust (/s) is currently active in the area.

The onset of superposed deformation (i.e. compression in NE-SW sub-horizontal direction) is simultaneous with the compression in NW-SE sub-horizontal direction (Fig. 15 c). The superposed deformation resulted in the formation of NE-SW trending superposed folds (Agarwal & Kumar, 1973, *Him. Geol.*, 3, 1-23), and left lateral oblique slip displacement along the oblique ramp. The displacement led to normal faulting along the early-formed thrusts (i.e. FR1, FR2 and FR3) (Dubey, 1997, *Tectonics*, 16, 336-346). Since the blind thrust is not locked because of its gentle dip it remains active as a thrust. Hence, normal faulting along FR1, FR2, and FR3, thrusting along the blind thrust and strike slip at the oblique ramps and their vicinity take place simultaneously (Fig. 15 c).

A.K. Mahajan studied nine isoseismal maps of shallow earthquakes (1905 Kangra earthquake, 1945 Chamba earthquake, 1975 Kinnaur earthquake, 1986 Dharamsala earthquake, 1991 Uttarkashi earthquake, 1996 Garhwal earthquakes, 1995 Chamba earthquake, 1997 Sundernagar earthquake: 4.3 ^{3}mb ^{3} 8.4) that occurred in the Himachal and Garhwal region of northwestern Himalaya. Based on their intensity distribution, the events

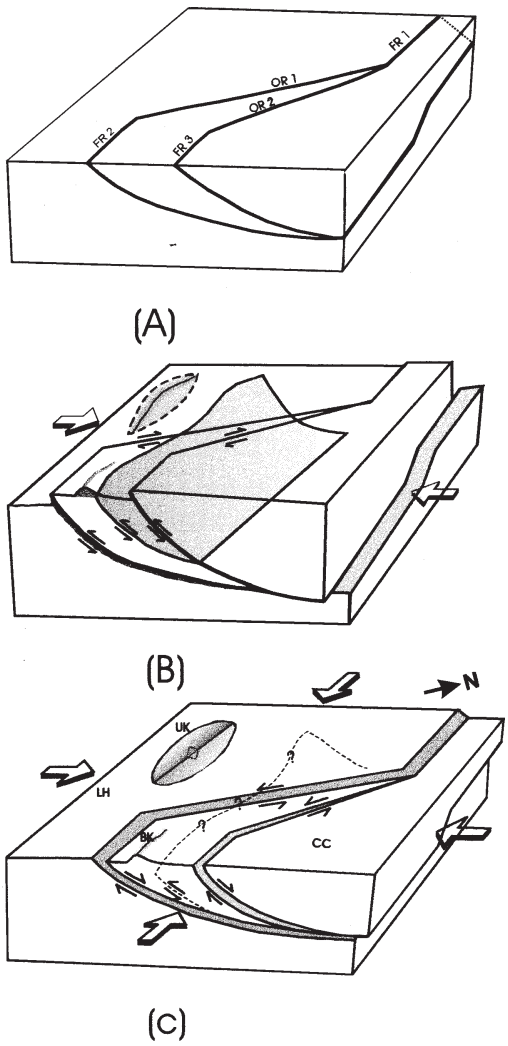


Fig. 15 : A simplified diagram illustrating structure evolution of the Uttarkashi area and simultaneous development of thrust, strike slip and normal faults. (a) Frontal (FR1, FR2, FR3) and bifurcating oblique fault ramps (OR1, OR2) at the null point. (b) Displacement out of the tectonic transport plane along the frontal ramps and right lateral oblique slip displacement along the oblique ramps during the early deformation. The gray shade indicates a later blind thrust, which led to formation of fault propagation folds. The large arrows indicate axis of maximum compression. UK – Uttarkashi antiform and BK – Budhakedar. (c) Left lateral displacement along the oblique ramps at the onset of superposed deformation and normal faulting at the frontal ramps (Dubey, 1997). The area suffers compression from orthogonal directions and the gently dipping blind thrust continues to act a thrust fault. Thus thrust, strike slip and normal faulting occurs simultaneously. North direction is marked in the diagram fro compression with the geological map. CC – Central Crystalline rocks, LH – Lesser Himalayan rocks.

are related to either NW-SE trending tectonic features or to north-south trending transverse features. As it is well known that most of the tectonic features in the Himalaya are longitudinal to the Himalaya, but the isoseismal pattern of some of the earthquakes have highlighted the existence of steeply dipping transverse faults. Furthermore, empirical curve fitting shows a linear relation between the magnitudes calculated from the maximum intensity. The comparison of these relations with equations from the literature suggests that the area shaken with a certain intensity by an earthquake in the Himalayan belt is approximately 10 to 15 times smaller than the area shaken by shallow earthquakes of the same magnitude in the intracratonic parts of North America. The areas calculated for intensity V, VI and VII for the trans–Maxican belt subduction zone earthquake are almost comparable with the Himalayan earthquakes.

The earthquake catalogue for the Himalayan region has been compiled, tectonic map of the Western Himalayan region is under digitization in a GIS format to prepare the seismotectonic map of Western part of the Himalayan arc and its adjoining region between 26^0-35^0 North and 74^0-82^0 East for seismic hazard analysis.

V. Sriram in order to understand the mechanical state of the crust, analysed small earthquakes recorded at local/regional distances, from 5 three component broad-band digital observatories operated by Wadia Institute. More than 540 events in the magnitude range of 1.3 to 4.3 with high signal to noise ratio were picked up for analysis. These events were recorded mostly in one or two stations only. For locating these events a single station 3- component moving window polarization analysis of the first few seconds of the P wave was used to obtain the back azimuth and angle of incidence. Using the epicentral distance obtained from the S-P times and the back azimuth the epicentral coordinates were computed. The epicentral plot of these events clearly indicates some localized spots of activity 48 km. NE of Kothi, 280 km NNW of Dharamsala, 58 km SW of Hanle observatories. By this single station location technique activity around the 1991 Uttarkashi earthquake rupture zone and the 1999 Chamoli earthquake zone could be located using the Dehradun records. A 4.3 magnitude event reported to have occurred near Bagheshwar by USGS (fixed depth) was relocated using the recording at Dehradun. Combining polarization analysis and SH energy in transverse component the event was relocated at 27 km. east of Chamoli earthquake epicentre and the depth could be constrained at 14.1 km using synthetics generated by discrete wave number integration. The source parameters for this event were obtained by matching Brune spectrum with the observed source spectrum. Further refinement of this technique and the data analysis is in progress.

In order to understand the attenuation characteristics of different sections of the Himalaya the Qs and coda Q are computed. The constant Qs computed by matching Brune source spectrum (W-2 model) to the corrected observed source spectrum shows a Q of 150 in the Gangetic Plains, 300 in the Lesser Himalayan path and 550 in the Central Crystalline region indicating more attenuating crust in the foot hill regions of Himalaya. The frequency dependent Q obtained from the lapse window analysis of the coda portion of the seismogram gives $Q(f) = 210f^{0.98}$ for the Lesser Himalayan path.

Deep teleseismic events recorded by the observatories at Kothi, Hanle and Itanagar are inverted for the 1-d crustal structure using converted phase mapping. A low velocity layer around 18 Km is prominently visible below the Kothi and Itanagar stations, which could be the top of the thrust plane. The Moho at Kothi is diffused in the depth range of 42 to 52 km. while at Itanagar it is sharp at 40 km. The Receiver functions obtained at Hanle Observatory shows lots of reverberation and scattering effects. These results are from the events in the azimuth range of 30-120 degrees. Analysis for the other azimuths is in progress.

A.K. Mundepi analysed the phase data recorded on the analog stations and prepared the phase data bulletins for the period January 2001 to April 2001 and sent the same to various geophysical groups in the country. He was assisted by *Ravinder Singh*, *H.C. Pandey* and *S.K. Chabak* in the analysis of seismic events recorded by WIHG's Network. A total of 3500 earthquakes (local, regional and teleseismic) have been read for further analysis. In all, about 95 local earthquakes have been rechecked and analyzed for their parameter estimation. Two stations in the array, i.e. Jadera and Kothi show high local seismicity.

He also fed about 1864 earthquakes (local, regional and teleseismic), for the months from 1st January, 2001 to 10th May 2002 to computer for further analysis. Out of these about 157 local earthquakes have been rechecked and analyzed. The hypocentre of these local earthquakes ranges from about 4 to 20 km and r.m.s. ranges less than 1. The ERZ and ERH vary with the epicentral location of the earthquake. The earthquakes which lie within the network have less ERZ and ERH, whereas earthquakes outside the network have higher ERZ and ERH. Other than this it is observed that one of the station in Himachal region i.e. Jadera shows high local seismicity, within 1 to 3 second S-P, which is recorded only in this station.

3.5 SUB PROJECT

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

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

Radon concentration has been measured in water samples of tube wells and hand pumps (bore wells) of Doon valley in pre-monsoon and in post monsoon period. Radon concentration in water samples of tube well and hand pump varies from 15 Bq/l to 110 Bq/l in pre-monsoon season as against 11 Bq/l to 93 Bq/l in post-monsoon with an overall average of 57 Bq/l and 49 Bq/l in pre-monsoon and post-monsoon season respectively. A significant decrease ranging from 4 to 54% with an average of 24% of radon concentration in the corresponding wells were noticed during the post-monsoon measurements. When radon concentrations of all the water samples were plotted against the depth of the wells, overall no correlation could be established. This is mainly due to the fact that the samples come from the different geohydrological units having distinct characteristics. Further, the lack of correlation may also be due to the mixing of groundwater from different levels of aquifers.

In order to understand the control of geohydrological characteristics on the emanation of radon in groundwater, the study area has been sub-divided into seven hydrogeological units depending upon the aquifer characteristics, flow path, geomorphic features and lithological composition of the aquifer. In addition, physico-chemical parameters of water like temperature, pH and conductivity were also measured and considered as a possible controlling factor. However, no correlation was found between radon concentration and temperature, pH and conductivity. On the other hand, depth of well and radon concentration showed good statistical relationship when they are considered separately in different geohydrological domains. The plots show a positive relationship in all the units except in unit V. The strong positive relationship has been observed in units I and II (r^2=0.51, 0.69), respectively for pre-monsoon data sets. The regression was improved in post-monsoon data for the same units I and II (r^2=0.76, 0.79) in the sub catchments of Surna and Tons rivers respectively. Correlation of radon variation in unit III, was found to be insignificant (r^2 < 0.25). In case of unit IV, the variation of radon with depth shows two distinct trends i.e. one with depth of well <100m and the second set with depth in excess of 100m. In this case also, the post-monsoon correlation (r^2=0.62 up to100 m depth and 0.89 >100 m depth) are much better than the pre-monsoon relationship (r^2 =0.43 for <100 m depth and 0.61 for depth >100 m). In contrast, the unit V data shows negative relationship in both pre- (r^2=-0.41) and post-monsoon (r^2= -0.50). Like unit III, the pre-monsoon data for unit VI and VII are also less significant (r^2=0.24 and 0.16) however, unit VI shows a strong positive correlation in post monsoon data set (r^2=0.72).

The above observations indicate that the tapped aquifers of the unit I and II (i.e. Surna and Tones) do not show much sign of mixing with the water from other aquifers. On the other hand, the aquifers in units III and VII profusely suffer from mixing/contamination from other adjacent aquifers. In case of Unit IV (i.e. central part of the Doon valley) the aquifer is more homogenous below 100 m depth and mixing of groundwater has taken place above 100 m depth. This also suggests that the water bearing horizons were probably formed at different time interval and there may be a compositional difference above and below 100 m depth. The negative relationship in unit V is because of higher radon concentrations at shallower depth. It is possibly because of the uranium mineralized sandstone of middle Siwalik and piedmont fan deposits from the southern flank were deposited over gravels of Lesser Himalayan formation from northern side and probably both got mixed up at shallow depths during recent neo-tectonic activity in the region. The less significant regression in units VI and VII may be because of several factors such as the hydro dynamics factors of the aquifer like, a leaky aquifer, turbulence in flow path, composition of gravels etc. which might have affected the dissolved radon content. The subsurface mixing of water and the uranium poor nature of the water bearing horizons in these units may also result in the less significant relationship between radon and depth of the wells.

Radon enters the groundwater from local sources and greater depth of well allows more water to interact with greater thickness of aquifer and thus have higher residence time. The higher residence time and larger surface area/ volume ratio will result in higher radon with increasing depth. A decrease in radon concentration in post-monsoon samples is possibly, because of the dilution by recharge or changes in contributing areas of the aquifers because of the pumping. The filled pore spaces of aquifers after recharge will also reduce the supply of radon into tube wells and may result in overall decrease in radon concentration in groundwater.

In general, post monsoon data sets have shown better relationship between depth of tube well and hand pumps (which in turn represent surface area of the aquifer)

and radon concentration in groundwater. This is probably because pre-monsoon period, groundwater is normally related to the longer residence time and sub-surface interaction than the post-monsoon water samples and gets enough opportunity to be contaminated and mixed with the deeper aquifers. Whereas in post-monsoon period, the tube wells and hand pumps draw water from the homogenous upper saturated zones and that water does not mix with deep water bearing strata. Thus, it is for this reason that the post-monsoon data invariably shows better correlation with depth than the pre-monsoon data.

3.6. SUB PROJECT

Densification of GPS network in NW Himalaya for Crustal Deformation studies.
(P. Banerjee)

Processing of repeat measurements over the GPS network revealed nearly 15 mm/yr shortening taking place within a 100 km narrow, arc-parallel zone, confined between the MBT and MCT, though none of these thrusts are active on the surface. This implies at least 50 km wide locking segment at the decollement, at a depth of nearly 15 km at its north head, just to the north of the MCT. Contrary to the popular concept, there is at least 3-5 mm/yr shortening taking place between Bangalore and Dehradun. The shortening between Dehradun and Delhi being negligible, the Narmada-Son Lineament is a major suspect where the shortening is being accommodated. There is westward extrusion taking place along the Karakorum Thrust as has been found from the GPS measurements.

4. GLACIOLOGY AND NATURAL RESOURCES

4.1 SUB PROJECT

Geohydrological investigations and water quality assessment in head ward region of Kumaun and Garhwal Himalaya with emphasis on identification of hill aquifers
(S.K. Bartarya)

The geohydrological characteristics of the aquifers and identification of spring zones were carried out in Champawat, Pithoragarh and Bageshwar areas of Kumaun region. The area falls in the subtropical Lesser Himalayan belt in eastern part of the Kumaun Himalaya. In general, the rocks are characterized by multiple deformations resulting in superimposed folding and repeated faulting and thrusting, and are dominated by the development of fractures and joints. The predominant ones are striking NW-SE, N-S, E-W, and ENE-WSW directions and are related to movements along the NW-SE to ENE-WSW striking MBF (Main Boundary Fault) and MCT and other fault systems. Most of the fractures/joints are developed either parallel or perpendicular to the regional strike of the major thrust plane. In its entirety the joint pattern is similar in all the formations where as the difference being only in respect of their spacing. The dominant structurally weak zones are identified on satellite data as major lineaments in this area. At places streams also flow along these lineaments/joints.These fracture – joints and lineaments are serving as easy conduits for infiltrating water and its further movement. The groundwater flow yield is therefore attributed to these lineaments. Incidentally the zones of faulting and closely spaced joints are more susceptible to weathering and serve as potential water bearing zones.

The availability of groundwater in this part of the Himalayan region is manifested in the form of springs and seepages. During the field investigations several geomorphic, structural and lithological features of the spring zones and hill aquifers have been identified. The springs are controlled by fault, fractures, joints, slope characteristics, landforms, lineaments and karst features.

The springs were classified according to their genesis and the factors controlling their formation. These include : 1) Lineament - fault controlled springs, 2) Colluvial related springs, 3) Fluvial related springs, 4) Fracture - joint related spring, 5) Karsts related springs in the Pithoragarh area. Each type have different discharges. A number of water table springs have been identified along wide U shaped valleys in Champawat - Lohaghat - Pithoragarh area. The aquifer in the Pithoragarh area consist of valley fill deposits in the central part and fractured and jointed limestone along the valley sides. In the Champawat area fractured and weathered granite, gneisses and schists having secondary porosity and permeability forms the aquifer. The combination of physiographic, lithological, structural, geomorphological, hydrological characteristics helped in the identification of potential aquifer of limited yield in this hard rock terrain of the Himalayan region. Several localized small aquifers of limited yield are present in Champawat area. The Static water level in these aquifers varies from 6 – 67 m b.g.l. in Champawat area and 12 - 91 m b.g.l. in Pithoragarh district. Water samples were also collected for chemical analysis.

In addition to the above 6 days field work was carried out in Doon Valley, for the identification areas of ground water potential.Large data related to spring discharge of the previous years were also collected from state government organization.Surveys of India maps along with published geological maps were interpreted to understand the geological control over drainage network and geomorphic features of the area.

4.2 SUB PROJECT

Glaciological studies of Dokriani glacier and Chorabari Glacier, Garhwal Himalaya
(J.T. Gergan, R.K. Chaujar, D.P. Dobhal, P.S. Negi)

Glacier contribution to the river suspended sediments

One of the main components of glaciological studies of Dokriani glacier is to understand the glacial sediment transfer characteristics and its contribution to the suspended sediment concentration in headwater river. Determination of suspended sediment concentration in the bulk glacial melt water by filtration is a time consuming job. Samples collected from three levels in the Din Gad at snout, Gujjar Hut and Tela stations in 1998 and 1999 ablation seasons were filtered now and results are presented here (Figs. 16 a & b).

Analysis of suspended sediment data from three stations suggest that channel storage occurs in the month of May, between Snout, Gujjar Hut and Gujjar Hut and Tela stations. In 1998 this was even noticed in June, September and October, in 1999 between Snout and Gujjar Hut stations. In these months suspended sediment flux at Gujjar Hut and Tela stations was lower than the sediment flux observed at the Snout. July and August months are significant, as most of the sediment flux, either from glacier origin or from monsoonal origin is transported in these two months. At Gujjar hut station 82% of the sediment flux is recorded in July 1998 and 1999. At Tela station 56 and 58% of suspended load in July and August in 1998 and 48 and 35% in 1999 respectively were contributed from the glacier catchment. In these two years, Gujjar Hut and Tela catchment experienced very good rainfall ranging between 1200 mm and 1600 mm. This observation suggests that the suspended sediment concentration of Himalayan rivers is significantly controlled by the sediment transfer from glaciers in the headwater regions. These results are contrary to the present line of thinking that the monsoonal rains play a dominant role in higher sediment transfer from the headwater of Himalayan rivers.

Erosion rates of Glacier and Forested catchments

The dominant role of the glaciers in causing a higher suspended sediment transfer from the head waters of Himalayan river is further strengthened by the study of variations in the erosion rates of different zones of the Din Gad catchment. The erosion rate of glacier catchment was 2038 and 2745 tonnes/km^2 respectively in 1998 and 1999. It is important to point out here that the erosion rate of glacier catchment in 1994 was 9611 tonnes/km^2. The erosion rate of Gujjar Hut catchment was 394 and 1005 tonnes/km^2 in 1998 and 1999 respectively and for Tela catchment 407 and 713 tonnes/km^2. This clearly brings out that there is a large difference between the erosion rate of glacierized catchment and non-glacierized catchment. However, these erosion rates of non-glacierized catchments cannot be generalized for the Himalaya as Din Gad catchment is a heavily forested catchment with minimal human interference. Hence these rates can be considered safely as the erosion rates of undisturbed forested Himalayan catchments experiencing monsoonal rainfall.

D.P. Dobhal in continuation of the glacier-monitoring programme in Dokraini glacier, has carried out mass balance, ablation accumulation and snout recession studies throughout the ablation period from June to October of the year 2001-2002. He analysed and interpreted the snow and ice melting data, snout recession and snowline (Equilibrium line). From the monthly melting data calculations, the mean average melting for entire ablation period was found to fluctuate between 3.1cm and 0.5 cm between altitude 3900 and 4900 m (Fig. 17 a). However, the melting was more in upper ablation zone (4500-4900 m) than in the lower ablation zone. The annual net ablation for each elevation band from snout to ELA, revealed that the maximum melting (50% of total annual melting) was registered in middle ablation zone (4300-4400 m, asl), where as in the lower and higher ablation zone it is 20% and 30% respectively. The winter snowfall measurements from snow course network (10 wooden poles at different altitudes) shows that the snowfall generally occurred between the months of January and March. Maximum snowfall was recorded in the month of March, 2002 and minimum in January, 2002. The snowfall recorded in winter 2001 and 2002 revealed that the snowfall generally occurred between January to April (Fig. 17 b). The snowfall in the month of April does not stand for long and melts away in the early summer season and snowline reached 4300-4350 m altitude in the month of May and reached 4700 m in late June and early July. The rapid rate of snowline recession is one of the causes of late winter precipitation, which does not get sufficient time to get metamorphosed and hence it melts-away immediately after accumulation.

The snout of the glacier was monitored by EDM survey to measure the recession during the year 2000 to 2001. The total recession of the snout at the center was 19.25 m where as on the left and right flank it has receded

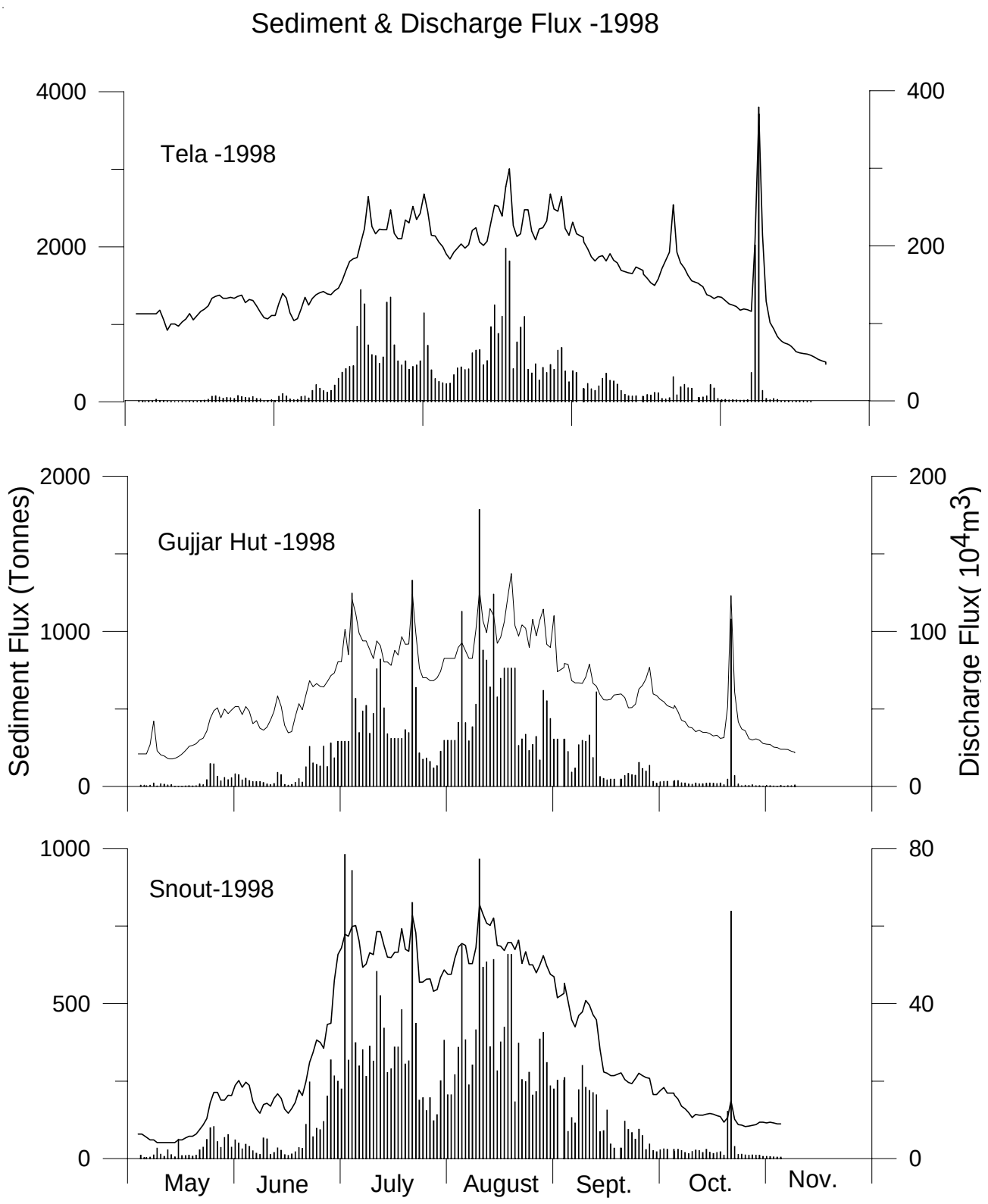


Fig. 16 a : Daily discharge and sediment flux variations through the ablation period at three stations during 1998 ablation period.

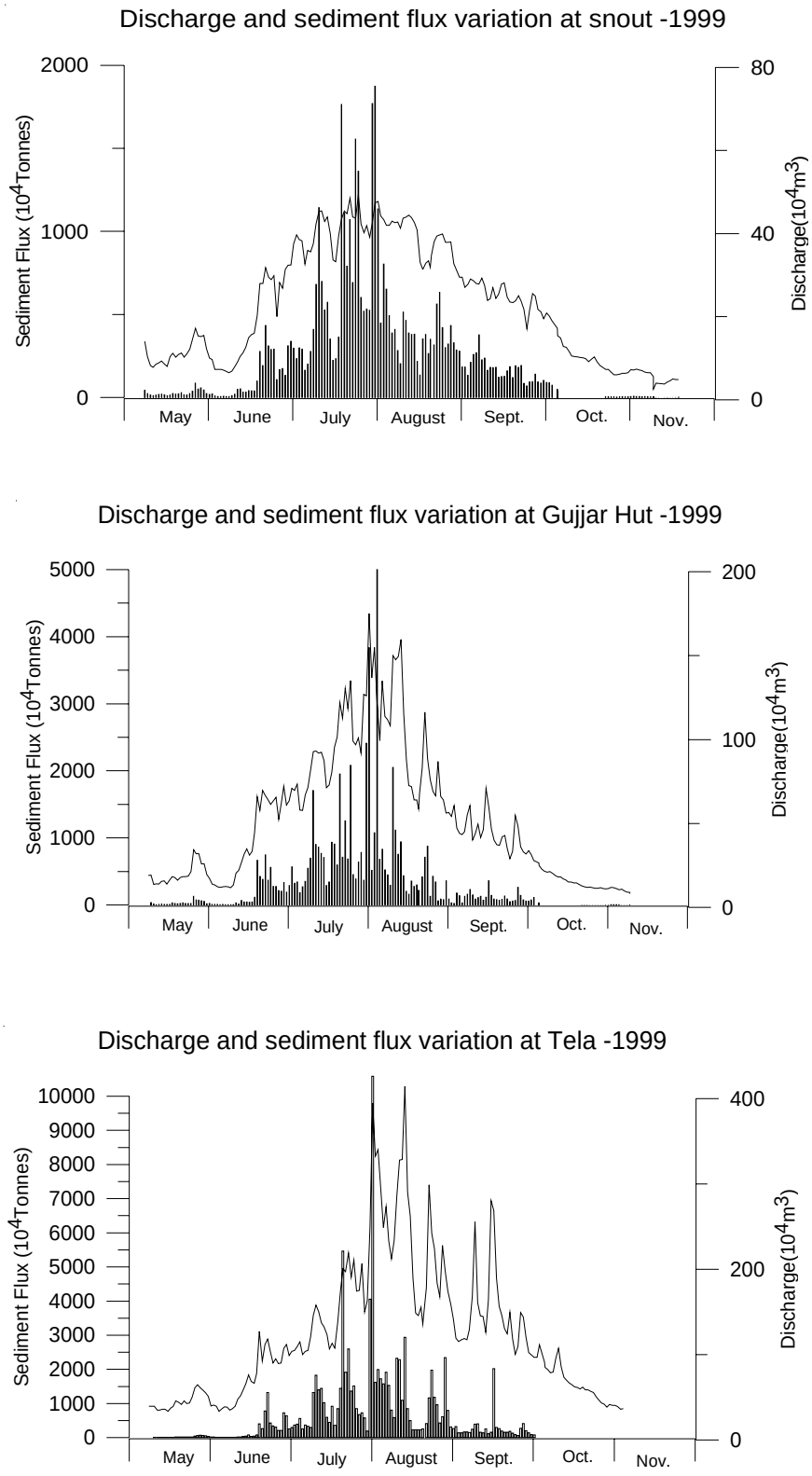


Fig. 16b : Daily discharge and sediment flux variations through the ablation period at three stations during 1999 ablation period.

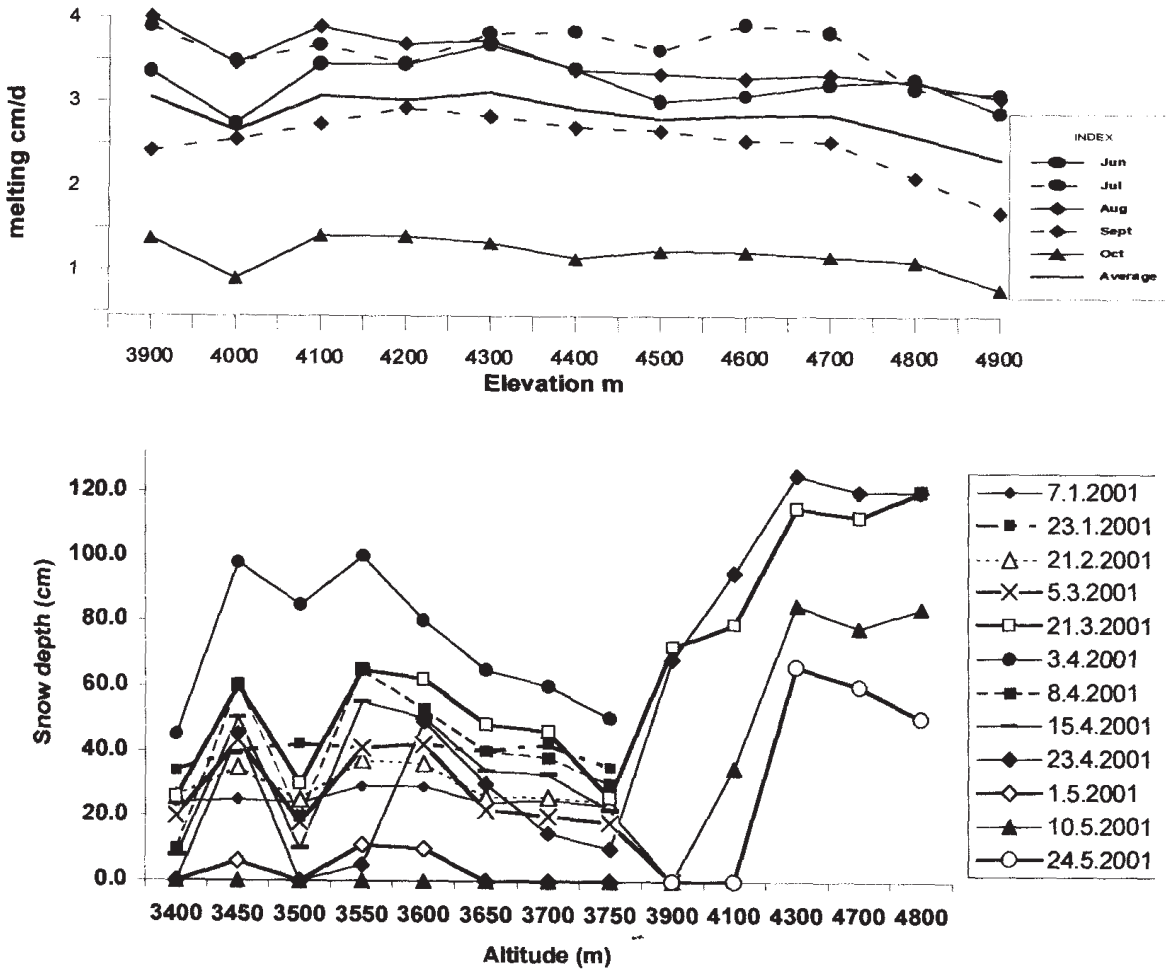


Fig. 17 : (a) Monthly mean average melting at the different elevations of Dokriani glacier in year 2001. (b) Snow depth measurement at different elevations in winter 2001.

about 10 m and 12 m respectively. The present snout elevation is 3891 m. During the period 1999 to 2000 the snout has retreated by 19.0 m

P. S. Negi in order to develop Bio-engineering as an eco- friendly and effective technique for delineation of area of potential mass movements or prediction of slope instability carried out a Geo-phytological investigation at few selected sites along the MCT zone in Garhwal Himalaya. The temporal and spatial affinities between slope instability/slope failure and reactivated landslide have been worked out. It is observed that process of initiation, development and accumulation of shear stress towards the effective level or periodic decrease in shear strength up to the threshold value of slopes is signaled qualitatively by invasion, growth pattern and floral dynamics of indicator species. The ecological dynamics of *Alnus nepalensis* were found simultaneously corroborated with decreasing value of factor of safety which is the indicative of the ratio of shear strength and shear stress along a critical failure surface. The phyto-geographical (1000-2600 meter) affinity between tool species and Lesser Himalaya (800-3000 meter) has been found to be very encouraging for Geo-bio-engineering studies in this zone of high fragility. The selected sites and areas along the MBT were also visited and studied in relation to phyto-geographical distribution of indicator species and their ecological relationship to landslides and other areas of potential mass movements.

It is also reported that areas of comparatively high speed mass movement are represented by vigorous vegetative propagation (Fig. 18 a) while the one time triggered slides are covered by one generation sampling of indicator species. The periodical landslides are delineated

(a)

(b)

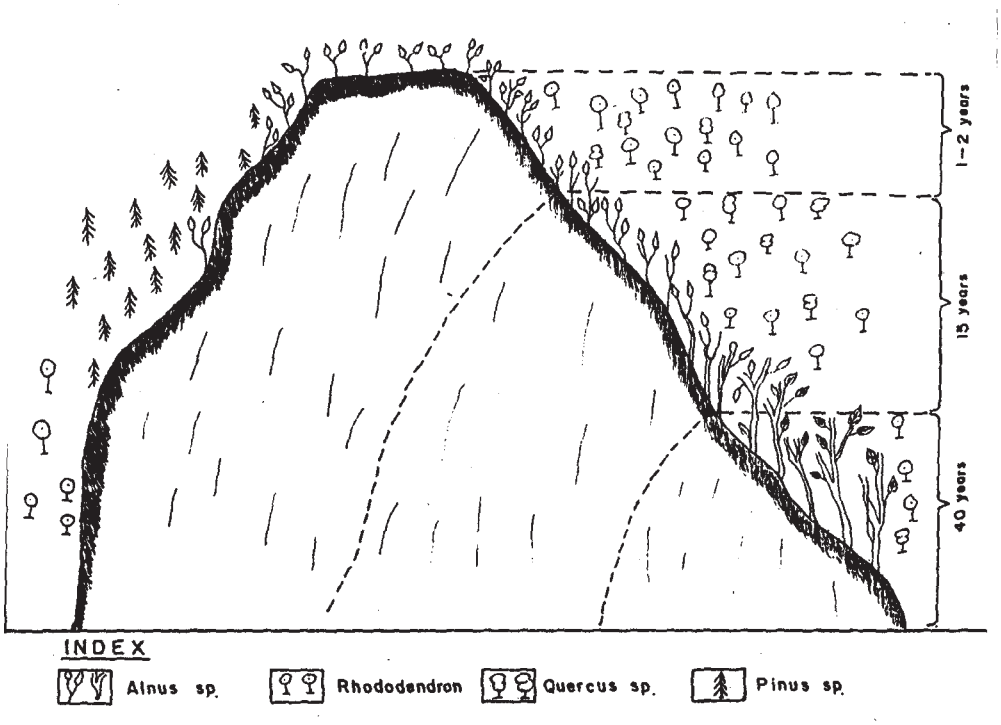


Fig. 18 : (a) Vegetative propagation and land reclamating capability - a tool for ecological restoration and bio-engineering technique for mitigation of land degradation. (b) Spatial – temporal affinity between landslides and floral dynamics.

by different generation of floristic composition. The testing sites i.e. Bhanti and Bursura are under investigation for study of behavioral pattern of mass movement and their phytological affinities. Since, *Alnus nepalensis* has been identified as sampling tool for said experimental technique, therefore its phyto-geographical distribution, floristic pattern, mode of seed dispersal and ecological association etc., are being studied with particular reference to MCT and other area of potential mass movement. The preliminary results of this study are shown in Fig. 18 b.

The lichenometric studies were conducted in Himachal region and required field studies, sampling and photography have been carried out in order to develop a reference for known dating evidence through vegetative development of lichen thallus.

4.3 SUB PROJECT

Geochemical investigations of active stream sediments and preparation of reference rock standards from Himalayan orogenic belt.
(M.S. Rathi, P.P. Khanna, N.K. Saini, K.K. Purohit, P.K. Mukherjee)

The Alakanada valley is constituted by lithotectonic successions that have been subjected to at least three episodes of deformation. The structural and tectonic complexity of the area, thus provides an excellent opportunity to study the geochemical dispersion of elements in relation to tectonic framework. Fifteen days field was carried-out by *N.K.Saini* and *P.K Mukherjee* in Bhagirathi and Bhilangana valleys along Uttarkashi-Gangnani, Uttarkashi-Agora and Uttarkashi- Lambgaon sections in Bhagirathi valley and along Tehri-Ghonti and Ghansyali-Mayali sections in Bhilangana valley. About 75 stream sediments and rock samples were collected from these sections. Also, samples were collected from Mandakini valley to fill up the gaps left over during the previous year.

Geochemical characteristics of active stream and river sediments from part of the main *Alaknanda catchment* have been investigated. Selected trace element (Cr, Ni, Pb, Zn, and Cu, Th and U) abundance in the sediments collected from Alaknanda catchment including its higher order streams and tributary rivers (mainly Nandakini, Pindar, Mandakini) were analyzed to study their spatial distribution in relation to structure and tectonics as well as mineralization. Distribution patterns of the elemental abundance show intrinsic relationship with the lithology and tectonics of the area. Background concentration of Cr is enhanced many folds as compared to average crustal abundance. However, Ni in relation to Cr is not so high if both are assumed to have common source, usually the basic and ultrabasic rocks.

Vivid influence of crustal deformation processes during the Himalayan orogeny is amply illustrated by the abrupt change in elemental anomaly patterns. High U and Th content in sediments are found delimited within or near the crystalline thrust sheets is possibly the result of contribution from granitic rocks and metasomatic fluids derived from them during deformation processes. Sharp change in the distribution pattern of Pb and Zn and also to less extent in case of other elements, is observed across Nandakini and Alaknanda faults. The stretching and elongation pattern of contours along some of the thrusts and anomaly pattern around the intersection of thrusts and faults are some of strong evidences illustrating the influence and role played by the structure and tectonic fabric of the area in controlling the dispersion of elements.

The distribution patterns of elements on the geochemical variation maps in the Bhagirathi-Bhilangana valley, are also found to be largely controlled by the lithology of the area. However, signatures of influence of tectonic fabric are strongly palpable. This is particularly more pronounced at the intensely sheared and mylonitized zones where selective enhanced mobility of some elements (Cu, Pb, U, Th and Zn) are observed. High Cr values (>150ppm) were also observed in most of the samples in this catchments. The gabbroic body that was reported earlier in the central part of Balganga valley could also be traced to extend from Bhilangana in the east to the Bhagirathi valley in the west. This is also reflected in the higher values of Ni, Mg and Ti in some of the samples. In a sizable number of samples strong enrichment of U (>5ppm) and Th (>15ppm) were observed in the upper Bhilangana and Bal Ganga valleys, north of Ghansyali, i.e. around Ghuttu and Budha Kedar area, that are demarcated as crystalline zone. This is of some concern and requires immediate attention and its detailed investigation.

5. PALAEOCLIMATE AND ENVIRONMENT

5.1 SUB PROJECT

Late Quaternary vegetation history and climate changes with respect to SW Monsoon in Garhwal Himalaya
(N.R. Phadtare)

Dokriani Peat Profile

The longest peat sequence so far known from the Higher Himalaya is reported from the upper tree-line area (~3500-

m altitude) in Din Gad valley of the NW Garhwal. Multi-proxy paleoclimate data from this peat profile have revealed full Holocene climate and monsoon history of the Garhwal Higher Himalaya.

- **1600 cal yr BP** *(1400 ^{14}C yr BP)* **– Present:** *Long-term progressive warm and wet climate, with improved monsoon until present.*
- **4000 – 1600 cal yr BP** *(3500 – 1400 ^{14}C yr BP)***:** *Unstable but step-wise warm and wet climate, with dwindling monsoon.*
- **5500 – 4000 cal yr BP** *(4850 – 3500 ^{14}C yr BP)***:** *Second phase of cold and dry climate of the Holocene.*
- **7300 – 5500 cal yr BP** *(6450 – 4850 ^{14}C yr BP)***:** *Recurrence of warm and wet climate with improved monsoon precipitation.*
- **8400 – 7300 cal yr BP** *(7250 – 6450 ^{14}C yr BP)***:** *Cold and dry climate with significantly decreased monsoon rains.*
- **+10,900 – 8400 cal yr BP** *(9620 – 7250 ^{14}C yr BP)***:** *First phase of progressively warm and wet climate of the Holocene with significant rise in SW monsoon.*
- **Before 11,000 cal yr BP** *(10,000 ^{14}C yr BP)***:** *Significant retreat of the Dokriani glacier, termination of the Younger Dryas (YD) event, and the initiation of the Holocene epoch.*

Dhakuri Peat Profile

Age-constrained (five AMS dates and seven ^{210}Pb dates) multi-proxy data (pollen, diatoms, dry weight loss on ignition, and magnetic susceptibility) of the Dhakuri peat deposit (2,650-m altitude) have revealed past 3500 yr high-resolution (bi-decadal) climate history of the Pinder valley in western-Kumaun Higher Himalaya. Preliminary interpretation reveals that the Himalayan climate is experiencing cooling trend since ~1953 AD. This cooling trend inferred from pollen and diatom data, also shows good coherence with tree-ring record from the Gangotri area as well as the instrumental data (annual temperature) from the Mukteshwar met observatory.

Dayara Peat Profile

A new peat deposit developed at ~3150-m altitude was discovered in Dayara grassland near Bhatwadi in the Uttarkashi district of Garhwal Higher Himalaya. Radiocarbon dates revealed that this 1.04-m thick peat sequence (continuously sampled at one-centimeter interval) documents around 6000-year climate and monsoon history of the area. Detailed lithology of this peat profile indicated that prior to ~6000 yr BP, there existed a large lake that was suddenly capped by a massive landslide, and subsequently followed by continued accumulation of peat till present (Fig. 19).

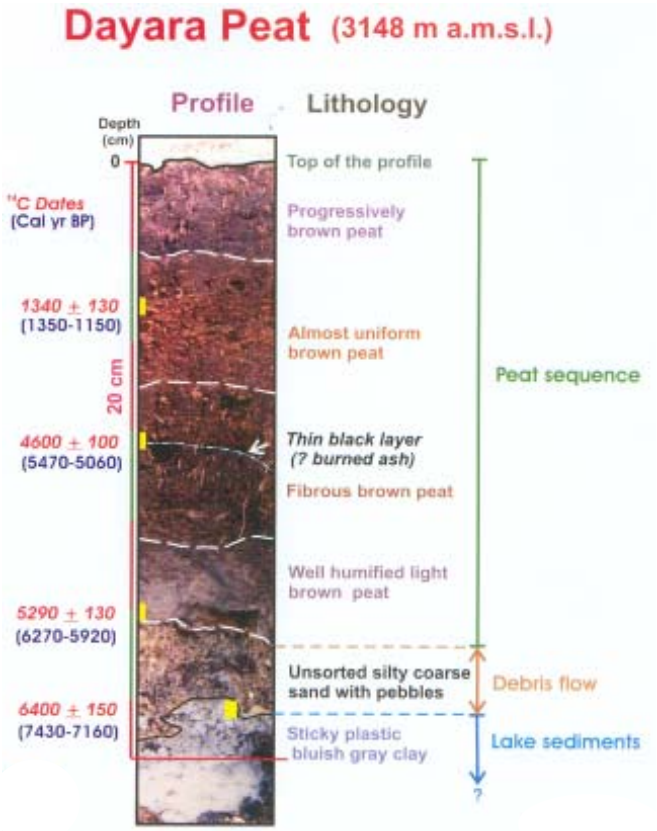


Fig.19: Newly discovered peat deposit of Dayara Grassland, Bhagirathi valley, Garhwal Higher Himalaya, showing lithological details together with radiocarbon dates and depositional environment

5.2 SUB PROJECT

Geo-Database for Uttaranchal: an information system for environmental management and monitoring of Himalayan Geo-Resources
(Devendra Pal, R.A.K. Srivastava, B.P. Sharma, A.K.L. Asthana)

D. Pal, Bhagwat Sharma & A.K.L. Asthana have prepared various thematic maps like drainage, slope, geomorphology and geology for the Mandakini valley under the component of quantitative geomorphology and GIS of the project. Since, the drainage basin is a fundamental unit of landform in fluvial terrain having a particular relevance to morphometric analysis, the morphometric analysis of Mandakini Basin has been made on the basis

of texture ratio, stream frequency, bifurcation ratio, circularity index, drainage density and basin elongation etc. The data pertaining to these has been transferred to the Dbase software for further analysis.

The Mandakini basin comprises of multi cyclic movements related to the main structure lineaments. The slope generally varies from below 10^o to above 40^o. The distribution of slopes reflects the control of geology and the cycle of erosion. The slope map has been further categorized into fine slope group i.e. gentle slope < 10^o, gentle to moderate slope 10^o - 20^o, moderate slope 20^o to 30^o, moderate to steep slope 30^o - 40^o and steep slope > 40^o reflecting the different processes.

Relief analysis of any terrain are planned to be done with the help of morphometric techniques. The absolute relief, relative relief of any physiographic elements can be very accurately quantified by the Morphometric techniques like dissection index, ruggedness number and relief ration. These techniques of morphometric analysis always help in diagnosing the terrain morphology to work out its morpho-units.

They have collected 150 samples of Quaternary sediments from the field. The samples are being analyzed in laboratory for textural, mineralogical, heavy mineral, chemical analysis and clay mineralogy.

R.A.K. Srivastava carried out 17 days field investigations in the Ukhimath, Phatta and Guptakashi areas of Rudraprayag district. He has done geochemical studies of 20 water samples from Pancheshwar Dam area, and mineralogical and textural studies of 40 samples of the Quaternary sediments of Saryu valley around Rameshwar area. The results of the geochemical investigations of the water samples, of Pancheswar dam area show that the concentration of Na, Mg, Ca, SO_4 and HCO_3 are above the standards of drinking water. These higher concentrations are mainly due to the dominance of carbonate rocks in the drainage area.The mineralogical/ textural and geochemical investigations of the Quaternary sediments from the Saryu valley around Rameshwar, Pithoragarh district indicate different size grades and provenance from the crystalline rocks.

P.S. Negi during his association with Geodata base project, made the basic frame work for data base development as designed, and inventoried in the form of computer compatible format and data input sheets. The non-spatial data collection format along 17 parameters is designed with compatibility of National Informatic Centres (NIC) to provide uniformity at National and Regional level. The data collection and field studies in Rudraprayag District, reveal that they contain 753 micro level units in the form of village settlement with its three developmental blocks, namely Augustmuni, Jakhali and Okimath and presently having 365, 164 and 145 village settlements consequently. The non spatial data collected from these developmental units on 17 parameters is proposed to be stored in GIS environment to facilitate development of comprehensive information and retrieval system for micro-level and site specific planning.

6. NORTHEAST HIMALAYA

6.1 SUB PROJECT

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

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

Fieldwork has been carried out in Siang river and Dibang river sections of eastern Arunachal Pradesh. Structural map of the various valleys is under preparation. In Roing-Anini section (Dibang valley) four major tectonic units have been identified. Each unit is separated from the other by a major thrust plane. All the thrust planes can be extended towards SE in the Lohit valley also. The synoptic diagrams of the regional foliation (S_2) and that of mineral lineation (L_2) have been prepared. The NW-SE trend of foliation is almost consistent throughout the area with minor variation due to subsequent folding, i.e., F_3.

The most prominent regional foliation in the rock types of this area is the S_2 schistosity, which is axial planar to second generation (F_2) folds, which are of isoclinal type. This foliation is mostly parallel or co-parallel to the S_1 in the limbs and cuts across the earlier foliation in the fold closures, which are tightly appressed and often difficult to recognize. Under the microscope S_2 is defined by parallel alignment of quartz, feldspar, as well as mica flakes and hornblende prisms. The trend of S_2 varies from NW-SE to WNW-ESE, with moderate to high angle of dip; at some places it is vertical. The π S_2 diagram shows a partial NE dipping girdle extending for nearly 50° with 40% maxima. The mean β S_2 maxima plunges 296° with mean plunge of 40°. The great circle plunging 60°.

Mineral lineation (L_2) is the most widespread lineation observed in this area, it shows a trajectory from NNE to ENE in N-S cross section. Lineations are generally marked by preferred orientation of streaky quartz, elongated flakes of mica and hornblende prisms and are observed in all the tectonic units. They are mostly down dip with the foliation plane, trending NE to NNE with some local variation due to subsequent folding. The plunge varies from 40^0 to 70^0. At places particularly in the thrust zones, the mineral lineation is associated with stretching lineation represented by elongated, broken aggregates of quartzo-feldspathic minerals and mica flakes. In thrust zones of

Lohit Plutonic Complex an E-W trending sub-horizontal lineation is observed which is superimposed on the mineral and stretching lineation, indicating post-thrusting strike-slip movement.

The first phase of foldings, which are tightly appressed isoclinal type, are rarely observed. F_2 folds are quite widespread and are coaxial to F_1. Axial Plane (AP) generally trending NW-SE with some local variation due to superimposition of later (F_2) folding. The F_2 folds vary from symmetric to asymmetric in nature, open to tight type and are mostly intrafolial. At places due to competency contrast between the rock types, minor puckers have developed specially in the mica rich horizon, where the Axial Plane (AP) of puckering follows the same trend of F_2. The F_3 folds that are exposed from mesoscopic to macroscopic scale are mostly represented in the field by minor undulation to tight drag type folds. The eastern syntaxial bend might have formed at this stage of deformation. The trends of AP of F_3 folds are NNE to NS. At places they are exposed on regional scale.

Petrography and geochemistry of the major rock types of the plutonic complex such as gabbro, quartz diorite, trondhjemite and leucogranites, has been carried out. Field relations, petrography and geochemical features suggest that the complex is made up of multiple intrusions.

The gabbro-quartz diorites are fundamentally metaluminous (mol. A/CNK = 0.58 - 0.83). The gabbros are olivine normative while the intermediate quartz diorites are quartz normative and the SiO_2 content varying from 44.2 to 59.17%. On Harker Variation diagram, inspite of some scatter, Fe_2O_3, MgO, CaO, TiO_2 decrease and K_2O, Na_2O increase with increasing SiO_2 content. The scatter in Al_2O_3 can be related to plagioclase content, while MgO is related to mafic mineral content. The K_2O (0.07 – 1 %) and Rb (2 – 5 ppm) contents are low in gabbro, and in quartz diorite of western belt both K_2O (0.15 – 2 %) and Rb (4 – 85 ppm) are generally low but higher than gabbro, since the quartz diorite is rich in amphibole. The quartz diorite of eastern belt is rich in biotite, in which the Rb varies from 54 - 85 ppm. In general the low K_2O and Rb in gabbro-quartz diorite indicate that these rocks types were derived from an original melt. The K/Rb ratio of gabbro varies from 145 to 664 (average 345 ppm) and in the western belt quartz diorite K/Rb ratio is between 311 - 758 ppm. The increase in K/Rb ratio in quartz diorite compared to gabbro is related to high content of amphibole and presence of biotite in which K and Rb are concentrated. Ba content varies from 1 - 52 ppm in gabbro and in quartz diorite it ranges from 28 - 321 ppm and show positive correlation with K_2O. The Sr content in gabbro varies from 291 - 667 ppm, and in quartz diorite it varies from 180 – 678 ppm. The overlapping Sr values and the strong positive Sr anomaly in the multi-element diagram indicate that these rock types are genetically related, and that plagioclase–dominant fractionation was not involved during their evolution. The overall decrease in Sr, and increase in Rb, Ba, K, suggest that they were evolved by fractionation from a basic magma. These rocks also show marginal enrichment of LILE relative to HFSE, and strong depletion in Nb that is typical of subduction related magmatism. The rare earth element (REE) pattern of the gabbro-quartz diorites are nearly flat and display low Ce/Yb ratios, and low total REE abundances, with positive Eu anomaly which indicate plagioclase accumulation. High Ca and Sr also support this feature. The quartz diorite away from the gabbro and the associated high grade rocks display enriched LREE while the HREE is similar to the other basic rocks. This type of LREE enrichment from basic to intermediate rocks suggests fractionation of hornblende.

The trondhjemite seems to have many of the geochemical characteristics of magma directly derived from melting of subducted oceanic slab (basaltic) leaving residues of 10% garnet amphibolite or eclogite. The trondhjemite on a plot of Sr/Y vs. Y evolve towards low Y and high Sr/Y. Alternately, these features can also be interpreted in terms of melting of newly underplated basaltic crust beneath a thickened continental arc.

6.2 SUB PROJECT

Lithotectonic terranes and Neo-tectonic features between the valleys of Kameng and Siang rivers, Arunachal Pradesh

(D.K. Misra, Trilochan Singh)

D.K. Misra & T. Singh carried out 46 days field work between Pasighat and Tuting in Siang valley of Eastern Arunachal Pradesh to identify lithotectonic terranes and neotectonic features of the region. Eight major tectonostratigraphic units have been demarcated from south to north (Table–II) during the detailed traverse mapping along the Pasight-Geku-Yinkiong-Tuting section.

The Siang segment of the NE Himalaya has a unique NE-SW trend in the west to NW-SE trend in the east across the Siang gorge. Considerable neotectonic movements have taken place along the 'boundary thrusts' that define the boundaries of lithotectonic terranes and along many 'tear faults' cutting the terrain transversely. To the south at Pasighat, the contact between Brahamputra Alluvium and rocks of the Siwalik Group is referred to as Himalayan Frontal Thrust (HFT) which is very sharp. Along the tectonic contact, there is abrupt rise of 2000m high mountain from a flat area of the Brahmaputra alluvial plain.

Table 2 : *Tectnostratigraphic units along Pasight-Geku-Yinkiong-Tuting Section from South to north.*

Lohit plutonic complex	Diorite, tonalite, granodiorite, hornblende granite, leucogranite, aplite, tourmaline bearing pegmatities, biotie rich garnetiferous gneiss, branded gneiss, schists and marble bands.
.....Lohit Thrust	
Tidding Formation	Metabasic volcanics, chlorite schist, serpentinished periodotites, foliated quartzite, grey marble with epidote and intrusive leucogranite
.....Tidding Thrust	
Mayodiya Group	Kyanite-sillimanite bearing, garnet-biotite schist and gneiss, psammitic gneiss, streaky gneiss, banded gneiss, graphitic schist,foliated quartzite and amphibolite.
.....Main Central Thrust	
Sewak Group	Mylonitic augen gneiss, sericite- chlorite puckered phyllonite, foliated serictic quartzite, quartz porphyry, and crystalline limestone.
.....Sewak Thrust	
Miri Group	Pink, Purple, green and white orthoquartizite, penecontemporaneous lava flows and tuffites
.....Miri Thrust	
Yinkiong Group	Purple and olive green slates, greywackes and limestone
.....Miri Thrust	
Gondwana Group	Black carbonaceous shale, ferruginous shale with concretions, bluish grey quartzite, Khaki shale and diamictite
.....Main Boundary Thrust.....	
Siwalik Group	Bluish grey sandstone, purple-green-grey siltstone, and shale with coal lenses, gravelly-boulder beds
.....Himalayan Frontal Thrust.....	
Brahmaputra Alluvium	

The SW facing slope of the mountain is not smooth but furrowed and cut by multiple landslide scars, debris fan and urgullied fresh triangular fault facets devoid of vegetation. The junction between flat plain area and mountain front is almost rectilinear. All these evidences and facts indicate neotectonic activity along the Himalayan Frontal Thrust.

Three levels of river terraces have been observed in the Pasighat area of Siang valley. It is observed that Pasighat, the district headquarter of East Siang, is situated on the gravelly fluvial terraces (T1, T2 and T3). The Degree College is located on the older T1 (150m), the main market is located on the T2 (130m) and the Air Strip is located on the T3 (120m) above mean sea level. The younger/present sandy alluvial flood plain (To) of river Siang is exposed at an altitude of 100 m above mean sea level. This indicates that the Pasighat area is uplifted by 50 meters above the Siang River Bed in three pulses. A major 10 km long transverse N-S trending active fault namely Pasighat Fault has been recognized. This fault has uplifted the gravelly fluvial terrace (T1) by 50 meters just west of the Degree College Pasighat.

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

6.3 SUB PROJECT

The terminal Proterozoic-Lower Paleozoic sedimentation, Palaeobiological and carbon isotopic events in the NE Lesser Himalaya.
(V.C. Tewari)

A well developed complete sequence of the Buxa Dolomite (800 m) exposed in the Ranjit Window, Sikkim Lesser Himalaya has been studied. The prolific growth and diversification of Mesoproterozoic to Terminal Proterozoic microbialites (Stromatolites) has been recorded for the first time from the Buxa Dolomite of the eastern Lesser Himalaya. The stromatolite assemblage recorded (Fig. 20) include Lower Riphean taxa (*Kussiella kussiensis, Colonnella columnaris, Omachtenia sp., Conophyton cylindricus, Stratifera* sp., and *Rahaella* Tewari. The Middle Riphean taxa include *Conophyton garganicum, Baicalia nova, Jacutophyton* sp., *Nucleiella* sp., *Tungussia* sp. and *Gymnosolen* sp. The Upper Riphean taxa include *Jurusania* sp., *Minjaria* sp. and the Vendian taxa include *Aldania* sp., *Boxonia* sp., *Colleniella* sp., mini digitate stromatolites *Conistratifera* sp., *Paniscollenia* sp. and *Collumnaefacta* sp.

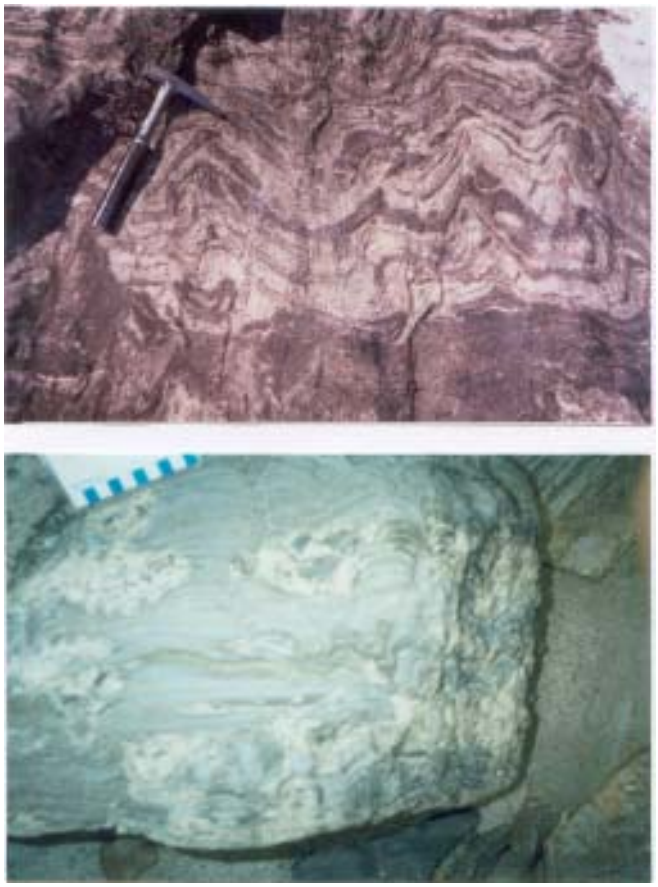


Fig. 20: (a) Conical stratified stromatotlite buildup in the Buxa Dolomite, Ranjit Window, Sikkim, NE Lesser Himalaya. (b) *Kussiella kussiensis* a Lower Riphean stromatolite form from the Buxa Dolomite, Ranjit Window, Sikkim, NE Lesser Himalaya.

The overall stromatolite assemblage suggests a Mesoproterozoic to Terminal Proterozoic age for the Buxa Dolomite in Ranjit Window. The primary sedimentary structures associated with these buildups like cross laminations, ripple laminations, oolites and intraformational pebbles and conglomerates, etc., and vuggy fenestral bird's eye structures indicate a subtidal – intertidal and supratidal depositional environment for the Buxa Dolomite (Fig. 21). The *Conophyton* forms were formed in foreslope bioherms below the wave base whereas the columnar branching and mound shaped forms were formed in back reef area. The domal and mini digitate forms were developed in Tidal flat – lagoonal areas of a shallow high energy shelf-carbonate platform.

The Lower Permian Gondwana belt is tectonically overlain by the Buxa Dolomite. The Lower Ranjit Pebble Slate/Tatapani Boulder Beds (Flysch/glaciomarine) and the upper continental plant fossil bearing Damuda (Namchi)

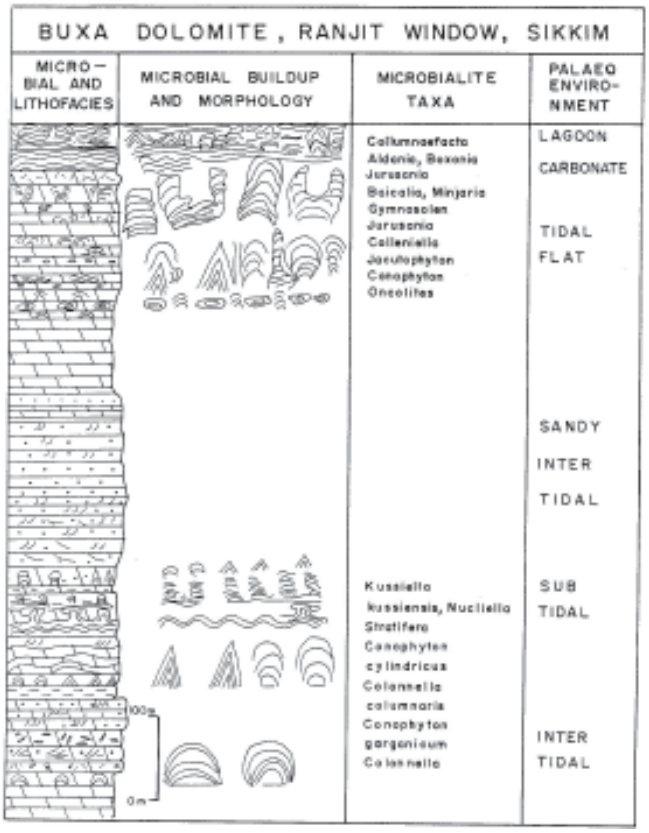


Fig. 21: Distribution of stromatolite taxa and palaeoenviroment of the Buxa Dolomite, Ranjit Window, Sikkim, NE Lesser Himalaya.

sandstone is well developed in the Ranjit valley of the Sikkim. New species of the Permian plant fossils *Gangamopteris* and *Glosspoteris* have been recorded from the Namchi Formation.

The carbon and oxygen isotope chemostratigraphy of the Buxa Dolomite (Chillipam, Dedza, Menga, Igo and Panging Limestones) in the Western and Eastern Arunachal Lesser Himalaya indicate that, in the Buxa Dolomite, $\delta^{13}C$ values vary from –0.50 $^{o}/_{oo}$ (PDB) to + 5.87 $^{o}/_{oo}$ (PDB). The mainly positive heavier isotopic values are characteristic of the Terminal Poterozoic age. The oxygen isotope values vary from + 22 $^{o}/_{oo}$ (SMOW) to 25.95 $^{o}/_{oo}$ (SMOW). The $\delta^{13}C$ value of the Permian Gondwana fossiliferous limestone nodules from the Garu Formation of the Siang district Arunachal Himalaya is highly depleted ($\delta^{13}C$ = - 13.02 $^{o}/_{oo}$ PDB) and the $\delta^{18}O$ value is 12.69 $^{o}/_{oo}$ PDB. These isotopic values are globally comparable with those from the Lower Permian Gondwana sediments in the Western and Eastern Gondwanaland.

MISCELLANEOUS STUDIES

T. Ahmad, R. Islam & B.S. Rawat studying the Phe volcanics suggested that they represent plume induced basaltic volcanic event that occurred during middle Permian. The volcanics vary in composition from high-Ti to low-Ti tholeiitic basalt. They show similarity in chemical characteristic with continental flood basalt in the case of low-Ti tholeiites and resemble initial rift tholeiite-enriched mid-oceanic ridge basalt-oceanic island basalt (IRT-E-MORB-OIB) in the case of high Ti-basalts.

Petrogenetic considerations suggest their derivation from enriched mantle sources, the high Ti-basalt with high abundances of Nb, P and Ti in addition to LILE and LREE, probably had more influence of plume derived melt and the low-Ti basalts with enriched LILE-LREE and depleted Nb, P and Sr appear to have been derived from plume enriched and stretched sub-continental lithospheric sources.

Geographical distribution, from NE Pakistan and Central Kashmir -SE Zanskar -NW Spiti and upper Lahaul regions of northern India, lithological and stratigraphical considerations suggest plume induced eruption at northern passive continental margin of Gondwana during late Palaeozoic followed by Permo-Mesozoic rifting and development of Neo-Tethyan Ocean in this region.

T.N Bagati carried out the field work in Pinjore Doon, which has yeilded dates of around 57 Ka to around 20 Ka in the Pinjore fans. Relationship of Siwalik with Quaternary deposits is unconformable but time interval could not be worked out. Further the geomagnetic excursion around 40 Ka at 697 cm level from the base of Kiratpur section corresponds to the OSL date of 40 $\pm$ 5 Ka coinciding with the Laschamp excursion. He also carried out the field work in Pinjore Doon to select trench sites for the Palaeoseismicity Project.The site was identified in Pinjore and Adi Badari. The detailed field work will be taken up in next season.

He also carried out the petro-mineralogical investigations on the samples from the Nidar Chert Member in eastern Ladakh. The studies showed the dominance of silica with abundance of radiolarians in Nidar area and their absence in Hanle Sector. The silica is generally in the form of chert whereas Mosaic Quartz is present in veins and void. Facies, faunal assemblage and mineralogy of Nidar Chert Member indicates complex array of depositional setting, change in basin morphology and tectonic setting. Radiolarian ooze was deposited below calcite compensation depth. The Liyan lacustrine fill near Nidar was formed under warm humid conditions with major detritus from the Melange zone followed by minor detritus from the crystallines.

Nidar Chert Member indicates Early Cretaceous age (Hauterivian to Aptain, based on radiolarian) whereas Liyan lacustrine sediments on the basis of magnetostratigraphy suggest an age younger to Cretaceous (< 65 ma). Miocene age has been suggested for Liyan sediments based on plant fossils and fresh water gastropods etc recorded by earlier workers.

R.J. Azmi collected micropaleontological samples from almost the entire Vindhyan succession during the *International Field Workshop on the Vindhyan Basin* (December 3-11, 2002). In Vindhyans, occurrence of earliest Cambrian SSFs in the Rohtas Formation has been established at least in 8 different localities. Hexactinellid sponge-spicules from the Rohtas limestones have also been recovered for the first time along with small acanthomorphic acritarchs in thin sections. Northworthy are the exceptionally well preserved *Olivooides* metazoan embryos in the phosphatic Tirohan Dolomite of the Lower Vindhyan of Chitrakoot. A rich assemblage of scolecodonts (annelid jaws) has been located in a thin section of Olive Shale (Lower Vindhyan) which was collected at *Site 11* of the Vindhyan Field Workshop. Oldest scolecodonts are known from the Redkinian Stage (Middle Vendian) of the Russian Platform which further strengthens the case that the Lower Vindhyans are definitely not older than Vendian (~600 Ma). It seems reasonable to correlate the Olive Shale unit of Lower Vindhyan with the Middle Krol (Krol B) red and green shales of the Krol Belt. SEM and thin section photomicrography of the above microfossils have been completed and their taxonomic work is in progress. All geochronological results available till date from the Vindhyan succession have been plotted in the stratigraphic column which present very confusing picture for the age of the Vindhyan Supergroup. Contrary to this, biostratigraphic results (barring stromatolites) are consistent which favour only a Vendian to earliest Cambrian age for the Lower Vindhyan (Semri Group). Therefore, the correlation of Blaini of Krol Belt of earliest Vendian age with the 'Basal Conglomerate' of the Semri Group is almost certain. Incidentally, both these units have also been considered as glaciogenic.

G.Philip has also been working on the natural hazards under JSPS programme. Selectively ten large active

thrusts and strike slip faults in populated mountainous areas in Japan were examined by laboratory analyses of aerospace data and topographical maps subsequently followed with field visits to these fault systems. Excavation trench logs have also been analyzed to understand the behavior of the fault system while discerning their paleoseismological history.

Sushil Kumar in collobaration with Japanese team of scientists applied tomographic inversion technique to the aftershock data collected after the January 26, 2001 Bhuj earthquake (Mw 7.7) in the state of Gujarat in western India. They used high quality arrival times from 8,374 P and 7,994 S waves of 1,404 aftershocks recorded on 25 temporary seismic stations. First they solved for hypocenters and a one-dimensional P and S waves velocity model, and then a three-dimensional tomographic inversion was conducted. They tried to use the Cross-Validation Technique for determining an optimum model. They observed that the aftershock distribution corresponds to the high velocity anomalies. Low V_P/V_S anomalies are generally found at the depths of 10 to 35 km, i.e. the depth range of the aftershock distribution. However, relatively high V_P/V_S and low V_S characterize the deeper region below the hypocenter of the main shock, at depths of 30 to 40 km. This anomaly is attributed to a weak fractured and fluid filled rock matrix, which might have contributed to triggering this earthquake. The earthquake occurred on a relatively deep and steeply dipping reverse fault with a large stress drop.

Kamal, Sushil Kumar & N.S. Virdi installed seismic array consisting 5 seismic observatories in the NW Himalaya (around Vishnuprayag hydroelectric power project, Joshimath). During the six months period, from February to August, 2002, a total 153 events were recorded and analyzed at this array. Out of this number 89 events were recorded at three and more seismic stations. The events were located using the hypo71 (Lee & Lahr, 1972) program. 25 events were located with in the satisfactory limits of error bars. Most (~90%) of the events are far from the seismic array. The study indicates the low seismic activities around the Vishnuprayag hydroelectric power project, Joshimath. The estimated the coda magnitude of these events using the Singh et al., 1976 method ranges between -0.57 to 3.4.

V.C. Tewari studied the meteorites from Antarctica (ALH samples) and Didwana (Rajasthan) India for Astrobiological research (presence of biomolecules and earliest evidence of entra-terrestial life). Laser Raman Spectroscopic and Moss Bauer Spectroscopic studies have been carried out in these meteorite samples.

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Seismological Data Base for the NW Himalaya	Sushil Kumar	D.S.T.
Geological, Geotechnical and Instrumentation Investigation of Karsingsa Landslide around Itanagar (Aunachal Pradesh)	N.S. Virdi M.P. Sah	D.S.T.
Modelling of Fluid migration and behaviour in Subduction Related Metamorphism in Indus Suture Zone (ISZ) Ladakh	H.K. Sachan	D.S.T.
Evolution of Bioevents in early Paleozoic Tethyan Sequence of Zanskar-Spiti and their relation to global event stratigraphy	S.K. Parcha	D.S.T.
Study of Cambrian Trilobite sequences of Tethys Himalaya and their global relationship	S.K. Parcha	N.S.F.
Eastern Syntaxis : Tectonometamorphic history of the crystalline thrust sheets and geochemical evolution of the Lohit plutonic complex, Eastern Arunachal Pradesh	N.S. Gururajan B.K. Choudhuri	D.S.T.
Influence of Lesser Himalaya Dhauladhar Ranges on Evolution of foreland basin in Kangra valley Punjab re-entrant	Rohtash Kumar S.K. Ghosh S.J.Sangode	D.S.T.
Glaciological studies of Dokrani Bamak Glacier in Garhwal Himalaya	J.T.Gergan	D.S.T.
Establishment of Geotechnical Laboratory for Landslide investigations and training of manpower	N.S.Virdi Yudhbir (upto Sept., 2002) M.P. Sah (after Sept., 2002)	D.S.T.
Site specification response studies for seismic Microzonation of the National capital region	Kamal V. Sriram	D.S.T.
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Lithosphere structure and dynamics of North-Himalaya and Ladakh	Kamal V. Sriram & others from NGRI & KUK	D.S.T
Microzonation & risk assessment of the Landslide effected areas between Bansderdawa-Gohpur in	T. Singh Ashok Kaushal	D.S.T.

Title of the Project	Principal Investigator/s	Sponsoring Agency
Itanagar capital Complex, Arunachal Pradesh, using GIS and Remote Sensing Techniques		
Earthquake Hazard Assessment through geological evidence along active fault zone (paleoseismicity) In part of Northwestern Himalaya	T.N.Bagati N.S. Virdi Rohtash Kumar	D.S.T.
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Seismotectonics of the North-West Himalaya	Surender Kumar A.K. Mundepi	D.S.T
Active Tectonic and Paleoseismic studies in the Meizoseismal region of Uttarkashi and Chamoli Earthquake	Prabha Pandey	D.S.T.
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Cretaceous-Eocene biotas from Northern margin of the Indian Plate and Indus Suture Zone of graphic significance	N.S. Mathur K.P. Juyal Kishor Kumar	D.S.T

PROJECT STAFF UNDER SPONSORED RESEARCH PROJECTS

Name of the Project Staff	Designation	Principal/Co-Principal Investigator(s)
Dr. Surya Parkash Sh. P. B. Reddy	Scientist 'C' Sr. Tech. Assistant	Dr. N.S.Virdi
Dr. R. J. Thayyen Sh. Rambir Kaushik	Scientist 'B' Lab. Tech.	Dr. J.T. Gergan
Dr. N. Suresh Miss Chandra Preeti Kaur	R.A. Res. Assistant	Dr. T.N.Bagati Dr. N.S. Virdi Dr. Rohtash Kumar
Dr. A. K. Pandey	R.A.	Director, WIHG
Dr. S.S. Bhakuni	R.A.	Dr. A.K. Dubey
Dr. B.K. Mukherjee	R.A.	Dr. Talat Ahmad Dr. H.K.Sachan
Sh. Gopal Krishna Ghosh	R.A.	Dr. V.C. Thakur
Dr, P. D. Mathur	R.A.	Dr. K.K. Sharma Dr. R.K. Mazari
Miss Reenu Joshi	S.R.F.	Dr. Surender Kumar Dr. A.K. Mundepi
Sh. Subhajit Sinha	J.R.F.	Dr. Rohtash Kumar Dr. S.K. Ghosh Dr. S.J.Sangode
Miss Indu Pant	J.R.F.	Dr. (Mrs.) Meera Tiwari Prof. C.C. Pant
Sh. Birendra Pratap Singh	J.R.F.	Dr. S.K. Parcha
Sh. V. Kumaravel	J.R.F.	Dr. S.J. Sangode Dr. N. Siva Siddaiah
Smt. Kalpana Bhandari	Project Assistant	Dr. N.S. Gururajan
Sh. Ajay Kumar Mishra	Project Assistant	Dr. P. Banerjee
Sh. Sandeep Nandi	Project Assistant	Dr. N.R. Phadtare
Sh. Nilesh Kumar	Project Assistant	Dr. Kamal

VISITS ABROAD

Dr. Sushil Kumar visited Tsukiba, Japan for 19 days from 13th March to 2nd April, 2003, to carryout Joint Research work with Dr. Hiroaki Negishi on real time seismology and seismic tomographic image of Bhuj Earthquake source region..

Dr. G. Philip visited Tsukuba, Japan for 3 months from 23-3-2003 to 24-6-2003, under JSPS fellowship to work on Active tectonics.

Dr. N. Siva Siddaiah visited Samani, Japan, for 13 days from 14-8-2002 to 6-9-2002, to present the paper in the International Workshop at Samani, Japan

Dr. V.M. Choubey visited Centre University of Luxembourg, Luxembourg for 8 days from 2-9-2002 to 10-9-2002, for participation in the International Conference.

Dr. Kamal visited Kathmandu for 7 days from 22-11-02 to 28-11-02, to attend 4th ASC and the Symposium on Seismology.

Dr. A.K. Mahajan visited ITC, Netherlands for 3 months from 5th January to 5th April 2003, to carryout Post Doctoral Studies.

Dr. N.S. Siddaiah visited Como, Italy, 30-31 March, 2003 for Laboratory visit and to deliver an invited talk on chromitites and methods of PGE analysis

Ph.D. THESES SUBMITTED

Name	Supervisor/s	Title of the Thesis	University
S.K. Chabak	Dr. P. K.Sharma Dr. A.K. Dubey	Numerical solution of seismic wave propagation	HNB Garhwal University Srinagar, Garhwal
B.K. Mukherjee	Dr.H.K. Sachan	Metamorphic and fluid evolution of ultra high – pressure rocks from Tso-Morari Crystalline complex, Indus Suture zone, Ladakh (India)	HNB Garhwal University Srinagar, Garhwal

AWARDS AND HONORS

Dr. G. Philip Received the Indian National Remote Sensing Award for the year 2002.
Awarded JSPS invitation fellowship, 2002

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOP/ TRAINING COURSES

Details of the Seminar/Symposia/Workshop/Training courses, Title of paper presented, Venue, Date(s) and Year	**Name(s) of Scientists**
Workshop on Indo Central Asian Republics of Glaciologists, Sponsored by DST, New Delhi, JNU, New Delhi, 11-13 April, 2002.	D.P. Dobhal
4th PAC-ES meeting of DST, Geology Dept., Kumaun Univ., Kumaun, 2-3 May, 2003.	V. C. Tewari
International Conference on "Mountain Development" organized by Global Organizations (Plan International USA & ICIMOD, Nepal), held at KDMIPE, Dehradun, 18-21 May, 2002.	P.S. Negi
Training Course in Fundamental of Soil and Rock Mechanics and their application in Landslide studies, WIHG, Dehradun under DST sponsored programme in 15th March 2001 to 2nd June, 2002.	K.S. Bist, S.K. Paul Keser Singh M.P. Sah, R. Sharma D.R. Rao, Kamal, Sushil Kumar, B.S. Rawat, A. K. Mahajan, P.S. Negi
Joint Meeting on 2002 Japan Earth and Planetary Science, Tokyo, Japan, 27-31 May, 2002.	G. Philip
Seminar on "Challenges of hill architecture, geological and environmental consideration in hill development", organized by the Indian Institute of Architecture, Lord Venkateshwara Convention Centre, Dehra Dun, 1st June, 2002.	D. Pal
Seminar on "Mother Earth: in context of NE India, Geoenvironmental threat vis-à-vis restless Arunachal", organized by NE India Council for Social Science Research, Shillong, 5 June, 2002.	T. Singh
National Symposium on "Advanced Instrumental Methods of Analysis (AIMA - 2002), Determination of major and trace elements in silicate reference samples using XRF and ICP-AES techniques: A comparative study", Organised in Dept. of Chemistry, DAV College, Dehra Dun, 7-8 June, 2002.	P.P. Khanna, N. K. Saini N.S. Siddaiah P.K. Mukherjee
Workshop on "Disaster Management, in NE India: Earthquake & Flood", organized by the Revenue Department of the Assam Government in collaboration with UNICEF, Kolkata, Assam Administrative Staff College, Guwahati, 28-29th June, 2002.	T. Singh
Round Table meeting on "Landslide Hazard Mapping Methodologies"; 14th August at BMTPC, New Delhi.	N. S. Virdi
1st International Workshop on "Natural nuclides in hydrology, hydrogeology, and geohydrology" Luxembourg, 4-7th September, 2002.	V.M. Choubey
International Symposium on "GEOMATICS-2002: IT Enabled Spatial Data Services" organized by Indian Society of Geomatics with Centre of Remote Sensing, Bhartidasan University, Tiruchirapalli, Tamil Nadu, 18-20 September, 2002."	T. Singh P. Banerjee
Strategic challenges and paradigm shift in hydrocarbon exploration with special reference to frontier basins", organized by association of Petroleum Geologists, 28 to 29th September, 2002.	N. S. Virdi
Training course on "Mass Balance Measurements", organized by School of Environment Sciences, JNU, New Delhi, 25th September to 11 October, 2002.	D.P. Dobhal
Landslide hazard zonation workshop, Disaster Management Cell, Uttaranchal Govt., Dehradun, 20th October, 2002.	R.K. Mazari
International Conference on "Science & Technology Capacity Building for Climate", New Delhi, 20-22 October, 2002. October, 2002.	R. K. Mazari
21st International Conference on "Nuclear Tracks in Solids", New Delhi, 21-25 October, 2002.	V.M. Choubey

National Seminar on "Central Himalaya: Environment and Development", Organized by Dept. of Geography, HNB Garhwal University, Srinagar, 23-25 October, 2002.	M.P. Sah P. S. Negi B. P. Sharma
Workshop on Landslide Hazard Zonation, using Remote Sensing & GIS technique. Disaster Management Cell, Uttaranchal Secretariat, Dehradun, 25th October, 2002.	G. Philip
Meeting of Geological Society of India, Punjab University, Chandigarh, 25-27th October, 2002.	V. C. Tewari H. K. Sachan
Training on Total Station Instrument received at Elcone Technologies Pvt. Ltd., New Delhi, 25th to 28th October, 2002.	M. P. Sah
National Day for Disaster Reduction (NDDR), Indian Institute of Public Administration, NCDM, 29 October, 2002.	A. K. Mahajan
Seminar on "Disaster mitigation and management", organized by ITBP Uttaranchal and Himachal Zone, 30th October, 2002, Dehradun.	N.S. Virdi R. K. Mazari Kamal M. P. Sah
18th National convention on "Disasters affecting NE, geodynamically restless NE India", organized by the Inst. of Engineers, Assam State Centre, Guwahati, 10 November, 2002.	T. Singh
Fourth South Asia Geological Congress (GEOSAS), New Delhi, 13-15th November, 2002.	N.S. Virdhi A. C. Nanda
Regional level workshop on "Geodynamics of NE region with special reference to Arunachal Himalaya", organized by Dept. of Geology & Mining, Govt. Arunachal Pradesh, in association with WIHG, Arunachal Unit, Hotel Arun-Subansiri, Itanagar, 14-15 November, 2002.	T. Singh
Workshop-cum-Training on "Medicinal and Aromatic Plant Cultivation & Management for Sustainable Development in Arunachal Pradesh", organized by State Biodiversity Research & Development Thrust in collaboration with State Forest Research Institute, Banquet Hall, Itanagar, 18-19 November, 2002.	T. Singh
National Seminar on "Role of engineering geology in National development", conducted by the ISEG, held at KDMIPE, Dehra Dun, 21-22 November, 2002.	N.S. Virdi K. S. Bisht Sushil Kumar B. S. Rawat
A DST sponsored Workshop to sensitize women scientists from different background, held in Eketa Hotel, Dehradun, 28-29th November, 2002.	Meera Tiwari
ISPRS TC-VII International Symposium on Resource and Environmental Monitoring, Hyderabad, 3-6 December, 2002.	G Philip
"International Field Workshop on The Vindhyan Basin, Central India", organized by the Palaeontological Soc. of India, Dept. of Geology, University of Lucknow, Lucknow 3-11th December, 2002.	R. J. Azmi V. C. Tewari
Workshop on "Developing road map for natural disaster preparedness and mitigation in NE region of India", organized by Ministry of Home Affairs, in collaboration with UNDP, Assam Administrative Staff College, Guwahati, 6-7th December, 2002.	T. Singh
Interaction meet – prevention and mitigation of geological hazards in Himachal Pradesh, State Council of Science, Technology and Environment, Shimla, 13 to 14th December, 2002.	N.S. Virdi
National Seminar on "Coastal and off-shore sedimentary basins and their resource potential" and XIX Convention of Indian Association of Sedimentologists, Dept. of Geology, Andhra University, Visakhapatnam, 16-18th December, 2002.	T.N. Bagati R. Kumar S. K. Ghosh R. Islam
International Symposium on "Earthquake Engineering", IIT, Roorkee, 16-18th December, 2002.	Sushil Kumar A. K. Mahajan
90th Indian Science Congress, Bangalore, 3-8 January, 2003.	T. N. Jowhar
5th International Petroleum Conference & Exhibition (PETROTECH-2003), Organized by ONGC, at New Delhi from 9th to 12th January, 2003.	N. S. Virdi

Group Monitoring Workshop on Deep Continental Studies, held on 11th Jan., 2003, at NIO, Goa.	T. Ahmad
International Symposium on "Bhuj Earthquake", IIT, Kanpur 27-29th January, 2003.	Sushil Kumar
National Seminar on "Himalayan Orogen-Foreland Interaction", Geology Dept. of Lucknow Univrsity, Lucknow, 29-30th January, 2003.	B. N. Tiwari
Seminar on Linux and Applications, Organized by Sir George Everest Research Soc, Dehra Dun, 7th February, 2003.	V. M. Choubey
National seminar on "GTS to GPS-Geodesy on the move", organized by Survey of India, Dehradun, 9th to 12th February, 2002.	N.S. Virdi
International PAGES Workshop on "Late Quaternary Environmental Change: emerging issues", French Institute, Pondicherry, 10-15th February, 2003.	N. R. Phadtare
Seminar on D-Link Net-vision 2003- towards a Networked Work, Dehradun, 14th February, 2003.	V.M. Choubey
Training programme on "Artificial Recharge of Ground Water", organized by the Central Ground Water Board, Dehradun	D. Pal
National Seminar on Technical Sabdawali & Rajbhasa (in Hindi), organized by the DST, New Delhi, 6-7th March, 2003.	A.K. Dubey B. N. Tewari P.S. Negi
International Workshop on Earthquake Risk Assessment and Mitigation, CBRI, Roorkee, 11-13th March, 2003.	Kamal Vikram Gupta
Meeting on "Mountain environment and climate changes over Himalayan region with special reference to Himachal Pradesh, organized by State Council of Science and Technology & Environment, Shimla, 14th to 15th March, 2003.	N.S. Virdi
PAMC meeting of Himalayan Glaciology Programme, held on 21st and 22nd March, 2003, at Lucknow	J.T. Gergan
Workshop on Gangotri Glacier, GSI, Lucknow, 26-27th March, 2003.	J.T. Gergan
1st meeting of Subject Expert Committee (SEC) held in New Delhi on 29th and 30th March, 2003.	Meera Tiwari

LECTURES BY VISITING SCIENTISTS

Name and Address	Date	Topic
Prof. Krishna Sappal Chairman Graduate Studies Committee Division of Resources & Environment, Australia	12.4.2002	Petrographic characters and trace elements of selected Gondwana Coals of India.
Dr. H. Negishi National Research Institute for Earth Sciences and Disaster Prevention, Tokyo, Japan	19.12.2002	Seismic network in Japan and recent development of real time seismology.
Prof. Gautam Mitra Univ. of Rochester, Rochester, NY, USA	23.1.2003	Balanced cross-sections in the Himalayas, and their implications for Himalayan tectonics.
Dr. B.K. Rastogi N.G.R.I., Hyderabad	3.2.2003	New and exciting results of seismological studies in India.
Dr. R. Magarini Perkin Elmer, Italy	14.2.2003	Technical presentation on ICP-MS.
Mr. B. Murray Thermo Elemental, U.K.	18.2.2.003	Technical presentation on ICP-MS.

INVITED LECTURES BY INSTITUTE SCIENTISTS

Name of the Scientist	Venue	Date	Topic
T. Singh	Dony Polo Vidya Bhavan, Itanagar	1.4.2002	Evolution of the Himalaya.
G. Philip	Geological Survey of Japan, Tsukuba, Japan	12.4.2002	Multifaceted application of remote sensing techniques in Himalaya: selected case studies.
A.K. Dubey	Geological Survey of India Training Institute, Dehradun	13.4.2002	Development of thrust faults.
T. Singh	Arunachal Univ., Itanagar	25.5.2002	Earthquake: awareness & personal protection.
T. Singh	Arunachal Univ., Itanagar	27.5.2002	Landslides in the Himalaya: causes and mitigation measures.
T. Singh	Arunachal Univ., Itanagar	29.5.2002	A tool for micro-level Planning: the Geographic Information System.
T. Singh	Geography Dept., North Eastern Hill Univ., Shillong	6.6.2002	Geodynamic evolution of the Himalaya with special reference to NE region.
A.K. Dubey	Geological Survey of India Training Institute, Dehradun	7.6.2002	Geology of the Uttaranchal Himalaya.
A.K. Mahajan	IIT, Roorkee	2.7.2002	Remote sensing & GIS applications for earthquake disaster management.
T. Singh	SIRD, Naharlagun Arunachal Pradesh	24.6.2002	Concept & philosophy of the watershed & water management.
T. Singh	SIRD, Naharlagun Arunachal Pradesh	25.6.2002	Land capability classification in watershed planning.

Name of the Scientist	Venue	Date	Topic
A.K. Mahajan	RTI, Ministry of Defence,Dehradun	29.7.2002	Construction of earthquake resistant buildings.
Sushil Kumar	Asian School, Dehradun	27.8.2002	Our understanding for earthquakes, precautions before and after an earthquake.
N.S. Virdi	ITBP, Dehradun	28.8.2002	Himalaya – origin and evolution.
R.K. Mazari	ITBP, Dehradun	28.8.2002	Effects caused by the Tehri Dam on geological and environmental balance in the region.
M.P. Sah	ITBP, Dehradun	28.8.2002	Cloud burst of August 10, 2002 and related mass movement around Budha Kedar in Balganga valley, District Tehri.
Kamal	ITBP, Dehradun	28.8.2002	Seismicity in the Himalaya.
V.M. Choubey	Physics Dept., Centre University Luxembourg	6.9.2003	Geological controls on emanation of radon.
V.C. Tewari	DBS (PG) College HNB Garhwal Univ., Dehra Dun	7.9.2002	Origin of life: Terrestrial or extra-terrestrial.
N.S. Virdi	Association of Petroleum Geologists, Mussoorie	28.9.2002	Late Proterozoic geotectonic events in the Western Himalaya and western part of the Indian shield and their significance.
R.K. Mazari	ITBP, Dehradun	30.10.2002	Global warming / climatic change and its implication on the earth's crust.
M.P. Sah	ITBP, Dehradun	30.10.2002	Landslide, debris, flows and cloud bursts in the Himalaya.
V.C. Tewari	IRDE, Raipur, Dehradun	2.11.2002	Himalaya Ka Udbhava (in Hindi).
Sushil Kumar	FRI, Dehradun	25.11.2002	Natural disasters with particular reference to Indian earthquakes.
R. Kumar	Dept. of Geology, Pt Ravi Shanker University, Raipur, Chattishgarh	26-30.11.2002	Extended lecture series on the various aspect of fluvial sedimentology.
Sushil Kumar	FRI, Dehradun	30.11.2002	Preparedness and planning for and urban earthquake disaster.
T. Singh	SIRD, Naharlagun, Arunachal Pradesh	3.12.2002	Concept & philosophy of the watershed & water management.
T.Singh	SIRD, Naharlagun, Arunachal Pradesh	4.12.2002	Land capability classification in watershed planning.
R.J. Azmi	Sakshi Hotel, Maihar, M.P.	9.12.2002	Inconsistent geochronological number vs.palaeontological data from the Vindhyan Supergroup of central India : age of the Vindyans in larger perspective. Presented during the 'International Field Workshop on the Vindyan Basin, Central India".

Name of the Scientist	Venue	Date	Topic
N.S. Virdi	State council of ScienceTechnology and Environment Shimla	13.12.2002	Natural disasters and their management with particular reference to seismic hazards in Himachal Pradesh.
T.N. Jowhar	Dept. of Geology Delhi University, Delhi	10-14.2.2003	Computer application in Geology and FORTRAN 77 programming.
R.J. Azmi	DBS College, Dehradun	19.2.2003	Kalpana Chawla Memorial Lecture-Precambrain-Cambrian boundary problem : Indian Scenario.
A.K. Mahajan	Technical Univ., Delft, Dept. of Soil Mechanics Netherlands	21.2.2003	Seismic hazard assessement of Himalaya: a methodology.
N.S. Virdi	DBS College Dehradun	26.6.2003	Kalpana Chawla Memorial Lecture-Recent advances in Himalayan Geology.
T.Ahmad	D.B.S. College, Dehradun	26.2.2003	Kalpana Chawla Memorial Lecture-Geochemistry of magmatic rocks from the Indus suture zone, Ladakh: tectonic implications.
A.K. Dubey	DBS College, Dehradun	27.2.2003	Kalpana Chawla Memorial Lecture-Balanced cross sections : construction and interpretation.
T.Singh	WIHG Unit. Itanagar	28.2.2003	Understanding earthquake and its perspective in Arunachal.
P.S.Negi	CSIR Vigyan Sadan, New Delhi	6-7.3.2003	Eco Friendly industrialization in Uttaranchal.
G. Philip	IIRS, Dehra Dun	7.3.2003	Remote sensing for applied geomorphological studies.
S.J. Sangode	IIG, Alibagh, Mumbai	10-21.3.2003	(a) Introduction to Palacomagnatism. (b) Mineral magnetic constraints of the Anisotropy of magnetic susceptibility.
A.K Dubey	IIG, Alibagh, Mumbai	17-19.3.2003	(a) AMS applications in faulted rocks. (b) Analysis and interpretation of AMS data from Himalayan terrain.
N.S. Siddaiah	Univ. degli Studi dell' Insubria, Via Valleggio, 11, Como, Italy	31.3.2003	Talk on Chromitities and Methods of PGE analysis.
J.T. Gergan	IIRS, Dehradun		Glaciers.

INTERACTION LECTURES

Name of the Scientist	Date	Topic
A.K. Mahajan	19.4.2002	A preliminary seismic hazard analysis of Northwest Himalaya.
S.K. Ghosh	10.5.2002	Records of late Neogene thrusting events in the West central part of Himalayan foreland basin.
N.S. Gururajan	17.5.2002	Geology & Tectonics of the Eastern Arunachal Himalaya.
Keser Singh	31.5.2002	Finite strain and microstructural evolution cross the MCT.
S.J. Sangode	7.6.2002	Palaeomagnetism in the Himalayan Amphitheatre.
Rohtash Kumar	14.6.2002	Sedimentation history of Himalayan foreland Basin.
Talat Ahmad	21.6.2002	Geochemical and isotopic constraints on tectonics: Himalayan examples.
H.K.Sachan	11.7.2002	Ultra High Pressure rocks and their occurrence in Indian Himalaya.
Kamal	2.8.2002	Will your house be safe during the next Earthquake? A prelude to local site amplication survey.
N.S. Mathur	9.8.2002	Lower Tertiary succession in the Western Himalayan Foothill belt: A review.
P.K. Mukherjee	23.8.2002	Quantitative estimation of chemical response to tectonothermal processes.
J.T. Gergan	27.2.2003	Himalayan Glaciers .

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEE, ETC.

Name of the Scientist	Status	Prestigious Committee/s outside WIHG
Dr. N.S. Virdi	(i) Member	National Working Group on Disaster Management, Govt. of India
	(ii) Member	Task Force on National Geospatial Database Infrastructure of the DST, Govt. of India
	(iii) Member	Working Group on Jai Vigyan Technology Mission of the DST
	(iv) Member	Expert Group on National Programme on GPS of DST
	(v) Member	PAMC on Himalayan Glaciology Programme of the DST
	(vi) Member	Research Degree Committee for Earth Sciences, HNB Garhwal University, Srinagar
	(vii) Member	Advisory Committee on Disaster Management in Uttaranchal
	(viii) Member	Advisory Board, Institute of Integrated Himalayan Studies, H.P. University, Simla.
	(ix) Member	Technology transfer and Research Committee on Watersheds – Uttaranchal Govt., Dept. of Forests of Rural Development
	(x) Patron	Technocrat Welfare Society of India, Uttaranchal Chapter
Dr. Surendar Kumar	Member	CED 39, Bureau of Indian Standards
Dr. D. Pal	Member	Expert Committee Landslides of the Deptt. of Science & Technology, New Delhi.
Dr. R.J. Azmi	(i) Corresponding Member	International Subcommission on Cambrian Stratigraphy (IUGS-ICS)
	(ii) Founding Member	TECOS, Terrestrial and Cosmic Spherules Research Group, Modena (Italy)
	(iii) Member	Philosophical Circle, Budapest (Hungary)
Dr. R.S. Rawat	(i) Deputy , Governor	Board of Gover's, American Biographical Governor Institutions, USA
	(ii) Adviser	Research Board of Advisor's of the American Biographical Institutions,USA
Dr. V.C. Tewari	(i) Associate Member	A.S. International Center for Theoretical Physics, Trieste, Italy
	(ii) Voting Member	International Society for the study of the Origin of Life, California, U.S.A.
	(iii) Corresponding Member	Therminal Proterozoic System (TPS) International Union of Sciences and International Commission on Stratigraphy
	(iv) Member	Research Board of Adviser America Biographical Institute, USA
	(v) Member	PAHAR, Nainital
Dr. T. Ahmad	(i) Member	Editorial Advisory Board of the Indian Journal of Geochemistry
	(ii) Member	Expert Panel for the Science & Engineering Research Council Fast Track Scheme for Young Scientists of the Govt. of India, Dept. of Science & Technology, New Delhi
	(iii) Member	Expert Panel for the Science & Engineering Research Council Deep Continental Studies *Programme of the Govt. of India, Dept. of* Science & Technology, New Delhi

	(iv)	Member	Editorial Committee, Deep Continental Studies in India Newsletter, : Dept. of Science & Technology, New Delhi
Dr.(Mrs.) M. Tiwari		Member	Subject Expert Committee on Earth and Atmospheric Sciences, DST
Dr. Kishor Kumar		Member	National Working Group IGCP 434
Dr. G. Philip		Member	Task team on Snow and Glacier studies (under NNRMS Programme): Ministry of Environment & Forests, Govt. of India
Dr. R. Islam		Member	IGCP-426 (Granite system & Proterozoic Lithospheric Processes)
Dr. S.K. Parcha	(i)	Member	International Cambrian Subcommission
	(ii)	Member	Trilobite Workers Society, USA
	(iii)	Working Member	IGCP project Member International Trace Fossil Workers Society, USA
Sh. P.S. Negi	(i)	Member	World Mountain Forum , Asia Pacific Mountain Network, ICIMOD, Nepal
	(ii)	Member	Himalayan District Working Plan Committee for Mitigation for natural calamities

FOUNDATION DAY CELEBRATIONS

The institute celebrated 34th 'Foundation Day' on 29th June 2002. The Foundation Day Lecture on 'Monsoons' was delivered by Dr. R.R. Kelkar, D.G. Indian Meteorology Department, Govt. of India. A Lecture in the honour of ex-chairman of Governing Body Sh. S.P. Nautiyal was delivered by Dr. R.K. Bhandari - Lecture entitled "Ocular Geomorphology in some simple measurements in Landslide Hazard Mapping" has been published by the Institute.

A brief report on Institute's activities was presented by the Director. Best Research Paper Award was presented to : Dr. R. Jayangondaperumal and Dr. A.K. Dubey for their paper "Superposed folding of a blind thrust and formation of klippens: results of anisotropic magnetic susceptibility studies from the Lesser Himalaya", published in *Asian Jour. Earth Science,* **19,** 713-725.

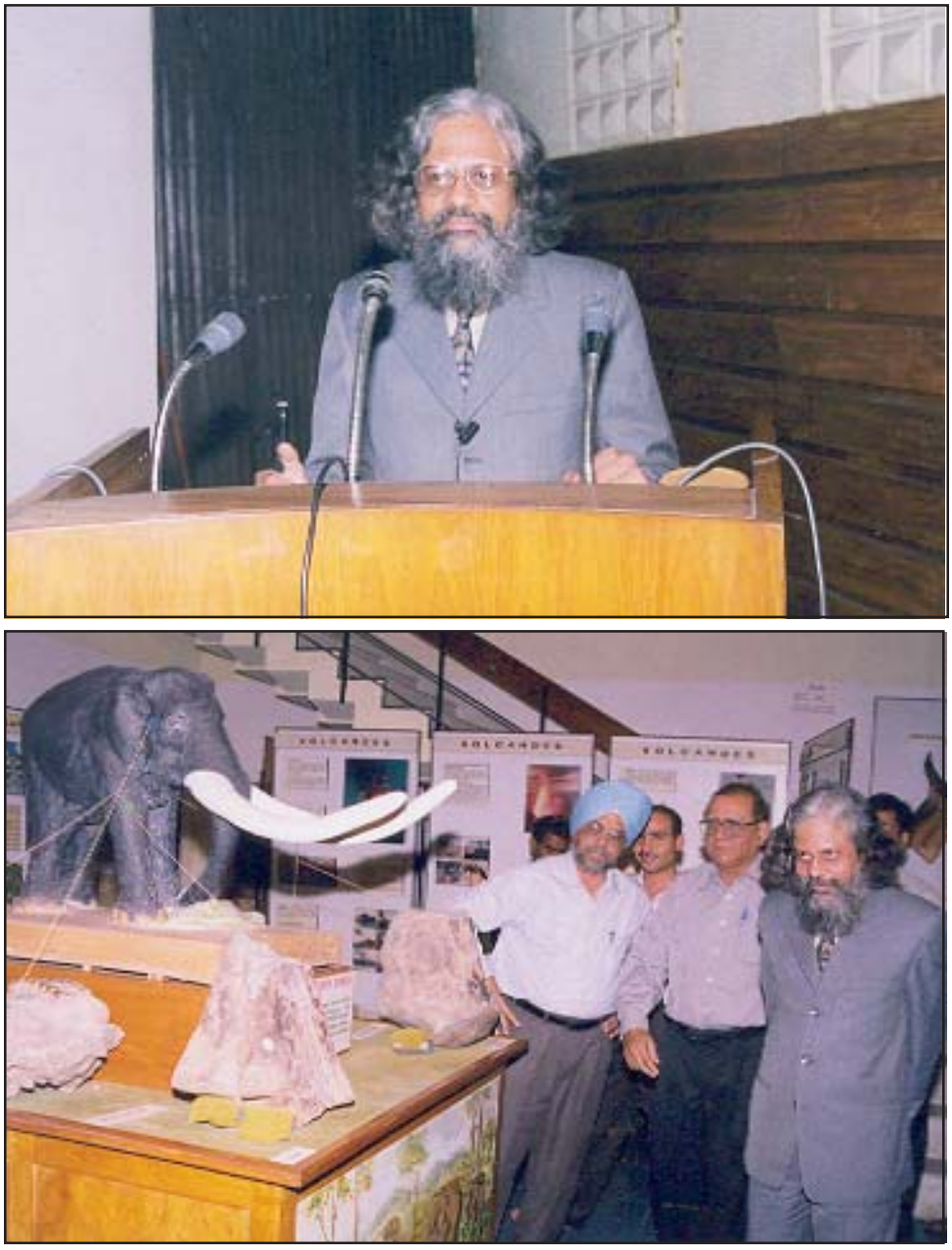
Awards were also presented to employees for good work done during the year 2001-2002. The awards were received by Shri. B.K. Juyal, Assistant; Shri. G.S. Khattri, Draftsman; Shri. Satya Prakash, Section Cutter; Shri. Kem Singh, Driver; Shri. Pratap Singh Gurung, Security Supervisor; Shri Khushi Ram, Field Attendant; Shri. Ashok Kumar, Mali; Smt. Kamla Manral, Bearer. Prizes were also given for scientific contribution in Hindi and the award was received by Shri. P.S. Negi, Scientist 'B'.

The above awards were given away by the Chief Guest. He also distributed prizes to school children who participated in Science Quiz and Hindi Essay competition organized in connection with National Science Day Celebrations

The Chief Guest Dr. R. R. Kelkar, D.G. Indian Meterology Department, Govt. of India, along with Dr. R. K. Bhandari and Dr. N.S. Virdi sharing the dais during the 'The Foundation Day' celebration of the Institute.

FOUNDER'S DAY

The 'Founder's Day' was celebrated on 23rd October 2002 to mark 119th Birth Anniversary of Prof. D.N. Wadia. In the Honour of Prof. D.N. Wadia, generally a lecture by some eminent person is organized. This year the Fifth 'D.N. Wadia Honour Lecture' on "Technology and Prosperity" was delivered by the Chief Guest Sh. Y.S. Rajan, Executive Director, TIFAC and Scientific Secretary to the Govt. of India. The lecture was well attended by scientists from different organizations from Doon Valley and was well covered by the media.



The Chief Guest Sh. Y.S. Rajan, Executive Director, TIFAC and Scientific Secretary to the Govt. of India delivering the Fifth 'D.N. Wadia Honour Lecture' on "Technology and Prosperity" on the 'Founder's Day' celebrations of the Institute (top). The Chief Guest visits the Museum of the Wadia Institute (bottom).

TECHNICAL SERVICES

Analytical Services

A total number of 1811 samples were analyzed in the Central Facility Laboratories using XRF, SEM, XRD and ICP-AES/AAS. Out of which 45% samples that ~600 samples were from outside users and rest of the samples belong to the Institute Scientists. During this period around 542 samples were analyzed on XRF, around 284 on XRD, around 675 on SEM and around 310 samples were analyzed on ICP-AES/AAS.

Photography Section

During the reporting year the photography section exposed and processed a total of about 35 black and white film rolls and printed over 3500 black and white prints of assorted sizes. The processed black and white films include, those exposed on SEM, for photomicrograph, and those exposed for close-up view of rock/fossil specimens. The processing also includes the contact, passport size, as well as plate-size prints. Besides this, at least 8 colour slide film rolls and 21 colour negative film rolls were exposed by the section. In all about 35 colour slide film rolls and 60 colour negative film rolls were got processed, and over 1000 colour enlargements of various sizes got made from the market

Various academic events and functions held in the Institute were covered by the photography section during 2002-2003, which include celebrations like Republic Day, National Science Day, National Technology Day, Foundation Day, Independence Day, Hindi Week, Founder's Day, Bhumi-Pujan and Foundation Stone laying ceremonies for Institute's Guest House Building and Superannuation-parties arranged for Prof. K.K. Sharma, Dr. Hakim Rai, Dr. N.S. Mathur and Mr. G.R.K. Nair. Besides this visits of academicians, dignitaries and VIP's were also recorded. These include visits of Hon'ble Minister for Science & Technology Shri Bachi Singh Rawat, Prof. V.S. Ramamurthy Secretary DST, and delegation from National Defence College of India.

Drawing Section

The drawing section catered to the cartographic needs of scientists of the Institute including the sponsored projects. Numerous posters and charts were prepared for the Museum and also for the seminar/symposia organized by the Institute. During the year 2002-03, the Drawing section has provided 180 geological/geomorphological maps/ litho-logs/ cross-sections, etc. It also prepared 60 labels and caption writing, 38 photo-plate writing, 149 ammonia prints of different sizes and modifications in 29 diagrams.

Sample Processing Lab

The Sample Processing Lab has catered to the requirements of the Institute scientists, as well as various other organizations, universities and sponsored projects. A total number of 536 rock samples were crushed to fine powder as required by the scientists. A total number of 1481 thin and polished sections were also prepared, besides carrying out other routine jobs

MUSEUM

Museum continued to remain the main centre of attraction of our Institute, both for national and international visitors. The exhibits and the information provided in the Museum continued to attract the students and general public not only from the remote corners of India but also from abroad. Some of the educative exhibits include Drifting Continents, Volcanoes, Earthquakes, Origin and Evolution of Life, Himalayan Glaciers, Landslides, Flash floods, etc. This year too, students in large groups from different educational institutions, universities, colleges and from other institutions visited the museum and benefited from the deliberation given by the experts guiding them.

Like in the previous years, Museum observed Open Days, on National Technology Day (11th May, 2001) on Foundation Day (29th June, 2001), on Founder's Day (23rd Oct. 2001), and on National Science Day (28th Feb., 2002). A large number of students and general public visited the Museum on these days. The Institute scientists Dr. J.T. Gergan also delivered a lecture on 'Glaciers of Himalaya' to school children. The print media gave a wide coverage of the functions. A science quiz and essay competition were organized on the eve of 'Science Day Celebrations'. Children from various schools of Doon valley participated in the quiz competition. Prizes were also distributed to the outstanding students who stood first,

second and third in the merit both in quiz and essay competitions. Two consolation prizes were also given for Hindi essay competition.

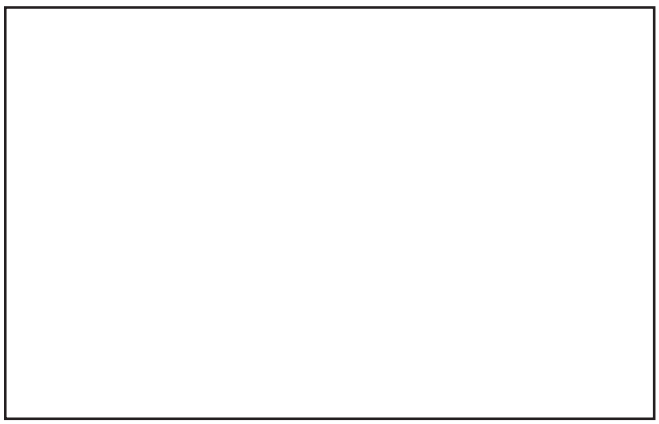
An additional attraction of this year's National Science Day celebration is that, Wadia Institute of Himalayan Geology co-sponsored with Technocrat Welfare Society of India (TWSI) organized joint exhibition by various organizations like IIP, ONGC, Anthropological Survey of India, FRI, IIRS, Falak Institute, Institute of Fashion Designing, in Wadia Institute. Technocrat Welfare Society of India also organized a quiz program for School children in Wadia Institute. The program was anchored by TV artist Mr. Pallav Bose.

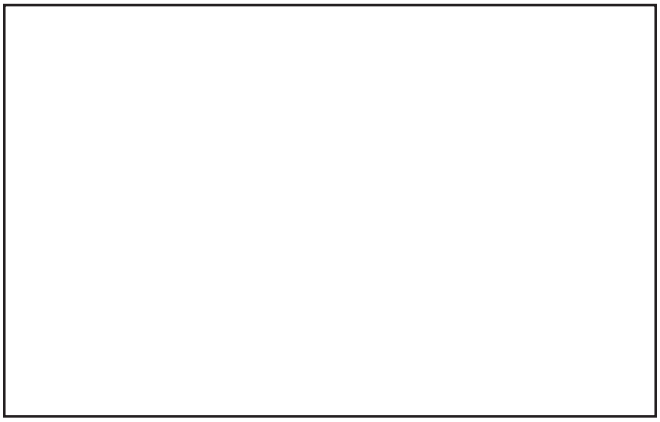
In the concluding year the visitors from Vietnam, Korea, France, Venezuela, Republic, Israel, England, Canada, USA, Bangladesh, Germany, and Nepal visited the Museum. Besides this, the Museum was visited by different dignitaries from different parts of India.

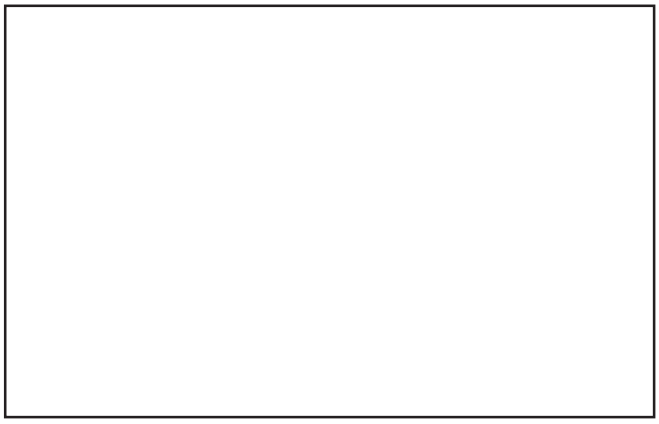
In the last year a base model depicting the cross section of Lesser and Higher Himalayan regions was prepared, presently the fiber glass model of the same model is under preparation. It is planned to have a new section on climate change and two new paintings depicting the Global warming are under preparation. Besides this various earlier maps were retouched. In addition to this the work is going on two small paintings at present.

The Museum at present is actively planning for preparation of database for the Lower Paleozoic successions in particular and Phaneorozoic in general and repository section of national level. The data present in the Museum has been computerized.

The brochure 'Personal Protection in an Earthquake', both in Hindi and English remained in popular demand for visitors and were distributed to general public for their awareness and for necessary precautions.







Children of different schools visited the Musuem on the Occasion of National Science Day Celebrations.

PUBLICATION & DOCUMENTATION

The Publication and Documentation section of the Institute is mainly involved in bringing out the regular journal on Himalayan Geology, regular magazine in Hindi, publishing the yearly annual reports, etc. During this year the section brought out *"Himalayan Geology*," vols. 23, 2002 and 24(1), 2003. Volume 8 of the Hindi magazine *"Ashmika"* was compiled and edited. The section also published the annual report of the Institute for the year 2001-2002 both in Hindi and English. Apart from the above jobs, it has printed the S. P. Nautiyal Memorial Lecture by Dr. R.K. Bhandari,. Invitation cards, certificates for Celebrations of Foundation Day and National Science Day, were also printed.

LIBRARY

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

A large number of National and International scientific core journals in the field of earth sciences are subscribed by the Library. The Library subscribes to 146 journals out of which 61 are national journals and 85 are international journals. Library received 12 titles of journals as gratis. This year the Institute has provided additional funds to remove the time lag in journal subscriptions. Library started subscribing to six new journal's titles, and revived the subscriptions of five journals. The Library has a good collection of Hindi books to promote Hindi language in the staff of the Institute. A total number of 446 books were acquired during this year, out of these 106 books were purchased for Hindi collection.

Three issues quarterly Current Awareness Service (CAS) were compiled and distributed to the scientific staff of Institute. They were also sent to various individuals as well as Geology/Earth science departments of Universities.

The Library is regularly bringing out the fortnightly Contents Information Service (CIS). This service has completed its ten years. It consists of table of contents of journals subscribed or received as gratis in the Library. Two volumes each consisting of twelve issues are compiled. Library has provided 23 annotated bibliographies on various aspects of Himalaya to the scientists and researchers of the Institute as well as other organizations.

The fourth volume of HIMGEO ABSTRACTS has been compiled consisting of 261 records of bibliographic references along with abstracts on various aspects of Himalayan Geology published during the year 2001. This is the printed version of HIMGEO database which is compiled and maintained by the Library. The Himalayan Geology database HIMGEO compiled by the Library has been updated by adding 261 bibliographic records.

The Library incorporates a reprographic cell which serves as a central facility for Photocopying and cyclostyling. The institute provided the Library with three new photocopier machines. Out of these, two machines are analog having copy speed of 18 and 20 copies per minutes and one is digital copier cum printer. A large number of photocopies of articles from journals/ monographs were provided to the scientists of the Institute. This facility was also extended to other organizations on payment basis.

DISTINGUISHED VISITORS TO THE INSTITUTE

Shri. Bachi Singh Rawat, Hon'ble Minister of State of Science and Technology, Govt. of India.
Prof. V.S. Ramamurthy, Secretary , Deptt. of Science & Technology, Govt. of India.
Prof. Krishna Sappal, Chairman Graduate Studies Committee, Division of Resources & Environment, Perth University, Australia.
Dr. R.R. Kelkar, Director General, Indian Metrology Department, New Delhi.
Sh. Y.S. Rajan, Exec. Director, TIFAC and Scientific Secretary to the Govt. of India.
Dr. Asha L. Vinayak, General Manager, Ordinance Factory, Dehra Dun.

Brig. G.D. Bakshi and Dr. H. Negishi, National Research Institute for Earth Sciences and Disaster Prevention, Tokyo, Japan.
Prof. Gautam Mitra, Univ. of Rochester, Rochester, NY, USA.
Dr. B.K. Rastogi, National Geophysical Research Institute, Hyderabad.
Dr. R. Magarini, Perkin Elmer, Italy.
Mr. B. Murray, Thermo Elemental, U.K.

Shri. Bachi Singh Rawat Hon'ble Minister of State of Science and Technology, Govt. of India with Director Dr. N.S. Virdi during his visit to Wadia Institute of Himalayan Geology.

Photographs showing Bhoomi Pujan, laying down of foundation stone by Prof. V.S. Ramamurthy, Secretary, DST for the Guest House-cum-Hostel of the Wadia Institute of Himalayan Geology.

STATUS OF IMPLEMENTATION OF HINDI

During the year all the official forms have been issued both in Hindi and English. As in the previous years, the Hindi magazine of the Institute 'Ashmika' vol. 8 which contains general and scientific articles was published.

Hindi fortnight was celebrated from 14th to 28th September, 2002 and during this period various programmes were organized. These include debate and Hindi essay competition, wherein children from various schools participated. Smt. Kaushalya Agrawal, a renowned poetess presided over the function and addressed the gathering.

The staff of Institute was encouraged to do office work in Hindi and awards were given for this. The scientists were also encouraged to participate in scientific programmes in Hindi and also write and publish articles and scientific papers in Hindi. Three scientists participated in National Seminar on Technical Shabdawali and Rajbhasha organized by the D.S.T. in New Delhi during 6-7 March, 2003 and made scientific presentations.

MISCELLANEOUS ITEMS

1. Reservations / Concessions for SC/ ST employees

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

2. Monitoring of Personnel matters.

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

3. Mechanism for redressal of employee's grievances

There is a Grievance Committees consisting of four Senior Scientist / Officers for redressal of employee's grievances. To look into the grievances of women employees in the Institute a separate Committee has also been constituted.

4. Welfare measures

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

5. Staff-strength (category-wise)

Group / Category	Scientific	Technical	Administrative	Total
A	61	6	2	69
B	-	15	5	20
C	-	24	41	65
D	-	19	25	44
Total	61	64	73	198

6. Approved budget grant for the year 2002-2003

Plan : Rs. 5.75 Crores
Non-Plan : Rs. 1.62 Crores
Total : Rs. 7.37 Crores

7. Xth Plan approved outlay

Plan : Rs. 30.00 Crores
Released : Rs. 5.75 Crores

Dr. N.S. Virdi, Director felicitating Prof. K.K. Sharma, on his superannuation on 30.04.02.

Dr. N.S. Virdi, Director felicitating Dr. N.S. Mathur on his superannuation on 31.12.02.

Dr. Hakim Rai is being felicitated on his superannuation on 31.07.02 by Dr. N.S. Virdi, Director of the Institute.

Sh. G.R.K. Nair Registrar is being felicitated on his superannuation on 30.11.02 by Dr. N.S. Virdi, Director of the Institute.

STAFF OF THE INSTITUTE

(A) Scientific Staff

1.	Dr. N. S. Virdi	Director
2.	Dr. A.C. Nanda	Scientist 'G'
3.	Dr. K. K. Sharma	Scientist 'G' *(Retired on 30.4.03)*
4.	Dr. N.S. Mathur	Scieintist 'F' *(Retired on 31.12.02)*
5.	Dr. Surendar Kumar	Scientist 'F'
6.	Dr. A.K. Dubey	Scientist 'F'
7.	Dr. T.N. Bagati	Scientist 'F'
8.	Dr. Trilochan Singh	Scientist 'F'
9.	Dr. Hakrim Rai	Scientist 'F' *(Retired on 31.7.02)*
10.	Dr. Devendra Pal	Scientist 'E'
11.	Dr. R.J. Azmi	Scientist 'E'
12.	Dr. R.S. Rawat	Scientist 'E'
13.	Dr. J.T. Gergan	Scientist 'E'
14.	Dr. V.C. Tewari	Scientist 'E'
15.	Dr. N.S. Gururajan	Scientist 'E'
16.	Dr. R.K. Mazari	Scientist 'E'
17.	Dr. M.S. Rathi	Scientist 'E'
18.	Dr. K.S. Bist	Scientist 'E'
19.	Dr. R.A.K. Srivastava	Scientist 'E'
20.	Dr. D.K. Misra	Scientist 'E'
21	Dr. B.K. Choudhuri	Scientist 'E'
22.	Dr. R.K. Chaujar	Scientist 'E'
23.	Dr. V.M. Choubey	Scientist 'E'
24.	Dr. N.R. Phadtare	Scientist 'E'
25.	Dr. Talat Ahmad	Scientist 'E'
26.	Dr. P.P. Khanna	Scientist 'E'
27.	Dr. Rohtash Kumar	Scientist 'E'
28.	Dr. Keser Singh	Scientist 'E'
29.	Dr. (Mrs.) Meera Tiwari	Scientist 'E'
30.	Dr. S.K. Ghosh	Scientist 'E'
31.	Dr. M.P. Sah	Scientist 'E'
32.	Dr. N.K. Saini	Scientist 'E'
33.	Dr. George Philip	Scientist 'E'
34.	Dr. S.K. Paul	Scientist 'D'
35.	Dr. B.N. Tiwari	Scientist 'D'
36.	Dr. T.N. Jowhar	Scientist 'D'
37.	Dr. K.K. Purohit	Scientist 'D'
38.	Dr. Kishor Kumar	Scientist 'D'
39.	Dr. N.Siva Siddaiah	Scientist 'D'
40.	Dr. Rajesh Sharma	Scientist 'D'
41.	Dr. Rafikul Islam	Scientist 'D'
42.	Dr. D. Rameshwar Rao	Scientist 'D'
43.	Dr. S. K. Bartarya	Scientist 'D'
44.	Dr. Kamal	Scientist 'D'
45.	Dr. P.K. Mukherjee	Scientist 'D'
46.	Dr. S.K. Sangode	Scientist 'D'
47.	Sh. B.S. Rawat	Scientist 'C
48.	Dr. Sushil Kumar	Scientist 'C'
49.	Dr. P. Banerjee	Scientist 'C'
50.	Dr. H.K. Sachan	Scientist 'C'
51.	Dr. S.K. Parcha	Scientist 'C'
52.	Dr. A.K. Mahajan	Scientist 'C'
53.	Dr. D.P. Dobhal	Scientist 'C'
54.	Dr. Vikram Gupta	Scientist 'C'
55.	Dr. A.K. Mundepi	Scientist 'B'
56.	Sh. V. Sriram	Scientist 'B'
57.	Dr. Bhagwat Sharma	Scientist 'B'
58.	Dr. A.K.L. Asthana	Scientist 'B'
59.	Sh. P.S. Negi	Scientist 'B'
60.	Dr. Jayangondaperumal	Scientist 'B'
61.	Dr. A. Krishnakanta Singh	Scientist 'B'
62.	Miss Kapesa Lokho	Scientist 'B'

(B) Technical Staff

1.	Sh. V. P. Singh	Sr. Pub. Doc. Officer Gr. III (5)
2.	Sh. Saeed Ahmad	Sr. Librarian Gr. III (5)
3.	Mrs. Abha Kumar	Sr. Pub & Doc. Officer Gr.III (5)
4.	Sh. J.J. Sharma	Sr. Technical Officer Gr. III (5)
5.	Sh. M.M.S. Rawat	Tech. Officer Gr. III (4)
6.	Sh. B.B. Sharma	Tech. Officer Gr. III (4)
7.	Sh. A.K. Pandit	Artist-cum-Modellor Gr III (3)
8.	Sh. Sanjeev Dabral	Jr. Technical Officer Gr. III (3)
9.	Dr. R.K. Sehgal	Jr. Technical Officer Gr. III (3)
10.	Sh. Chandra Shekar	Jr. Technical Officer Gr.III (3)
11.	Sh. V.P. Gupta	Jr. Technical Officer Gr. III (3)
12.	Sh. Samay Singh	Sr. Technical Asstt. Gr. III (2)
13.	Sh. Ravindra Singh	Sr. Tech Asstt.
14.	Sh. H.C. Pandey	Sr. Tech. Asstt.
15.	Sh. Rakesh Kumar	Sr. Technical Asstt. Gr. III (2)
16.	Sh. N.K. Juyal	Technican Asstt Gr. III (1)
17.	Sh. D.N. Dutta	Mech. Tech.
18.	Sh. Vishnu Shrestha	Lab. Asstt. Gr. II (5)
19.	Sh. Satish Chandra Kothiyal	Lab. Asstt. Gr. II (5)
20.	Sh. Chandra Bhan Sharma	Junior Engineer
21.	Sh. V.K Kala	Draughtsman Gr. II (5)
22.	Sh. G.S. Khatri	Draughtsman Gr. II (5)
23.	Sh. Navneet Kumar	Draughtsman Gr. II (5)
24.	Sh. B.B. Saran	Draughtsman Gr. II (2)
25.	Sh. Chandra Pal	Section Cutter Gr. II (5)
26.	Sh. Shekhara Nandan	Section Cutter Gr. II (4)
27.	Sh. Pushkar Singh	Section Cutter Gr. II (4)
28.	Sh. Satya Prakash	Section Cutter Gr. II (4)
29.	Sh. Santu Das	Section Cutter Gr.II (1)
30.	Sh. S.K. Chabak	Sr. Lab. Tech.
31.	Sh. Lokeshwar Vashistha	Sr. Lab. Tech.
32.	Sh. R.M. Sharma	Sr. Lab. Tech.
33.	Sh. C. P. Dabral	Sr. Lab. Tech.
34.	Sh. Nand Ram	Elec.-cum Pump Operator Gr. II (4)
35.	Sh. S.K. Thapliyal	Field-cum-Lab. Attendant Gr. I (4)
36.	Sh. S.P. Bahuguna	Field-cum-Lab. Attendant Gr.I (4)
37.	Sh. Shiv Prasad Bahuguna	Field-cum-Lab. Attendant Gr. I(4)
38.	Sh. Shashidhar Balodi	Field-cum-Lab. Attendant Gr. I (4)
39.	Sh. Rajendra Prakash	Field-cum-Lab. Attendant Gr. I (4)
40.	Sh. Tirth Raj Ram	Field-cum-Lab. Attendant Gr. I (4)
41.	Sh. A.K. Gupta	Field-cum-Lab. Attendant Gr. I (4)
42.	Sh. Balram Singh	Field -cum-Lab. Attendant Gr. I(4)
43.	Sh. Ram Kishore	Field -Cum-Lab. Attendant Gr. I (4)
44.	Sh. Anop Singh	Field -Cum-Lab. Attendant Gr. I (4)

45.	Sh. Pratap Singh	Field -Cum-Lab. Attendant Gr. I (3)
46.	Sh. Jaya Nand Khanduri	Field -Cum-Lab. Attendant Gr. I (3)
47.	Sh. Ansuya Prasad	Field -Cum-Lab. Attendant Gr. I (3)
48.	Sh. Puran Singh	Field -Cum-Lab. Attendant Gr. I (2)
49.	Sh. Ram Khilawan	Field -Cum-Lab. Attendant Gr. I (2)
50.	Sh. Madhusudan	Field -Cum-Lab. Attendant Gr. I (2)
51.	Sh. Hari Singh	Field -Cum-Lab. Attendant Gr. I (2)
52.	Sh. Ravi Lal	Field -Cum-Lab. Attendant Gr. I (2)
53.	Sh. Preetam Singh	Field -Cum-Lab. Attendant Gr. I (2)
54.	Sh. Subodh Kumar	Lab. Asstt.
55.	Sh. Nain Dass	Lab. Asstt.
56.	Sh. Rama Pant	Field Attendant.
57.	Sh. R.S. Negi	Field Attendant
58.	Sh. Ramesh Chandra	Field Attendant
59.	Sh. Kushi Ram	Field Attendant
60.	Sh. Tikam Singh	Field Attendant
61.	Sh. Bharosa Nand	Field Attendant
62.	Sh. B.B. Panthri	Field Attendant
63.	Sh. M.S. Rawat	Field Attendants

(C) Adiminstrative Staff

1.	Sh. G.R.K. Nair	Registrar *(Retired on 30.11.2002)*
2.	Sh. Dinesh Chandra	Registrar *(w.e.f 1.12.2002)*
3.	Sh. Harish Chandra	Finance & Accounts Officer
4.	Sh. R.K. Matah	Adminstrative Officer
5.	Sh. G.S. Negi	Asstt. Finance & Accounts Officer
6.	Sh. Dinesh Chandra	Stores & Purchase Officer *(upto 30.11.2002)*
7.	Sh. Tapan Banerjee	Sr. Personal Assistant
8.	Sh. U.S. Tikha	Accountant
9.	Mrs. Manju Pant	Assistant
10.	Mrs. Shamlata Kaushik	Assistant (Hindi)
11.	Mrs. Nirmal Rattan	Assistant
12.	Sh. Kishan Lal	Assistant
13.	Sh. O.P. Anand	Assistant
14.	Sh. N.B. Tewari	Assistant *(On lien w.e.f. 30.9.2001 to R.L.I., Chennai)*
15.	Sh. P.P. Dhasmana	Stenographer Gr.II
16.	Sh. D.P. Chowdhury	Stenographer Gr. II
17.	Mrs. Rajvinder Kaur Nagpal	Stenographer Gr.III
18.	Sh. B. K. Juyal	Asstt.
19.	Sh. Hukam Singh	U.D.C.
20.	Sh. D.S. Rawat	U.D.C.
21.	Sh. S. S. Bisht	U.D.C.
22.	Mrs. Sarojani Rai	U.D.C.
23.	Mrs. Sharda Saigal	U.D.C.
24.	Sh. M.M. Barthwal	U.D.C.
25.	Sh. M.C. Sharma	U.D.C.
26.	Sh. Anand Singh Negi	U.D.C.
27.	Sh. S. K. Chhetri	U.D.C.
28.	Sh. Vinod Singh Rawat	U.D.C.
29.	Sh. Sushil Kumar	U.D.C.
30.	Sh. S. K. Srivastava	L.D.C.
31.	Mrs. Prabha Kharbanda	L.D.C.
32.	Sh. R.C. Arya	L.D.C.
33.	Mrs. Kalpana Chandel	L.D.C.
34.	Mrs. Anita Choudhari	L.D.C.
35.	Sh. Shiv Singh Negi	L.D.C.
36.	Mrs. Neelam Chabak	L.D.C.
37.	Mrs. Seema Juyal	L.D.C.
38.	Mrs. Suman Nanda	L.D.C.
39.	Sh. Puran Singh	Driver
40.	Sh. Khem Singh	Driver
41.	Sh. Diwan Singh	Driver
42.	Sh. Sohan Singh	Driver
43.	Sh. Ganga Ram	Driver
44.	Sh. Chattar Singh	Driver
45.	Sh. Chander Pal Singh	Driver
46.	Sh. Naresh Kumar	Driver
47.	Sh. Shyam Singh	Driver
48.	Sh. Alok Narayan Sharma	Driver
49.	Sh. Mani Kumar Tamang	Driver
50.	Sh. R. S. Yadav`	Driver
51.	Sh. G.C. Singh	Guest House Attdt. Cum Cook
52.	Sh. Bhagat Singh	Bearer
53.	Mrs. Kamla Devi	Bearer
54.	Sh. Shyam Lal	Bearer
55.	Mrs. Deveshwari Rawat	Bearer
56.	Sh. S. K. Gutpa	Bearer
57.	Sh. Chait Ram	Bearer
58.	Smt. Omwati	Bearer
59.	Sh. Jeevan Lal	Bearer
60.	Sh. Surendra Singh	Bearer
61.	Sh. Rahul Sharma	Bearer
62.	Sh. Lal Bahadur	Chowkidar
63.	Sh. Har Prasad	Chowkidar
64.	Sh. Mahendra Singh	Chowkidar
65.	Sh. Minu Ram	Chowkidar
66.	Rahlu Ram	Chowkidar
67.	Sh. H.S. Manral	Chowkidar
68.	Sh. G.D. Sharma	Chowkidar
69.	Sh. Swaroop Singh	Mali
70.	Sh. Ashok Kumar	Mali
71.	Sh. Satya Narayan	Mali
72.	Smt. Dukni Devi	Mali
73.	Sh. Ram Singh	Safaiwala
74.	Sh. Ramesh	Safaiwala
75.	Sh. Hari Kishan	Mali

Security Staff

1.	Sh. Pratap Singh Gurung	Security Supervisior
2.	Sh. Manohar Lal Uniyal	Security Guard
3.	Sh. Om Prakash Thapa	Security Guard
4.	Sh. Mohan Singh Rawat	Security Guard
5.	Sh. Rattan Singh Panwar	Security Guard
6.	Sh. Kirti Dutt	Security Guard
7.	Sh. D. P. Saklani	Security Guard.

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

(a) Governing Body
(w.e.f. 1.11.2000)

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

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

(b) Research Advisory Committee

(w.e.f. 1.11.2000)

Sr. No.	Name	Address	Status
1.	Prof.S.B.Bhatia	House No. 441 Sector - 6 PANCHKULA - 134 109 (Haryana)	Chairman
2.	Dr. L.M.S Palni	Senior Scientific Advisor Biotechnology and Project Director State Biotechnology Programme GB Pant University of Agriculture & Technology TDC Building, PO, Haldi, U.S. Nagar – 263 146 (Uttaranchal)	Member
3.	Dr. J.R. Trivedi	Solar System and Geochronology Area Physical Research Laboratory Navrangpura AHMEDABAD – 380 009	”
4.	Dr. R.K. Bhandari	C-II / 61, Satya Marg Chanakyapuri NEW DELHI - 110 001	”

5.	Dr.M. Ramakrishnan	Editor Journal Geological Society of India 63, 12th Cross Basappa Layout Gavipuram, P.O. BANGALORE - 560 019	Member
6.	Shri V.D. Mamgain	(Ex.Dy.Director General,GSI) B-9, Indira Nagar Faizabad Road LUCKNOW - 226 016	”
7.	Dr. A.K. Chaudhury	Geological Studies Unit Indian Statistical Institute 203, B.T. Road KOLKATA - 700 035	”
8.	Shri C.P. Vohra	Ex. Director General, GSI House No. 1879, Sector-34-D CHANDIGARH-160 022	”
9.	Prof. P.K. Saraswati	Department of Earth Sciences I.I.T., Powai MUMBAI - 400 076	”
10	Dr. G.D. Gupta	Advisor Deptt. of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110016	”
11.	Shri N.K. Lal	G.M. (Geology) KDMIPE, ONGC Ltd. 9, Kaulagarh Road DEHRA DUN - 248 195	”
12.	Brig. (Dr.) B. Nagarajan	Director Geodetic & Research Branch, Survey of India. P.B. No. 77 DEHRA DUN - 248 001	”
13.	Prof. K.N. Khattri	100, New Rajender Nagar DEHRA DUN – 248 001	”
14.	Dr. Sumit K. Ray	Director GSI Eastern Region, MSO Building CGO Complex, DF Block, Salt Lake, Sector - I KOLKATA - 700 064	”
15.	Dr. P.S. Roy	Dean Indian Institute of Remote Sensing 4, Kalidas Road DEHRA DUN - 248 001	”
15.	Dr. A.C. Nanda	Scientist ‘G’ WIHG DEHRA DUN - 248 001	”
16.	Dr. N.S. Virdi	Director W.I.H.G. DEHRA DUN - 248 001	Member & Convenor

(c) Finance Commiittee

(w.e.f. 1.11.2000)

Sr. No.	Name	Address	Status
1.	Dr.D.K.Paul	BF/217, Sector-I Salt Lake KOLKATA- 700 064	Chairman
2.	Shri Arun Sharma	Joint Secretary & Financial Adviser Dept. of Science & Technology Technology Bhawan New Mehrauli Road NEW DELHI - 110 016	Member
3.	Dr.K.R.Gupta	Adviser Dept. of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI - 110 016	”
4.	Mrs.Alka Sharma	Surveyor General's Office Survey of India P.B. No. 37, Hathibarkala Estate DEHRA DUN - 248001	”
4.	Shri K.C. Misra	Additional Secretary to the Govt. of Uttaranchal Dept. of Finance Secretariat, Subhash Road DEHRA DUN - 248 001	”
5.	Shri A.D. Chawla	Dy. Finance Adviser (Nominee, JS&FA, CSIR) CSIR, Rafi Marg NEW DELHI - 110 001	”
7.	Dr. N.S. Virdi	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	”
8.	Shri G.R.K.Nair	Registrar Wadia Institute of Himalayan Geology (Upto 30-11-2002) DEHRA DUN - 248 001	”
8.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology (w.e.f. 1-12-2002) DEHRA DUN - 248 001	”

(/d) Building Committee

(w.e.f. 1.11.2000)

Sr. No..	Name	Address	Status
1.	Dr. N.S. Virdi	Director Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Chairman
2.	Dr. A.C. Nanda	Scientist 'G' Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member

3.	Shri A.K. Sharma	Suptdg. Engineer Dehradun Central Circle CPWD, Nirman Bhawan 20, Subhash Road DEHRA DUN - 248001	”
4.	Shri H.M. Vyas	Chief Engineer (Civil) O.N.G.C. Ltd. Tel Bhawan DEHRA DUN - 248 003	”
6.	Shri Avinash Dikshit	Director Deptt. of Science & Technology Technology Bhavan New Mehrauli Road NEW DELHI-110016	”
7.	Shri G.R.K.Nair	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary (Upto 30-11-2002)
8.	Shri Dinesh Chandra	Registrar Wadia Institute of Himalayan Geology DEHRA DUN - 248 001	Member Secretary (w.e.f. 1-12-2002)

STATEMENT OF ACCOUNTS

R.N. SHARMA
F.C.A.

R.N.S. & ASSSOCIATES
CHARTERED ACCOUNTANT
M-118, First Floor, Shri Radha Palace,
78, Rajpur Road, Dehra Dun - 248 001
Tel.: 0135-2747571, 2742119, 2747561 (O) 2756063 (R)
Fax : 0135-2741112

AUDITOR'S REPORT

The Members,
Wadia Institute of Himalayan Geology Society,
Dehra Dun - 248 001
(Uttaranchal)

Ladies and Gentlemen,

We have examined the Balance Sheet of Wadia Institute of Himalayan Geology Society, Dehra Dun as on 31st March 2003, Income & Expenditure Account and Receipt & Payment for the year ended on date, which is in agreement with the books of accounts maintained by the said Institute.

We have obtained all the information and explanation, which to the best of our knowledge and belief were necessary for the purpose of our audit. In our opinion, proper books of accounts have been kept by the Institute, so far as appears from our examination of the books.

In our opinion, and to the best of our information and according to the explanations given to us, the said Accounts, read with notes on accounts as per Annexure gives a true and fair view:

1. In the case of Balance Sheet of the state of affairs of the abvoe named Institute as on 31st March 2003.
2. In the case of Incoem & Expenditure Account of the surplus for the accounting year ended on 31st March 2003.
3. In the case of Receipt & Payment Account of the receipts and payments during the year ended 31st March 2003.

For R.N.S. & Associates,
Chartered Accontants

Date : 26-6-2003
Place : Dehra Dun

Sd/-
(R.N. Sharma)
F.C.A.

R.N.S. & ASSSOCIATES
CHARTERED ACCOUNTANT
R.N. Sharma, F.C.A.

M-118, First Floor, Shri Radha Palace,
78, Rajpur Road, Dehra Dun - 248 001
Tel.: 0135-2747571, 2742119, 2747561 (O) 2756063 (R)
Fax : 0135-2741112

WADIA INSTITUTE OF HIMALAYAN GEOLOGY SOCIETY, DEHRA DUN
SIGNIFICANT ACCOUNTING POLICIES AND NOTES ON THE ACCOUNTS
FOR THE YEAR ENDING ON 31.03.2003

SIGNIFICANT ACCOUNTING POLICIES

(A) ACCOUNTING CONVENTION

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

i) Interest accured on FDR of GPF / CPF and Pension Fund.
ii) Interest accrued on Employee's / Employer's contribution of GPF/CPF.
iii) Expenses payable.

(B) FIXED ASSETS

i) Fixed Assets are stated at cost of acquisition or cost of construction plus the related expenditure. Depreciation on Fixed Assets has not been provided as per past convention. Those fixed assets that have become obsolete and out dated are written off from the books at the time of disposal of the same at its book value.
ii) Vehicle purchases prior to 01.04.98 have been debited to Equipment account.

(C) CLASSIFICATION

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

R.N.S. & ASSSOCIATES
CHARTERED ACCOUNTANT
R.N. Sharma, F.C.A.

M-118, First Floor, Shri Radha Palace,
78, Rajpur Road, Dehra Dun - 248 001
Tel.: 0135-2747571, 2742119, 2747561 (O) 2756063 (R)
Fax : 0135-2741112

WADIA INSTITUTE OF HIMALAYAN GEOLOGY SOCIETY, DEHRA DUN

NOTES TO ACCOUNTS

(A) MAIN ACCOUNT OF WIHG

i) Schedule '1' to '15' forms part of the Balance Sheet, '16' to '38' forms part of Income & Expenditure and Receipt & Payments Account as on 31.03.2003.

ii) Balance of Debtors and Creditors as on 31.03.2003 subject to confirmation.

(B) GENERAL PROVIDENT FUND / CONTRIBUTORY PROVIDENT FUND

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

(C) PROJECTS

The Miscellaneous Contingency account head includes expenses pertaining to Repairs and Maintenance, Registration Expenses, Printing and Stationary and other expenses related to Projects.

Sd/-	**Sd/-**	**Sd/-**
(Dr. N.S. Virdi)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY SOCIETY, DEHRA DUN
BALANCE SHEET AS ON 31ST MARCH 2003

Amount in Rupees

Particulars	Current Year	Previous Year
Liabilities		
Corpus / Capital Fund	261371398	217669906
Reserves and Surplus	--	--
Earmaked/Endowment Fund	232078	11537952
Secured Loans & Borrowings	--	--
Unsecured Loans & Borrowings	--	--
Deferred Credit Liabilities	--	--
Current Liabilities & Provisions	567398	457473
Pension Fund	22491827	19408958
CPF/GPF Fund	24771950	24111064
Total	**309434651**	**273185353**
ASSETS		
Fixed Assets	208100216	186792299
Investment from Earmaked/Endowment Fund	16356	11239728
Investment others	6785000	245000
Current Assets Loans & Advances	47269302	31388304
Pension Fun	22491827	19408958
CPF/GPF Fund	24771950	24111064
Total	**309434651**	**273185353**

AUDITOR'S REPORT

"As per our separate report of even date"

Significant Accounting Policies and Note on Accounts as per Annexure

For R.N.S. & ASSOCIATES
Chartered Accountants

Sd/-
R.N. Sharma
(F.C.A.)

Date : 26-6-2003
Place : Dehradun

Sd/-	**Sd/-**	**Sd/-**
(Dr. N.S. Virdi)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY SOCIETY, DEHRA DUN

Income & Expenditure A/c for the period ended 31st March 2003

Amount in Rupees

	Particulars	Current Year	Previous Year
A.	**INCOME**		
	Income from sales/services	-	-
	Grants/Subsidies	64300000	44900000
	Fees/Subscription	10750	13500
	Income from Investments (Income on Invest from earmarked/ Endowment - Fund)	72000	65121
	Income from Royalty. Publication etc.	94643	153039
	Interest earned	906172	536575
	Other Income	2408375	1454170
	Increase/Decrease in stock of Finished goods & WIP	–	–
	TOTAL (A)	**67791940**	**47122405**
B.	**EXPENDITURE**		
	Establishment Expenses	42514102	35801529
	Other Research & Administrative Expenses	7225854	7284473
	Expenditure on Grant/Subsidies etc.	-	-
	Interest/Bank Charges	8703	5358
	TOTAL (B)	**49748659**	**43091360**
	Surplus (Deficit) being excess of Income over Expenditure (A - B)	18043281	4031045
	Transfer to Special Reserve (Specify each)	-	
	Transfer to / from General Reserve	-	-
	GRAND TOTAL	**67791940**	**47122405**

AUDITOR'S REPORT

"As per our separate report of even date"

Significant Accounting Policies and Note on Accounts as per Annexure

For R.N.S. & ASSOCIATES
Chartered Accountants

Sd/-
R.N. Sharma
(F.C.A.)

Date : 26-6-2003
Place : Dehradun

Sd/-	**Sd/-**	**Sd/-**
(Dr. N.S. Virdi)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY SOCIETY, DEHRA DUN
Receipts & Payments Account for the year ended 31st March 2003

Amount in Rupees

Particulars	Current Year	Previous Year
RECEIPTS		
Opening Balance	7003212	802829
Grants - in Aid	75300000	51900000
Grants - in - Aid (Ear Marked)	-	466800
Loan & Advances	297211	2926741
Fees/Subscription	10750	13500
Income from Investments	72000	65121
Income from Royalty, Publication etc.	94643	153039
Interest earned on Loan to Staff	906172	536575
Other Income	2408375	1454170
Investment	14000728	21314437
Decrease in Stock (Publications)	149435	-
	100242526	**79633212**
PAYMENTS		
Establishment Expenses	42514102	35801529
Other Administrative Expenses	7225854	7284473
Interest/Bank Charges	8703	5358
Loans & Advances	3134605	1883861
Investments	9323696	18469700
Fixed Assets	10719071	6406899
Ear Marked Fund Expenses	82714	2105265
Grant-in-Aid (Ear Marked) Refunded	11216820	630110
Closing Balance	16016961	7003212
Increase in Stock (Publications)	-	42805
	100242526	**79633212**

AUDITOR'S REPORT

"As per our separate report of even date"

Significant Accounting Policies and Note on Accounts as per Annexure

For R.N.S. & ASSOCIATES
Chartered Accountants

Sd/-
R.N. Sharma
(F.C.A.)

Date : 26-6-2003
Place : Dehradun

Sd/-	**Sd/-**	**Sd/-**
(Dr. N.S. Virdi)	**(Dinesh Chandra)**	**(Harish Chandra)**
Director	Registrar	F. & A.O.

Cover Photo :

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

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

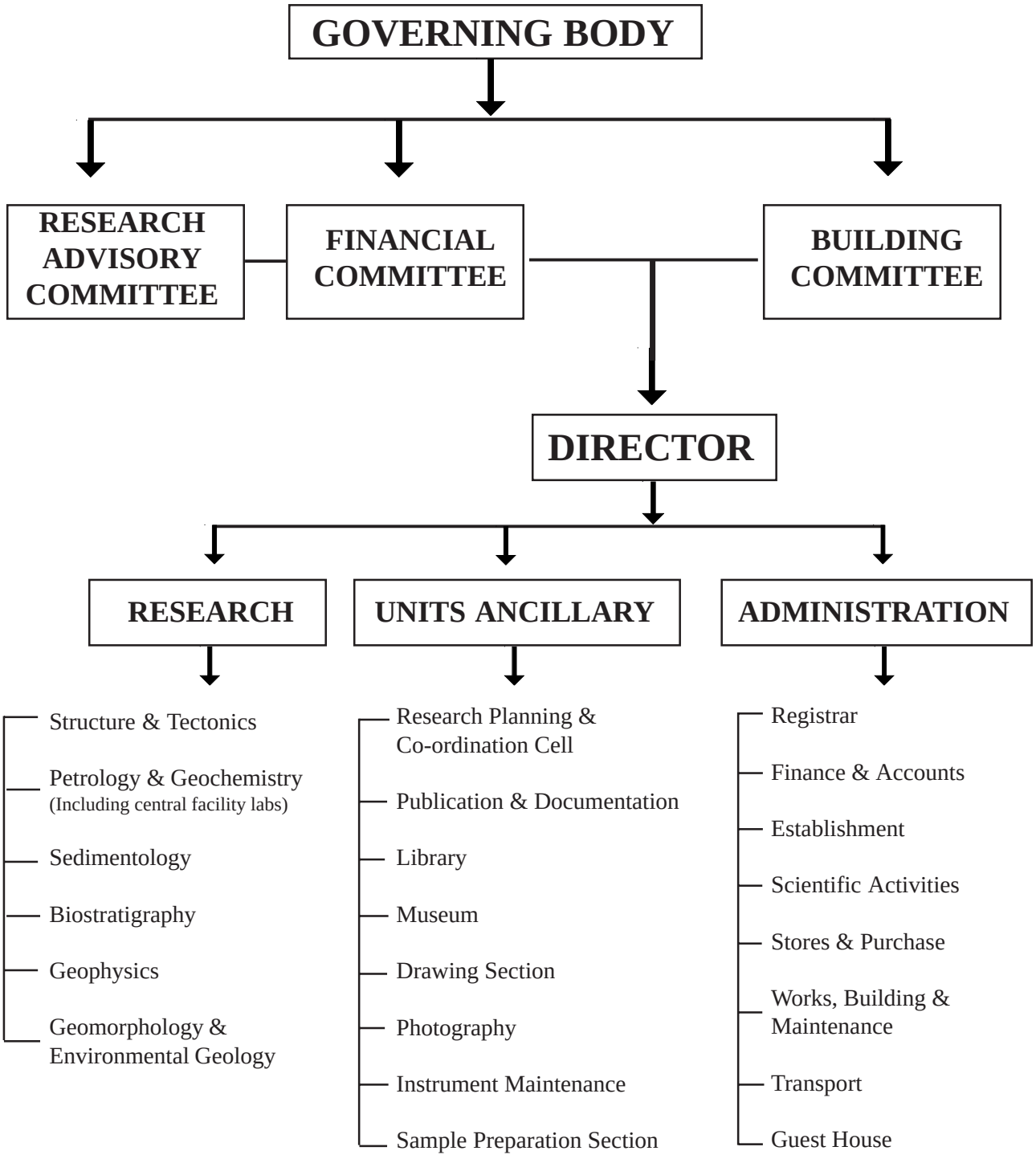
Text Typed : D. P. Chowdhary

ANNUAL REPORT
2002-03

WADIA INSTITUTE OF HIMALAYAN GEOLOGY

33, General Mahadeo Singh Road, Dehra Dun - 248001
EPABX : 26227387, 2624806, 2623109
Fax : (91) 0135-2625212 E-mail : wihg@sancharnet.in
website : http://www.himgeology.com

WIHG ORGANISATIONAL SET-UP



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