Quaternary Geology and CLIMATE CHANGE Newsletter

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Welcome to the first edition

India is gifted with a vast majority (and variety) of Quaternary archives within tropical, subtropical to Alpine conditions, records of land-ocean-atmosphere coupled monsoon system; and the voluminous oceanic records to provide enormous material for interaction amongst Quaternary Geoscientists. In this context, there is large disparity between the expertise available and the demands of specializations. Little expertise is available on high resolution proxies (*such as* pollen, tree ring, speleothemes) and the techniques (e.g., isotope, OSL, clay mineralogy, micromorphology, mineral magnetism). So also there are few takers to the enormous records available from ocean sediments, deserts and the well exposed Quaternaries in the Himalaya and the coastal areas. Although climate science is in great demand, there is little holistic participation from University departments (in the Indian Subcontinent), probably due to under-representation of the subjects like glaciology, (Paleo-) oceanography, soil-, weathering-, and desert sciences in their curricula. It is time to cultivate the scope of the subjects like Climate change, Global warming etc. into the curricula beyond the themes of seminars, meetings or workshops.

Quaternary geology in its present state is largely represented by sedimentologists and geomorphologists contributing to reporting, documentation and correlation of the archives and processes (although geochronology remains an issue). Further it reflects an interdisciplinary gap with the disciplines like atmospheric sciences and geoarcheology. The existing workers are largely clustered around some geographic domains and although they make good contributions, vibrant interdisciplinary teams and competitive focus groups are missing. It demands better interaction by developing focus-/discussion groups, -disseminating the information on various findings and development with an interaction through a media like Newsletter. Since the funding agencies have already recognized Climate Change as thrust area we need to adopt a focused, teamed and well organized approach for a vibrant QGCC community.

In the current scenario, Quaternary geologist has an emergent responsibility to educate the society, policy makers and the economists. He can address it by disseminating appropriate information from the past records and their effects on nature, life or habitat. He can rightly asses the pace of climate change from the past records in order to envision the adaptability responses of different natural systems and advice the same to allied sciences for further research. He can inform the developmental agencies about the components and the complexities of nonlinear dynamics of the natural systems such as sea level changes, deglaciation and fluvial responses from the study of their past records. For this purpose he needs to take the help of popular media and newsletter can be one of the effective tools.

Quaternary geologists make an important link between the climatologists to read the past records in order to feed their models. Climate science being highly interdisciplinary, the Universities provide better platform for such attempts for inputs from diverse disciplines like climatology, atmospheric chemistry, computational mathematics, palaeobotany, archeology, glaciology, isotope chemistry, geoarcheology, history, soil and agriculture sciences, social and economic sciences by interaction amongst various departments. Instrumental and laboratory facilities from Physics and Chemistry departments are vital for many analyses. Universities and funding agencies may find innovative solutions such as built-own- and operate- MOU's with reputed commercial manufacturers to set-up advanced laboratories in the campuses. More training workshops are needed to guide the-existing faculty on the above interdisciplinary aspects before introducing it to the syllabus. Existing experts in their own fields should undertake greater responsibility of sharing knowledge through interaction, workshops, internet portfolios, blogs and a media like newsletter.

There is urgent need to create a better linkage of climate science with society, economy and disaster mitigation at various levels to yield amicable solutions and provide correct inputs to the policymakers and stakeholders. Archeological records should be seriously understood as evidence of the rise and fall, or the migration of civilizations in response to climate change. Paleoclimatologists need to change their scales of observations in order to match with the climate models. Agriculture scientists need a better input from climate scientists for developing adaptive crop culture based on local climatic variability.

Climate change inputs, results and ideas from the western world are to be followed cautiously due to different latitudinal, topographic and regional atmospheric setup. Such information can be good insights, but not necessarily good input to work with our local/regional records. Studies to search the extent and correlation of the global events (such as YD, Little Ice Age or Medieval Warm) would be futile without establishing our own records to the level of global standards.

Inspired by the young participants and guided by the experienced faculty recently gathered at Pune during January 2014 for the DST sponsored Winter School (on the same topic); with little editorial qualities, I believe this first edition is a crude form envisaging a good scope for next issue by inputs, suggestions and remarks from a wider Quaternary Geoscientific Community.

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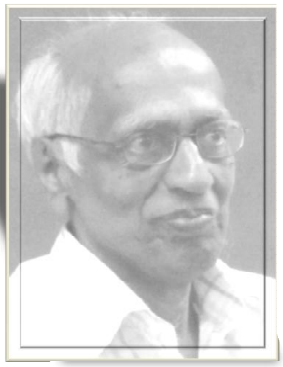
Message from Prof S N Rajguru



After carrying out research in the field of Geoarcheology for about 50 years, I feel that there is a strong need for fundamental research in rock weathering, soils, pediments and bed rock controlled fluvial channels operating in monsoonic climate which has prevailed relatively stable parts of Peninsular India since the Neogene. Any understanding of the Quaternary environmental changes in Peninsular India will remain incomplete if we do not take into consideration environmental aspect of the Late Miocene and Pliocene. Besides, archeological stratigraphy should be part of Quaternary studies as it provides broad chronology for sediments containing human antiquities.

-S N Rajguru

Prof S N Rajguru served as faculty and the former joint Director and Head of Department of Archaeology at Deccan College, Pune.

Message from Prof. S K Tandon

I am indeed very happy to learn of the efforts to start a Newsletter on Quaternary Geology and Climate Change that has the purpose of fostering coordinated programs among various research groups representing the different sub-disciplines required to take up integrated studies in this knowledge domain. Developing deeper insights into the subject of climate change is a matter of critical concern for industrial societies; in this direction there is much to learn from the nature of past climate shifts in the Quaternary and of analogous shifts in the earth' s deeper past, for example the Late Palaeocene.

The 'climate machine' operates at and near the earth's surface. The surface of the earth is largely the product of the last tectonic cycle extending over 200 million years. Physiographic development and climate systems have co-evolved over geological time scales. What is the trajectory of this co-evolution in the Quaternary? This is a highly relevant question globally, and particularly so in India in view of the importance of the physiographic development of the Himalaya and Tibet, and their roles in the developmental history of the monsoonal systems at different spatio-temporal scales.

Apart from the significant issues pointed out above, post 1750 A.D., remarkable changes have taken place at the Earth's surface and in its near surface environments owing to the human agency. Paul Crutzen drew attention to this issue once again in this century, following several others in the early twentieth century like Vernadsky, through his one page long article published in Nature and titled aptly 'The Geology of Mankind'. The human induced transformation of the Earth has resulted in global scale changes in land cover, the terrestrial biosphere, oceans, the atmosphere, the hydrosphere, the pedosphere and the uppermost crust.

The prosperity of Industrial societies depends crucially on water, food, and energy security. As we are aware, the extensive use of hydrocarbons for energy production over the last century has been advanced as a reason for the global temperature increase of 0.75 degrees C. The unabated increase in atmospheric carbon dioxide to approximately 400 ppm V has become a matter of global concern, despite the criticism of some sceptics who contest the attribution of GHG enhancement to anthropogenic causes.

Highly populated countries such as India, that have development in the coming decades as the main agenda, will need flexible and evolving policy platforms in the area of Climate Change; these policy platforms will have to be informed by strong and rigorous scientific data sets. It is in this context, that the teaching and research efforts in India should be strategised into coordinated programs that are multi-disciplinary and societally relevant, keeping in mind the limited manpower availability in the country and the requirement of appropriate manpower development.

The initiative of launching a Newsletter is timely and will most likely serve the cause of promoting synergy across various research groups and their disciplines and Institutions.

I look forward to the success of the Newsletter on Quaternary Geology and Climate Change and compliment Professor S. J. Sangode for taking this initiative and wish him well for the future in this endeavor.

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Critical Zone Research

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A complex suite of chemical, biological and physical processes at the Earth's surface combine to create a dynamic system that transforms bedrocks and biomass into soil. Soil is a fragile natural resource that provides for life support and mediates most of the bio-geological and chemical interactions on land surface, groundwater and atmosphere. The rock weathering products provide nutrients to nourish ecosystems and human society, controls water runoff and infiltration, mediates release and transport of toxins to the biosphere, and creates conduits for the water that erodes bedrocks. Weathering also affects the sequestration and release of greenhouse gases that impact climate change. All these processes operate in a complex manner in the Critical Zone (CZ) which is the external surface of the earthy extending from the outer limits of the vegetation down to and including the unconfined aquifer. At present, anthropogenic pressure has and is radically changing the CZ dynamics by altering the magnitudes of both reservoirs and the fluxes such that the idea of Anthropocene has been muted to age-bracket this scenario.

The Critical Zone is a dynamic interface between the solid earth and its fluid envelopes, governed by complex linkages and feedbacks among a vast range of physical, chemical and biological processes that may be organized into four categories, namely, Tectonics that controls surface architecture, Weathering that controls soil formation, erosion and chemical mobilization of near-surface rocks, Water transport that shapes landscape morphology and Biological activity that controls chemical cycling among rock, air and water. CZ can thus be considered as an integrated group of systems and sub-systems that act to move energy and matter down gradients that give rise to physical transport and chemical transformation that organize CZ into producing sol horizons, catenas, stream networks, vegetative structure, microbial communities etc. in a complex interactive manner where fluxes of matter and energy play a significant role. Therefore, the study of CZ calls for systems approach and thermodynamics-based integration of CZ components.

As human activity is increasingly impacting the CZ structures it has become necessary to project how the environment would evolve in the future. This forecasting which some researchers termed as "earthcasting" would require modeling and simulation of interactions among CZ systems including the human perturbations. It is known that the soils and weathering products including sediments record signatures of surface processes, environmental fluxes and changing dynamic conditions, and hence, models need to be generated to interpret the intricacies of natural and anthropogenic forcings and to "earthcast" future changes in the CZ. Quaternary geologists can and should play an important role in such studies.

It is important to study the processes and multiple feedback loops that control landform evolution, sediment generation and transport, soil formation, hydrologic and geochemical cycling in order to understand the present status of CZ in different climatic regions of the country and predict how CZ will change in response to anthropogenic and climatic perturbations. This makes Critical Zone one of the most compelling and challenging research areas in Earth Sciences in the 21st century. In order to meet this challenge and to promote CZ research the Department of Science and Technology, (Earth Sciences), Govt. of India, would invite research proposal for support in any of the aspects mentioned above, particularly on the following themes: Landform, ecosystem and climate interactions, Soil-landform system, Hydrology and flux flow within CZ, Modern and ancient weathering and erosion systems, Geomicrobiology and geochemical cycling.

Critical Zone Exploration Network (CZEN) is a network of people as well as a network of field sites to foster interdisciplinary research spanning all aspects of the Critical Zone and to bridge researchers from around the world. Everyone engaged in Critical Zone research and related fields can join CZEN by registering on their site **http://www.czen.org**. Once registered the user will have the ability to interact with other members and also have access to posted datasets, field protocols, sampling methodologies and other content.

Excerpts from the Experts

Dendroclimatology: Scope and Limitations

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Information on climate and its variability during the recent past is vital to understand various internal and external forcing on the climate and thereby make a reliable future prediction. The present knowledge of decadal to century scale variations in climate is based upon discontinuous and limited information beyond the observed meteorological data. Very little information is available on the Indian climate, particularly over the Himalayan region earlier to about a century when the instrumental records commenced. Proxy records (ice core, tree-ring, pollen, lake sediment etc.) of climatic fluctuations prior to the instrumental period are useful for understanding of the nature of past climate variability and determining the future course of climatic variations on a global scale. These proxy records are of different temporal extent and resolution depending upon the nature of the proxy source. The tree-ring records, though shorter in palaeoclimatic time frame, are accurate and their time resolution is to a specific season or year. A very useful tool to extend the climatic series back in time on annual or even seasonal scale is the dendroclimatic analysis. Dendroclimatology is the science of extracting climatic information from the study of the growth pattern of trees using the characteristics of their ring structure.

Many long lived trees grow with annual ring structure. Climatic information recorded by trees growing in stressful forest environments can be extracted from the size, structure and chemical composition of these annual growth rings. The precisely dated and continuous climatic information from tree-rings is an important addition to other available data on seasonal to decadal scale climatic variability. With the availability of a large number of samples and cross matching in their growth pattern, it is possible to date each ring accurately. Filtering of downward trend in growth associated with increasing tree age and averaging of many series makes it possible to maximize the large scale extensive climatic signal in tree growth time series. When a large number of tree-ring chronologies are available for a region and they are demonstrated to represent the effect of a specific climatic variable, the climatic elements like temperature, rainfall etc. can be reconstructed backward for a much longer time. The spatial anomalies in tree

growth / climatic elements may be mapped and used to deduce the climatic anomalies over a wider geographical region.

Dendroclimatic activities over the western Himalaya indicate high dendroclimatic potential of conifers (*Pinus, Abies, Picea, Cedrus*) to reconstruct summer and winter temperature and rainfall for a millennium period. A 553-year long tree-ring records over high altitude regions of western Himalaya give the history of warm and cold episodes. Anomalous higher growth during the recent few decades observed in these tree-ring records can partially be attributed to the overall warming trend over the region. Tree-ring variations in teak (*Tectona grandis*) from central and Peninsular India is strongly influenced by monsoon rainfall and related global parameters (e.g. ENSO). They also show the strong positive relationship with moisture index at root zone and give the monsoon drought history of more than 500 years.

In addition to the climate studies, changes in ecological processes over time such as defoliation by insect outbreaks, the effects of air, water, and soil pollution on tree growth and forest health; the age maturity, the effects of human disturbances and management on forest vitality (dendroecology), glacier fluctuations in the past (dendroglaciology) are some important areas where tree ring (dendrochronology) studies can successfully be applied over the India region.

Some recent Texts on Tree Ring Study

1.**Dendroclimatology: Progress and Prospects**; Series: Developments in Paleoenvironmental Research, Vol. 11; Hughes, Malcolm K., Swetnam, Thomas W., Diaz, Henry F. (Eds.); 2011, XII, 368 p. ISBN 978-1-4020-5725-0. This book presents a review of the current state of dendroclimatology, its contributions over the last 30 years, and its future potential. Also addresses strengths and weaknesses associated with the use of tree rings to aspects of paleoclimatology. Provides examples of tree rings use in dendroclimatology and its applications to other fields.

2.**Tree Rings and Natural Hazards: A State-of-Art**; Series: Advances in Global Change Research, Vol. 41; Stoffel, M., Bollschweiler, M., Butler, D.R., Luckman, B.H. (Eds.); 2010, XV, 505p. 177; Details on tree-ring dating of natural hazards. Compilation of classical and unpublished studies in related research. Outlines and demonstrates practical applications of tree rings in natural hazards study.

Stable Isotope practices of High Resolution Records

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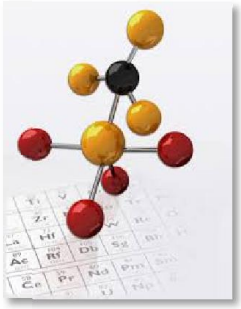
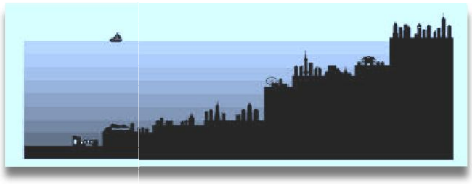


Isotopic analysis provides an important means to understand various natural processes. Starting from quantifying the temperature change from local to global scale, reconstructing the past eco-system, understanding the past rock system and volcanic activities, hydrological changes, migrating paths of animals, past atmospheric CO_2 levels and evolution of the atmosphere, estimating the budget of the atmospheric trace gases, food habits of the ancient humans, identifying a fallen meteorite from its terrestrial counterpart, the applications are myriad. The underlying principle is simple. Preferential separation of the lighter isotopes from the heavier isotopes during a physical, chemical or biological process. Precise measurement is possible with an isotope ratio mass spectrometer, which makes it possible to quantify an environmental parameter or reconstructing a system.

Application of stable isotopes has several advantages. Firstly, it can quantify a physical parameter (say temperature) rather than measuring a relative change. Secondly, the extent of variability is relatively less than the other parameters. For example, the tree ring width (of an arbitrary ring) will be typically higher than its isotopic variabilities. In statistical term, the isotopic variance is less than the ring width variance. This characteristic helps improve the signal over noise. Isotopic hydrology also offers a similar situation. Observations show that rainfall in a given region can have a high variability, whereas its isotopic ratio has much smaller variation. This simply means that the rainfall in a given region is driven more by local processes (noise) but its isotopic variability is responding more to the low frequency component of the hydrological system. Hence the isotopic analysis appears to be better equipped in identifying the larger scale processes. This has an important implication in paleo monsoon studies.

Isotopic technique is also used to 'calibrate' a natural change through laboratory simulation, which in turn help establishing 'empirical equations'. As an example, foraminiferal species can be grown in laboratory while the changes in ambient temperature are recorded. Hence the isotopic properties of the foraminifera and the temperature are calibrated. Another characteristic of the isotopic study is that it can be applied practically to any time scale, starting from studying the modern systems to billions of years old earth processes. On the other hand with the advent of modern technologies the spatial scale resolution has been improved to sub millimeter to micron scale analysis. This has enabled to understand the processes that operate on finer scales, thus making it possible to perform high resolution analysis.

Quaternary Sea Level Changes and Early Human Cultures in Coastal India: A Geoarcheological Approach



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Recent technological developments in various branches of earth science have changed our earlier concepts of sea level changes during the Quaternary. Glacial eustacy is only one of the factors controlling the sea level changes which include vertical fluctuations and lateral movements like transgression and regression. Globally the last interglacial high (+7m) sea level (dated around 125 Ka BP) and the last glacial maximum sea level (-100m) low (dated to around 17 Ka BP) are well recorded. Gujarat coast has well preserved evidence of high sea level in the form of fossil mud flats and coral ridges. Evidence for low sea level is well documented in terms of submerged fluvial gravels and terraces all along the marginal continental shelf of India. There was a rapid rise in sea level due to warm and relatively wet climate of the early Holocene and the sea level reached its present level around 7 Ka BP. It appears that any attempt of reconstructing sea level curve even for Holocene is premature at this stage of available

scientific data in coastal parts of India. Against this background attempts have been made to understand the nature of sea level change in the context of early human cultures (prehistoric and historic) in coastal area.

The earliest evidence (1.5 Ma BP) of existence of early man is located at Attirampakkam near Chennai in coastal Tamilnadu. Stone artifacts of Lower paleolithic (Early Acheulian) are found in low energy flood plain deposits of a meandering river originating in the Eastern Ghats and draining into the Bay of Bengal. The sea level at that time (Early Pleistocene) was low and the climate was relatively wet. Another lower Paleolithic site (dated >200 ka BP) has been found in relict fanglomerate resting over basalt and capped by Milliolite limestone of littoral origin in the Hiran valley, near Junagarh, Gujarat. The Arabian sea has considerably regressed towards west sometimes during Middle Pleistocene. On the other hand the Lower Paleolithic artifacts are found to occur in a reddish brown paleosol sandwiched between Milliolite limestone of early Late Pleistocene age. This evidence indicates human activity during the high sea level phase of the last interglacial (around 125 Ka BP).

Subsequent cultural phases – Middle and Late Paleolithic- have been located in exposed littoral surface near Malvan in coastal Maharashtra, in relict fanglomerates in Dahisar valley near Mumbai and estuarine mud flats and gravels near Morvi in Gujarat. During this period the sea level was low by scores of meters, shallow continental part was exposed due to regression of Arabian sea and the climate was dry due to global glacial climate. An interesting Neolithic (?) site rich in microliths and crude handmade pottery is found to occur in a paleochannel buried 40m below the present sea level in Gulf of Cambay 20 km west of Hazira in Gujarat. This has been dated between 9 ka and 7 Ka BP. Famous Harappan sites, dated between 5 Ka and 3.5 Ka BP are closely associated with littoral and estuarine sediments in Gujarat and these sites throw interesting information on growth and decay of maritime trade during the mid-Holocene. Coastal historical sites of the Late Holocene age (< 3 Ka BP) occur in deltaic and estuarine context in Bengal basin and in estuarine context in coastal Maharashtra. The decay of maritime trade during historical period is connected with inbuilt configurational processes and minor (<3m) sea level fluctuations. The climate during the late Holocene was drier than during early Holocene. Good understanding of estuarine and deltaic processes will bring out better picture of 'Cultural Ecology' of historical sites commonly occurring in Coastal India.

Future geoarcheological work in coastal India needs to be focused on good correlation between littoral zone archaeology and piedmont zone archaeology in the footsteps of Western Ghats and Eastern Ghats. Besides, data generated in coastal zone may be tested against shallow continental shelf (<100m) data of Arabian Sea and Bay of Bengal.

Sedimentological Evidence of Past Extreme Floods

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Understanding the flooding behavior of flood-dominated monsoonal rivers on longer timescale is not only of great scientific interest to palaeohydrologists and palaeoclimatologists but also has important implications for flood hazard management from the standpoint of recurrence of extreme flood events with low probability (< 0.01) but high social, economic and environmental consequences. However, for hydraulic engineers and hydrologists, the estimation of the recurrence interval of extreme floods is a major challenge because large-magnitude flood events with a recurrence interval of 100 years or more are not represented in the short instrumental or gauge records, which are usually less than 50 years. More often than not, smaller and medium sized rivers are ungauged. Additionally, better insight into the relationship between the magnitude and frequency of extreme floods events and climatic fluctuations is also crucial in the context of projected global warming.

Under such circumstances natural archives provide a potential means of extending the instrumental and historical flood records and obtaining information on past flood events or palaeofloods. Sedimentological data, recorded in sediments deposited during past flood events could be used to lengthen the records of discrete large-magnitude floods by several centuries to millennia. Certain fluvial reaches, under suitable geologic and geomorphic conditions, preserve, more or less, a complete record of past floods.

Evidence of multiple flood events, in the form of vertically-stacked sequences of slack water flood deposits have been discovered in bedrock gorges of about half-a-dozen rivers of the Indian Peninsula (such as Narmada, Godavari, Krishna, etc.) during the last two decades. The flood records derived from the sediments from these rivers cover a significantly longer period of almost one to two thousand years. The results suggest clustering of major flood events and a general lack of floods of large-magnitude in periods during which the regional climate over the Indian Peninsula was relatively dry, such as during the Little Ice Age.

Faunal Response to Climate Change

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There are several factors involved in the faunal evolutionary changes which include the geological, biological, ecological, water resources etc., each component having an important role to play. Climate change and other environmental issues are closely related to the concept of biodiversity – diversity of ecosystems and the species diversity which are both interlinked. The ecosystems provide the spaces in which the biota lives and interacts with the physical and chemical factors of the environment. The species diversity generally depends on geographic locations wherein most of the biological resources are concentrated, for example in South Asia where ecosystems like the savanna, wetlands, deserts, mountain forests etc. provide a suitable ambience. These environmentally sensitive areas with richness of endemic species, living in restricted pockets, have been successfully mapped. The most well known prehistoric site complexes in India include the Siwaliks of the NW, the NE region in part, the Indogangetic plain, the Peninsular India (notably, the river valleys of Narmada, Godavari, Krishna etc. and the cave deposits of Andhra Pradesh) and other isolated fossiliferous pockets. The Nepal Siwaliks, fossiliferous regions of Myanmar and Sri Lanka also constitute important prehistoric hotspots in South Asia which are important from the point of view of migration patterns, man/land relationship and palaeoenvironment. An important

prehistoric region is Indonesia in SE Asia which is important in view of its significance in hominid discoveries and similarity with other prehistoric hotspots in South Asia.

In recent researches emphasis has been laid on prehistoric faunal wealth, their geological provenance and related lithologies and their response to climatic change. A large variety of faunal remains comprising mammals, ostrich egg shell pieces, reptiles, amphibians, fishes, microvertebrates and molluscan shells obtained from the above mentioned deposits, many of these in association with Stone Age tools, help in a better interpretation of palaeoenvironmental conditions during the deposition/formation of the fossil-bearing sediments. This also helps in a better understanding of the contemporary environmental issues like fragmentation of habitats, introduction of exotic species, gradual elimination of autochthonous ones and extinction of animal populations due to natural hazards, human activities and other allied factors.

A brief account of the fossil sites and fossils found therein with remarks on migration patterns, provinciality aspects, evolutionary history, palaeoenvironmental deductions, causes of extinction and other related aspects will enhance our understanding of the faunal response to climatic change.

The **Paleocene–Eocene Thermal Maximum** (PETM) or "Eocene thermal maximum 1" (ETM1), formerly known as the "Initial Eocene" or "Late Paleocene Thermal Maximum" refers to a climate event that began at the boundary between the Paleocene and Eocene epochs (close to 55.8 Ma) whereby the global temperatures rose to about 6 °C. The PETM probably provides our best past analog to understand impacts of global warming and massive carbon input to the ocean and atmosphere, including ocean acidification. Also there was a sudden appearance of modern mammal orders (including primates) in Europe and North America. Sediment deposition changed significantly at many outcrops and in many drill cores spanning this time interval. The time interval is represented by many outcrops in the Himalayan foreland basin and elsewhere in India demanding detailed study on this aspect.

QGCC News and Info

The Indian Institute of Technology **Kanpur** created a new **Department of Earth Sciences** on February 5, 2014.

Indian Institute of Science Education and Research (**IISER), Pune** has launched the Earth and **Climate Science** program from the current academic year.

India's first **Climate Change Theatre** was opened at Pushpa Gujral Science City in **Kapurthala.** This will provide visitors an experience aiming to sensitize about subject of climate change and global warming. Visitors will be made aware of and have a better understanding and appreciation for the latest climate science and issues surrounding human role in climate change.

Divecha Centre for Climate Change was established at Indian Institute of Science, **Bangalore** in January 2009 with primary goal to understand climate variability and climate change and its impact on the environment. This centre operates through interdisciplinary interaction from faculty at Centre for Atmospheric and Oceanic Sciences(CAOS), Department of Civil Engineering, Centre for Earth sciences(CEaS) and Centre for Ecological Sciences(CES) at IISc.

The Government of India opened a '**Centre for Himalayan Glaciology**' at Wadia Institute of Himalayan Geology, Dehradun. It is aimed at coordinated research initiative on Himalayan glaciology to understand the factors controlling the effects of climate on glaciers in order to develop strategies for climate change adaptability for sustained growth of society. Centre will take up programs of capacity building in this field and to nurture the independent Indian Institute of Glaciology at it's Mussoorie campus.

The Government of India created **Earth System Organisation** (ESO) along with the Ministry of Earth Sciences (MoES) to deal comprehensively with the matters relating to earth system and climate involving Ocean, meteorology, marine environment, atmosphere, seismology and earth sciences. A coordinated research programme on **Global and Regional Climate Change** (GRCC) during the XI Plan was launched to build a National Climate Change Monitoring and Research Network.

As a part of GRCC, a dedicated **Centre for Climate Change Research** (CCCR) to undertake studies on science aspects of Climate Change at the Indian Institute of Tropical Meteorology (IITM), **Pune** has been established. The CCCR is endeavoring to serve as a nucleus for research in the tropical and Asian monsoon region.

IODP Expedition-355 (Arabian Sea Monsoon) is scientific drilling program in the Arabian Sea to understand co-evolution of mountain building, erosion and climate over various time scales. National centre for Antarctic and Ocean Research (NCAOR), an autonomous research institute under Ministry of Earth Sciences (MoES) has been designated as the nodal agency responsible for the Indian activities pertaining to the International Ocean Discovery Program (IODP). See details at : http://iodp.tamu.edu/scienceops/expeditions/arabian_sea.html And http://www.ncaor.gov.in/iodps

DST Winter School on Geomathematics

A Report by ***Nivedita Mehrotra***, Birbal Sahni Institute of Palaeobotany Lucknow, India.

With the beginning of advanced computing and mathematical techniques amalgamated with programming, large and time consuming problems were minimized and solved easily. The spatio-temporal and dimensional aspects in earth system sciences became more significant and conjoined with mathematics as geomathematics. These techniques are developing at an immense rate in modern times and helping geoscientists to solve many riddles of the past, present and future. Internationally at all levels of learning and professions in geosciences, these techniques are taught rigorously. Recently the Science and Engineering Research Board (SERB), Department of Science and Technology, New Delhi sponsored a winter school in geomathematics at Wadia Institute of Himalayan Geology, Dehradun held during December 2013. The key framework of the training was to enhance the mathematical skills of the participants by introducing them to basic and advanced mathematical modeling methods, software techniques, and programming mathematical solutions to earth system science. The eminent faculty delivered the lectures and guidance on the aspects of forward and inverse problems in Geophysics, Uncertainty of quantification, Bayesian formulation, basic level statistics such as summary statistics, hypothesis testing, and graphical representation of statistical information spatial variability modeling, Parameterization, approximation, Matrix methods in Inversions, Partial Differential Equations and inverse problems, Neural network, Krigging, Discritization of domain, transformation, of PDE/IE into matrix equation using method of moments, solution of matrix equation, computation of derivative response, artificial neural network, fuzzy logic method, optimizations, numerical dispersion-minimization of errors, time series analysis. Climate change being a highly mathematical subject, the Quaternary Geologists should have a good knowledge on such geomathematical methods.

SOME RECENT PUBLICATIONS

Vegetation Response and Landscape Dynamics of Indian Summer Monsoon Variations during Holocene: An Eco-Geomorphological Appraisal of Tropical Evergreen Forest Subfossil Logs. Kumaran NKP, Padmalal D, Nair MK, Limaye RB, Guleria JS, et al. (2014) PLoS ONE 9(4): e93596. doi:10.1371/journal.pone. 0093596

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First hand Reports, Findings and Analyses

Loess-Paleosol Sequence of Karewa basin

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The global climatic changes during the Quaternary and its effects on the deposition of sediments have become a subject of multidisciplinary scientific study since recent past. These sediments are the most recent part of geological time, comprising less than 0.1% of the total history of the earth (Bowen, 1978). Though it is a very small part but the geological processes operated during this time have had a much greater effect on sculpturing the architecture of the earth's crust as well as the deposition of sediments. This was the time of global climatic fluctuations, intense erosion and deposition. The Plio-Pleistocene glacial-interglacial periods are also reflected in these sediments.

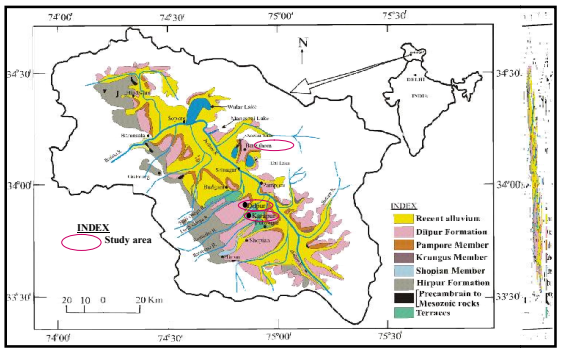

Fig.1. Geological map of Karewa Group showing Loessic sediments in Kashmir Valley (after Bhatt, 1989).

It has been well established that during Plio-Pleistocene the Himalaya uplifted rapidly, which caused significant tectono - climatic changes. The climatic record during this period is well preserved in the Quaternary sediments of 'Karewa - of Kashmir'.

The Kashmir Valley lies between the Great Himalayan Range to the north east and Pir-Panjal Range to the south western side. The geomorphic setting of the Kashmir Valley reveals that due to rise of the Pir-Panjal Range, the drainage was impounded as a vast lake in which the sediments of Karewa Group were deposited as intermontane valley fill deposits (Fig, 1).

Middle Pleistocene to Recent loess - paleosol sediments of Dilpur Member of Upper Karewa is an important litho-facies of the Upper Karewa which comprises a major part of the present day valley floor showing typical loessic geomorphic landscapes (Fig.2).

These sediments occur as the plateau deposits, terrace deposits and slope deposits, representing the youngest deposits of Karewa Group. Beside these loessic sediments, Dilpur Member is also characterized by the presence of interbedded paleosol profiles (Pant et al., 1982). Geochronologically, these sediments falls within the Brunhes normal chron, ranges in age from Ca 18,000 years B.P. to more than 31,000 years B.P. (Kusumgar et al., 1980, 1986; Burbank and Johnson, 1982; Singhvi et al., 1987; Bronger et al., 1987). It is interesting to note that the topmost profile of paleosol which represent the warm climate was present in the Kashmir Valley at about 18,000 year B.P. showing the earliest warm period detected for the first time in India (Agrawal et al., 1979). Later Singhvi et al. (1987) proposed TL dating for these sediments which varies from Ca 13,000 to 34,000 years B.P.

Fig. 2. Field photograph showing loessic geomorphic landscape of Kashmir Valley.

Geochemically, these sediments are rich in MgO, Fe_2O_3, Sc, V, Ni, Co, Cu, Y, Th, U and Zn and depleted in Hf and Nb associated with felsic rocks. The other elements which are also rich in felsic rocks are slightly higher than the UCC. Therefore, it is interpreted that these sediments are derived from the intermediate source rocks. Geochemical analysis shows that mobile elements Ca, Na and P are depleted in the paleosols to a varying degree while immobile elements Ti, Al, Si and Fe are enriched in the paleosols. The mean CIA value of Kashmir loess is (68.6804) which suggest that these sediments have undergone weak to moderate degree of weathering under cold arid to warm semi-arid climatic conditions (Ahmad and Chandra, 2013).

Some more Photos from Karewas below:

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Holocene Climate variability in Lahaul Himalaya

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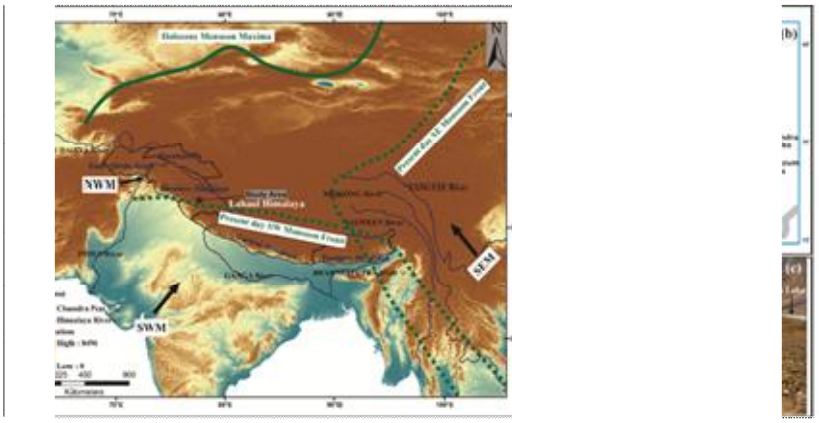
The Indian Summer Monsoon (ISM) is one of the most important climate systems in the world which provides moisture to the South Asian countries crucial for the livelihood and agrarian economy of the region. In contrast to Himalayan region, number of high resolution studies had been carried out from the Arabian Sea and off Himalayan ranges to understand the past variability in monsoon.

The Chandra valley in the Lahaul Himalaya preserve some of the dynamic records of climate change occurred during the Late Pleistocene and Holocene. It also preserves a unique peat deposit that was attempted by Rawat et al (2012) to generate high resolution (century to millennial scale) palaeoclimate record from the peat sequence and underlying lacustrine sediments deposited near the Chandra Tal.



A 53 cm thick sequence of lake sediments and overlying peat deposit was trenched and sampled at 1 cm interval.

The objective was to reconstruct floristic and climate pattern based on abundance and depletion of plant taxa growing in a favorable set of climate along with other proxies such as environmental magnetism, loss on ignition, total organic carbon and stable carbon isotope. The chronology of this profile is based on 9 AMS 14C radiocarbon dates. All the dates ideally satisfy the stratigraphy order. The uniform lithology suggesting uninterrupted sediment deposition helped in interpolation of intermediate ages. The AMS 14C radiocarbon date of bottom sample (53-52 cm depth) is ~12,880 cal yrs BP. Therefore, the study reports continuous record of vegetation and climate of Lahaul, NW Himalaya from past 13,000 cal yrs BP. The cold and dry event corresponding to the Younger Dryas event was precisely documented from ~12,880 to 11,640 cal yrs BP in the Lahaul region (Rawat et al., 2012). This event was terminated with a gradual re-appearance of local and regional flora marking the initiation of Holocene warm and wet conditions at ~11,640 cal yrs BP. The present study also records other global events i.e. 8.2 ka cold event, the Holocene Climatic Optimum, the Medieval Warm Period and the Little Ice Age. This indicates the sensitivity of this region to the above global events. The pronounced 4.2 ka cold aridity was recorded only for a very brief duration from 4,808 to 4,327 cal yrs BP. The improved vegetation after 4,327 cal yrs BP, reached its maximum from 3,333 to 2,032 cal yrs BP. This study discards long and continuous cold dry arid conditions in the Himalayan regions, due to the observed increase in vegetation pattern indicative of high precipitation with favorable plant taxa in the Lahaul Himalaya from 3,333 to 2,032 cal yrs BP. However, to corroborate this hypothesis more detailed high resolution records are required from other parts of the Himalayan domains.

Figure: (a) The location map of the present study area in different Asian Monsoonal settings (monsoon outlines after Winkler and Wang, 1993); (b) The map of Chandra valley showing present study site in rectangle with different glaciers setting of the region. The thick grey line shows Rohtang ridge which acts as an orographic barrier and prevents normal entry of ISM in the NW Himalaya; (c) Field photograph of the Chandra peat bog developed over the lateral moraine of the Batal glacial stage.

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Manasbal lake, J&K as a record of Holocene Monsoon variability

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Fresh water resources, lakes in particular, afford excellent and easily available opportunity for studying the structural and functional processes of an aquatic ecosystem. Today lakes are subject to intense public and political debate world-wide, mainly because their usage for recreational purposes has shown visible degradation changes. Contemporary monitoring data series are often too short to cover the reference state and typically only the largest and most abundant types of water bodies have been monitored (e.g. 38% of lakes >5 ha, 1.3% of lakes between 0.1-5 ha and 0.5% of lakes between 0.01-0.1 ha).Therefore, knowledge of smaller and rarer lake types is limited. Palaeolimnological studies may serve as an alternative approach when time series are insufficient or absent. Such studies may provide important information on the onset and the rate of change in physico-chemical and biological processes within the water body assessed. (Anderson 1995).

The Kashmir Himalayas in North West India abound in fresh water lakes which are important for fisheries, agriculture and

recreation. A wealth of limonological investigations have been undertaken on these lakes in recent years related to different aspects. De-terra and Paterson (1937), presented data on the distribution of detritus and mineral grains in three basins of Dal Lake, Srinagar. Zutshi (1968) and Mir (1977) and correlated the biological productivity with the nutrient status of the sediments. Kant & Anand (1968) reported high turbidity in Mansar Lake during monsoon rains. Kaul *et al.*(1972), while studying the high altitude Kashmir lakes revealed that these ecosystems are moderately fertile while Kaul (1977) reported very high macrophytic production in the three valley lakes (Dal, Anchar and Manasbal) of Kashmir. This indicated their high fertility level in these lakes.

Vass (1978), while investigating the trophic status of lakes in Kashmir Valley reported that these lakes are generally shallow and situated in the flood plain of the river Jhelum. Vass revealed that thermal stratification is fairly uncommon, and stable stratification occurs in Manasbal Lake and in other deeper lakes. The waters are mostly low in dissolved solids, medium hard and slight to highly alkaline.

Zutshi et al. (1980), reported that the lakes at high altitudes (>3000 m) have very low electric conductivity which increases with the decrease in altitude. The study revealed that the most dominant ions found in water are calcium and bicarbonate and average total ionic composition of the lakes indicated that they are of medium hard-water type with divalent cations dominating over monovalent ones. The order of the cations is Ca > Mg > Na > K and that of anions HCO3 > Cl > SO_4.

Wangano (1984), while studying primary production characteristics of a Himalayan lake in Kashmir concluded that the Lake Manasbal is the only lake in the region with a true thermal stratification during summer.

Kango et al. (1987), while discussing the sediment chemistry of Kashmir Himalayan lakes using X- ray diffraction and differential thermal analysis found that Illite, calcite and chlorite were the main clay minerals and their percentage contribution to the lake sediments differed significantly, with illite ranging from 16% to 84% and calcite between 22% and 72% with Manasbal Lake showing about 22% of Calcite.

Zutshi (1989), studied the limnology of high altitude lakes of Himalayan region and reported that the lakes remained thermally stratified between August and September and developed a stable thermocline.

Sara et al. (2011) while assessing the variability of water quality of groundwater-fed perennial Manasbal Lake using linear geostatistics revealed that the concentration of major ions in the water samples in winter was higher than in summer. In their study the scatter diagrams suggested the dominance of alkaline earths over the alkali elements and the major (Ca^{2+}, Mg^{2+},Na^{+},K^{+}, NO_3 and HCO_3 ,CO_3 and Cl) and trace elements of the lake water were found within the World Health Organization standards.

Khan et al. (2012) while exploring the hydrochemistry and sediment chemistry of Dal Lake revealed that the water of Dal Lake is alkaline and is characterized by medium TDS and EC. The geochemical characteristics of the Lake water is mostly influenced by the lithology of the basin and weathering of carbonate and silicate rocks. Anthropogenic activities show an impact on both water and sediment chemistry of the lake, particularly in portions proximate to habitation, hotels, houseboats, and sewer drains etc.

Romshoo and Muslim (2011), while assessing the nutrient load of lake-Manasbal through geospatial modeling, observed that the highest amount of nutrient loadings are observed during wet season in the month of March. Their 11-year simulations (1994–2004) showed that the main source areas of nutrient pollution in lake are agriculture lands and wastelands.

Javid et al. (2013) while studying the Weathering and anthropogenic influences on the water and sediment chemistry of Wular Lake observed that the lake water is alkaline in nature characterized by medium total dissolved solids and electrical conductivity. The concentration of the major ion towards the lake central showed a decreasing trend from the shore line. The geochemical processes suggested that the chemical composition of lake water is mostly influenced by the lithology of the basin (carbonates, silicates and sulphates) which had played a significant role in modifying the hydro-geochemical facies in the form of Ca–HCO3, Mg–HCO3 and hybrid type. Thus the above literature reviews shows that a large number of studies have been dedicated to the limonological studies in Jammu and Kashmir in recent decades with an aim to understand palaeoenvironment dynamics, sediment influx, water quality etc.

Scope for Paleoclimate study in Kachchh

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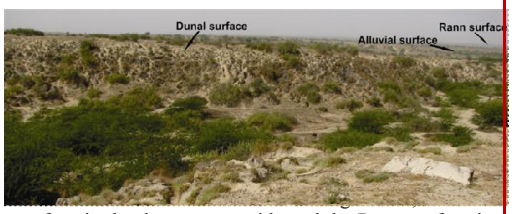
The Kachchh landscape of Gujrath has a varied geological history throughout the Quaternary period. One of the major challenges that questions the reliability of paleoclimate study in this region is the neotectonically active nature of the terrain as well as the constant interaction with the coast. Combined effect of all the three geological processes made it difficult to unravel the paleoclimate studies in this region quite challenging. Quaternary tectonics and eustatic sea-level changes makes some of the most important aspects in the Quaternary geology of the region. Climatic signatures are thus overprinted by the above effects and each of these components needs to be studied in the context of their responses to each other.

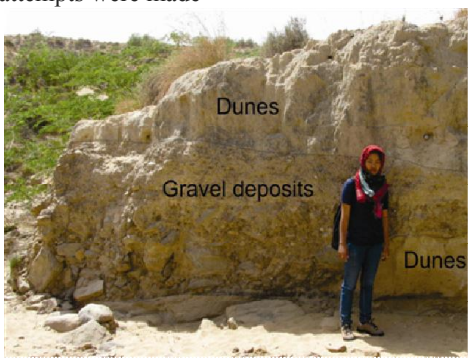
A panoramic view of pediment zone of Kuran basin in North of Pachham Island of Kachchh rift basin shows obstacle dune and colluvial surface that is incised to form wider gullies and valleys.



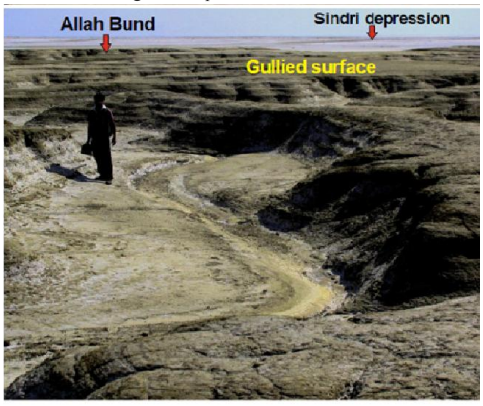
surface in the downstream side and the Rann surface in the background.

Photograph showing the Quaternary section of the Gainda Bet in great Rann of Kachchh near Indo-Pakistan border.

During the last two decades the work on Quaternary sediments and tectonic episodes in Kachchh focused more on the site specific conditions, and the global correlation is lacking barring some work in 2012 and 2013 in the Great Rann of Kachchh where some attempts were made



A view of ravine face exposes three consecutive sequences; the older dune surface is overlained by ~5ft of debris flow with gravel deposits probably in extremely favourable higher rainfall/ flash floods, while again on the top arid climate dominates showing dune deposite.



Photograph showing highly dissected and gullied surface of the Allahbund uplift. In the rear background, the Sindri depression is visible while in the foreground 1m of erosion/ incision is visible.

Photograph showing the remnants of the archaeological site near Karim Shahi in great rann of Kachchh. Note the pieces of the pottery samples buried at the abandoned site. Inset views are of some potteries collected from the site and dated to be of 3000yrs BP.

to correlate with the global climates. Hence, there are scopes on paleoclimate study especially in the Great Rann sediments, coastal Quaternaries and hinterland Quaternary fluvial deposits. In addition, Kachchh is one of the promising and challenging area where climate and tectonic interplay can be studied together.

Scope of the study of Weathering in Western Ghats using different mineralogical and geochemical approaches

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Rock weathering is fundamental geological process which determines the composition of the soils and sediment cover and thus it is having a huge impact on the human life. Soil is the base of the life as it provides food and it is important storage of water. The weathering of rocks is affected by different parameters like climate, parent material, time, structure of rock, porosity, topography, vegetation and drainage. The type and extent of weathering in an area determines the chemistry of the soil which is formed and the dissolved load which is being carried by the rivers to the sea. Climate affects the degree of weathering and at the same time weathering affects the climate by acting as a global sink for CO_2. Thus the study of the weathering profiles is important to understand the nature of sediment and solute load which is of local implication and the climatic events which is of global implication.

Systematic study of rock weathering can be done on the in situ weathering profiles which preserve the evidence of gradual changes from the fresh parent rock to the top soil. The effect of climate and lithology can be explained by studying the rocks weathered under different climatic set up and profiles developed on different parent rocks. The major changes that we can observe immediately within the profile are the change in the texture and colour of soil from bottom to the top of the profile. The rock gets friable as it gets weathered. The weakening of the hard rock to the loose soil is due to the removal of material from the rock. The systematic study of this process includes the estimation of "what is removed? how much? and what triggered its removal". If we see the change in the bulk density of a rock during weathering it is observed to show great degree of decrease while moving towards the soil stage. The density decrease is caused by the development of the secondary porosity and the secondary porosity is the result of expansion of the primary porosity due to the solution actions due to the weaker planes. The development of the porosity in the rock further increase the solution flush through the rock and it prompt the removal of the mobile constituents from the system.

The removal of the elements from the rocks depends on the resistance of the constituent minerals to weathering. The mobile element removal will cause a residual enrichment for the immobile elements and they may always form complex secondary minerals, basically clay minerals. With the degree of weathering, there is a different pathway with which the mineralogy of a rock changes to that of a complex soil. The removal or enrichment of each element will be different under different physico- chemical conditions that in turn are also governed by climate that controls the vegetation cover.

The weathering profiles developed on some gneissic and charnockitic rocks are studied to determine the changes in chemical, mineralogical and physical parameters during the process of chemical weathering. The objectives of the study is to understand the behavior of elements to understand its pathways during weathering of rocks and to elucidate the influence of lithology, structure and climate on the above; to estimate the porosity development and density difference up the weathering profile and to compare its relationship with the elemental mobility and the secondary mineral formations.

The results so far obtained on the bulk mineralogy of the samples analysed by the XRD on the samples from the bottom to top of the profile shows the diminishing trend of the primary minerals with the increasing degree of weathering. The secondary clay minerals appear as the alteration products of the primary minerals. According to the degree of weathering, the type of clay mineral formed also showed changes. The secondary minerals are seen to follow different pathways while undergoing weathering depending upon the parent rock type and climatic set up. The major element chemistry in the samples from profile was determined and their CIA values were calculated from the molecular proportion of the oxides like Al_2O_3, CaO, Na_2O, K_2O etc. The trend of the weathering was determined by plotting the samples taken from profile and the parent rock in the ACNK diagram. The change in the intensity of the weathering can be understood by observing the spread of the

Ti normalized plot of elements. The behavior of the REE elements in the weathering profiles are of special interest. REEs are assumed to be immobile during weathering. Some workers later found them to be slightly mobile, and they concluded they are getting mobilized and then getting redistributed in the profile itself. In our study we find that the distribution and behavior of REE is not uniform and show variation during weathering of different parent rocks, under different climatic and redox conditions and the presence of particular secondary phases also affect their concentration or depletion in the soil profile. The details of the results on our study on weathering profiles are at different stages of preparation for future publications.

Middle to Late Holocene monsoon, ancient civilizations and fluvial systems

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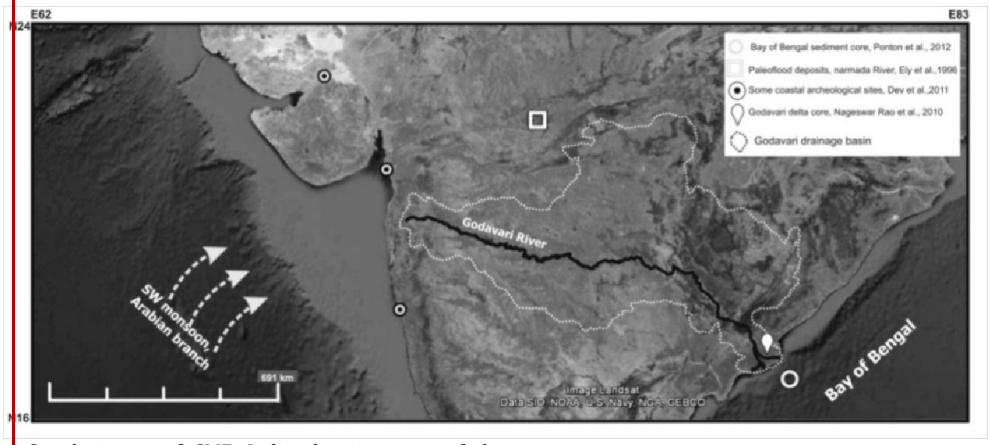
In the Holocene epoch, certain geological processes such as tectonics, climatic changes and sea level fluctuations affected the human culture (Deo et al., 2011). Most of the cultural changes in ancient civilizations are due to some short period of abrupt climatic change taken place in Holocene. In Indian subcontinent, the most influencing climatic factor on human settlement is



Google image of CMZ, India showing some of the major sites studied by various workers for Middle to Late Holocene climate/ monsoon discussed in text.

monsoonal precipitation. SW monsoon which brings most of the rainfall in months of July to October has large scale impact on agricultural patterns and human habitat. Therefore the study of monsoon on spatial as well as temporal scale becomes requisite.

Ponton et al. (2012) based on the Carbon isotopes of leaf waxes in sediment core retrieved from Bay of Bengal off the Godavari delta suggested the intense aridification dominated in Late Holocene at sub-millenium scale which results into large scale cultural changes in Indian sub-continent. Staubwasser and Weiss (2006) summarized different climate proxies with discussion on present day precipitation patterns and their study suggest that the weakening of Indian monsoon during the Holocene took place mostly over northern region of Indian subcontinent i.e. the Ganges and Indus catchments and the western Arabian Sea whereas in southern regions of Indian Peninsula there is an increase in summer monsoon precipitation. Deo et al. (2011) studied west coast of India for Holocene environmental and cultural changes. Their study suggested that majority of coastal and estuarine archeological sites used as trading ports were affected by rise in sea level in middle Holocene. According to Rajguru and Mishra (1996), the farming was adopted by some groups around 3.5 ka at alluvial strips close to rivers in Maharashtra which comes in CMZ.

Most of the ancient civilizations in Indian subcontinent are flourished along the major Rivers like Indus, Ganga, Godavari etc. and the cultural changes in these ancient settlements are result of change in monsoonal precipitation. For rivers from Peninsular India, the sediment transport takes place in very short time span i.e. in couple of days during monsoon season (Vaithiyanathan et al., 1988) which results in rapid change in the river morphology. Hence the study of fluvial deposits can give an insight into the paleomonsoonal variations in CMZ.

Laskar et al (2013) studied alluvial plains in lower Narmada valley Gujarat using sedimentary carbon and isotope ratios and they observed two arid dry phases at 2.1 and 1.3 ka. Whereas the last 1700 years of paleoflood record on the lower Narmada River given by Ely et al. (1996) reveals an increase in the magnitude and frequency of severe floods during the past three to four decades. The prehistoric material recovered from the deltaic sediments of Godavari River leads Nageswar Rao et al. (2010) to suggest that the site was an ancient habitation, probably of Andhra Satavahana period sometime between 3rd century BC and 3rd century AD which after buried at least by about 3.5m thick fluvial sediments of Godavari River. The sedimentation takes place most probably by sediment compaction, and the accommodation space provided by the subsidence was filled with recurring riverine deposits.

The recent preliminary mineral magnetic study carried out on modern sediments in Godavari drainage basin which lies in CMZ and Western Bengal fan by Kulkarni et al. (in press) suggests an increasing Deccan basaltic source to Bay of Bengal sink in Late Holocene as a result of coalesce effect of distinct catchment lithology, spatial distribution of monsoon and physiography of the basin. The detail study of relationship between Monsoon and River system is still needed in CMZ for understanding of response from past civilizations and to prepare for future climate change.

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Soil-anthropogenic response and climate change in monsoon dominated urban and industrialised areas of India

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Considering the developing status of countries like India, and government's encouragements over industrial and economic activities, the effluents makes cumulative contribiutors to the soils. It is pertinent to understand the complex biogeochemical reactions over the urban soils. In this context it is a prerequisite to map and delineate the spatio-temporal degradation of the soils in metropolitan regions. Particulate emission from variety of polluting sources to the atmosphere and its spread in the lower atmosphere is governed by local atmospheric conditions of a region. Atmospheric temperature makes one of the key factors in affecting such local conditions to decide the suspension, transportation and loading of the particulate matters resulting in soil pollution. Efforts are being made by our team to generate Qualitative maps of the top soils (~15cm) based on environmental magnetic and geochemical approaches for three metropolitan regions (Delhi, Mumbai and Pune).

Such spatial and temporal database of soils (polluted by particulate loading) can have several implications. However the style of loading, resuspension, distribution and re-distribution needs to be understood by the interplay of the monsoon precipitation with geomorphology. These maps are therefore being integrated with such information for its effectiveness. Shown below is one such parameter for the Mumbai Metropolitan region.

Quaternary Geomorphometric analysis of river basins in semiarid zone: Climatic signatures

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Quaternary sediments are concentrated as narrow fringe along the River valleys e.g. Godavari, Pravara, Sindphana, Purna, Penganga and Manjra in Marathwada region of Maharashtra. The Quaternary deposits are complex in nature and might have resulted from the vertical stacking and amalgamation of low sinuosity channels dominated by massive bedded gravels similar to that described in Kale (1989) and Rajguru et al (1993). The high proportion of cobbles indicates high energy, with wide shallow channel and prevalent bed load transport. The deposits consist of rounded to sub-rounded pebbles and cobbles of basalt, chalcedony, jasper, agate, chert and quartz set in a matrix of granular sand and silt showing cross bedding and local inverse grading (Dole et al, 2002).

The general predominance of coarse sediment in semi arid rivers is responsible for less stability and more mobility of sediments. Such channels are therefore, unstable and dynamic and are characterized by constant channel migration. Further the semi arid rivers respond fast to the changes in the hydraulic regime because of the higher average rate of motion of coarse sediments.

In the present study the depositional environment have been deduced on the basis of the sedimentologic characters of the fluvial deposits of the Sindphana River. The deposits of sediments in the upper reaches of Sindphana river comprises rounded to sub rounded pebbles and cobbles of basalt, chalcedony, agate, chert, zeolites and quartz set in a matrix of granular sand and silt, whereas in lower reaches the sediments are medium to fine grained sandy silt and silty clay.

Three main types of fluvial formations in the Sindphana basin are: 1. Sandy Silt – weakly calcified, 2. Silty Sand – moderately to strongly calcified, 3. Pebbly gravels sediments. The Sandy Silt (Poorly Calcified) Quaternary sedimentary deposit is represented mainly by less calcareous, faintly laminated brownish silt or sandy silt with thin (~ 2m) intercalated with patches of pebbly gravels, has developed a distinct terrace (6 to 8 m above modern bed level) cut into the older terrace surface developed on the calcareous alluvial fill at an average elevation of about 15 to 20 m above modern bed level. These deposits are found in younger floodplain areas especially in the channel bar deposits of Sindphana River. These are younger sediments compared to the moderately to strongly calcified deposits.

Silty Sand (Moderately to Strongly Calcified) deposits are generally 5 to 10 m thick and are the most prominent Quaternary formations in the valley. However, only the upper 15 m section is generally available for examination on the banks of the Sindphana river and along its tributaries. It is observed that these deposits are laid down in channels, near channel and floodplain environments. The silty sand deposits occur either as inter-fingering layers with gravels and sands or as uniform, more or less massive or faintly laminated sedimentary units in the upper part of deposits are brownish in colour and are traversed by calcareous bands (calcretes) and concretions. Sorting is poor and lamination is poorly preserved probably due to post diagenetic changes. Dissection cracks in the sediments indicate the periodic drying after the deposition in the channel to overbank environment, were also observed in the sections.

The pebbly gravels are grey to dark grey, yellowish and reddish brown, poorly sorted and matrix-supported. In most cases, the matrix comprises medium to coarse grained sands, argillaceous and carbonaceous materials. They are polymictic, texturally immature and crudely stratified or massive. The pebbly gravel units were deposited most probably as small lenticular bodies of channel lag or low sinuous streams (Reineck and Singh, 1980). They might have been deposited as debris flow deposits. Some of the siliceous pebbles display surface cracks due to weathering. The coarseness of sediments, poor sorting, lack of grading and stratification and general absence of cross bedding are suggestive of deposition by non-meandering, shallow and wide streams.

Please send your suggestions, remarks and 'contributions to next issue' to S J Sangode at <sangode@unipune.ac.in> or <sangode@rediffmail.com>

Lake sediments of Kerala: Significance to Southwest monsoonal records

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A lake is a body of fresh or salt water of considerable size, localized in a basin and are very complex natural systems that interact with the climate and their catchment areas. Water can enter lakes from a variety of sources including groundwater, runoff from the watershed, surface waters (like streams and rivers) flowing into the lake, and direct precipitation into the lake.

The sedimentation rates in the lakes are generally higher than in oceans. Sediment accumulated in the lake depends on the available sources of suspended sediment load, the transport efficiency of inflowing streams and within-lake processes consequent upon water circulation, turbulence and shoreline stability. This will gives the sediments distribution pattern within the lake.

Lakes in southwest Kerala, India, are ideal sites as the Kerala region receives strong southwest monsoon and hence any change in lake sediment textural characteristics and its geochemical parameters would help in understanding the variation of SW monsoon and recent climate events. Narayana et al., (2002) observed peat deposit at different depths between sandy clay and clayey sand sedimentary facies in Vembanad lake. These peat deposits gave a radiocarbon age of 40,000 yrs BP. Pollen analysis of peat revealed the existence of mangrove vegetation and evergreen forest, suggesting humid climate during that time. Presence of desiccated clays beneath the peat deposits suggests arid climate prior to the humid climate during 40,000 yrs BP.

The late Quaternary pollen/spores diversity indicates that the modern climatic conditions in the southwestern Ghats have facilitated the conservation of moist evergreen rainforest and dry/moist deciduous forest (Farooqui et al 2012). Based on the occurrence of cyanobacteria from the wet lands and lake sediments of Kerala (Ayiramthengu, Panavally and West Kallada), Limaye et al (2010) postulated that the hydrological set-up of the studied region is chiefly controlled by SW rainfall. The cyanobacteria have been used as biomarkers to distinguish palaeoenvironmental scenario and ecological shifts ranging from Late Pleistocene to Early Holocene in the studied boreholes of the South Kerala Basin (Limaye et al 2009).

A study was carried out by Veena et al., (2013) in Pookode lake, Kerala by analyzing sediment texture, dating, phytolith, diatoms, pores and pollens and had found out its age from mid- Holocene to more recent. The study reveals a change in Lake Hydrology as well as shallowing of lake. Pookode sediment core represents Medieval Warm Period (MWP) and the Little Ice Age (LIA) textural analysis, geochemistry and palynology shows the presence of warm and dry period prevailing during warm and dry conditions prevailed during 6200–420 ^{14}C BP and was interrupted by the wet phases between ≈ 3900 - 1900, 1400 - 760, 420- 140 CMP due to strengthening of SWM, rise of water level, and the expansion of Pookode lake margin. Pollen and phytolith analysis has been carried out in Kalanji, Trissur district of Kerala to understand the vegetation and climate during Holocene. Expansion of mangrove vegetation during 7272 to 3530 BP suggests warm and humid climate and monsoon level at its maximum. After that declination of mangroves reflects decrease in southwest monsoon (Misra and Bhattacharyya, 2013).

On tools in Quaternary Geology

Some Underutilized Tools in Quaternary - S J Sangode

Some of the tools and methods in Quaternary needs attention due to their advantage of producing routine and regional database. The use of Schmidt hammer and the Lichenometry approach represents such tools especially in the study numerous morain and other glacially derived deposits in the Himalayan region. Despite of several limitations these tools can be useful in producing map based chronology. When calibrated with other age methods can yield important information. Both the methods are affordable and rapid, therefore described below.

1. Schmidt hammer: A rapid relative age dating method for moraines

Himalaya is a repository of the glacially derived sediments in general and the remnant moraines in particular. A rapid field based method of relative age determination using the Schmidt hammer can be very useful in the stratigraphic reconstruction of these sediments.

The Schmidt hammer, also known as a Swiss hammer or a rebound hammer, measures the elastic properties or strength of surface, (hardness or penetration resistance). Invented by Ernst Schmidt, a Swiss engineer, the hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. The test hammer hits the surface at a defined energy and the rebound is dependent on the hardness of the surface. By reference to the conversion chart, the rebound value can be used to determine the compressive strength. The Schmidt hammer is an arbitrary scale ranging from 10 to 100. Schmidt hammers are available from their original manufacturers in several different energy ranges. These include: (i) Type L-0.735 Nm impact energy, (ii) Type N-2.207 Nm impact energy; and (iii) Type M-29.43 Nm impact energy.

A commercial Schmidt hammer from Google Image

Schmidt-hammer rebound values (R-values) enable relative-age dating of landforms, with R-values relating to degree of weathering and therefore length of exposure. A spring-loaded bolt impacting a surface yields a rebound- or R-value, which is proportional to the hardness (compressive strength) of a rock surface. The old rock surfaces exposed to weathering processes for a long time provide low R-values and vice versa. Since the 1980s the method has also been successfully used for relative age dating of geomorphologic features such as moraines, rock glaciers or rockfall deposits. Recent publications discuss the possibilities and limitations to calibrate R-values, for instance with results from 10Be and 14C-analyses or optically stimulated luminescence and photogrammetrical measurements. A random sample of fifty measurements is usually recorded on as many different boulders as possible, selecting surfaces which have comparable lithology and which are dry, flat, clean and free of lichens, visual fissures and cracks. The mean or the median of the values can then be considered representative for the effective hardness of the analysed surface. R values measured by Castelli (2001) closely correlate with the chronology estimated by

photogrammetry and radiocarbon dating. Furthermore, the results are in good agreement with weathering rind measurements.

More details can be found in several case studies e.g.,

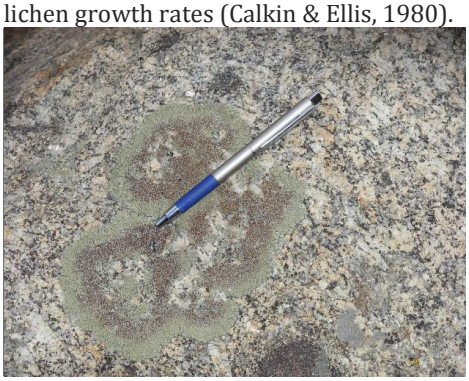
Schmidt-hammer exposure-age dating (SHD) of rock glaciers in the Schöderkogel-Eisenhut area, Schladminger Tauern Range, Austria *The Holocene July 2012 22: 761-771.*

Application of Schmidt hammer relative age dating to Late Pleistocene moraines and rock glaciers in the Western Tatra Mountains, Slovakia, Piotr Kłapyta Klapyta in Catena 2013 | 111 | 104-121

New Zealand Journal of Geology and Geophysics-**The Schmidt hammer as a relative-age dating technique**: Potential and limitations of its application on Holocene moraines in Mt Cook National Park,Southern Alps, New Zealand, Stefan Winkler, Geographisches

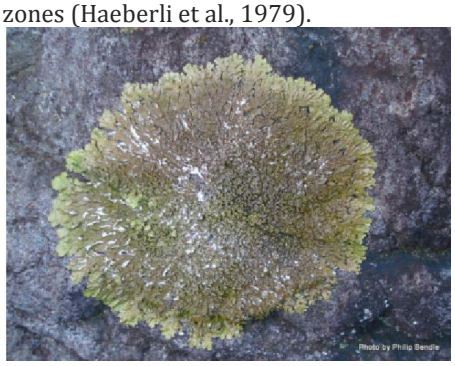
2. Lichenometry

Lichens are a symbiotic relationship between an alga and a fungus. They can be classified as crustose (forming a thin flat crust), foliose (flat, with leaf-like lobes) and fruticose (upright and branched) (Abercrombie, 1980). The radial growth of crustose lichens as an indicator of substrate age (Locke et al., 1979) was routinely used in dating glacial deposits in tundra environments where lichens often form the dominant vegetation cover (Erikstad & Sollid, 1986; Matthews, 1992). Growth rates vary from one region to another and may decline after initial colonization to an almost constant value. Lichenometry has a useful range of ca. 500 years with exceptional lifetimes up to 4500 years or more under cold and dry continental conditions. Climate type (mainly moisture supply, solar radiation/rock temperatures and altitude a.s.l.) is a major factor affecting lichen growth rates (Calkin & Ellis, 1980).



A Lichen growth photographed by author from Chandra valley, Lahaul Himalaya

Permanent snow cover and unstable blocks within zones of extending flow on rock glaciers may lead to reduced or lichen-free zones (Haeberli et al., 1979).



An image of Crustose Lichen from Google Image adopted from http://www.terrain.net.nz

Lichen diameters correlate with relative age differences as estimated from photogrammetric flow determinations. However, lichen growth is limited to the frontal parts of the rock glacier, whereas no lichens of major size can be found in its upper part. This striking feature is most probably due to the adverse effects of rock-fall activity, extending flow and long snow cover duration within the root zone of the rock glacier. Much larger lichen diameters and denser surface cover can be observed on inactive and relict features.

As a calibrated-age dating technique an empirical relationship can be established between lichen size and time since lichen colonisation. Lichenometry has been used for dating many types of surfaces including raised beaches, river terraces, talus, rockfalls, trimlines, snow-avalanche activity and outwash plains. Lichenometry has a multitude of assumptions and potential errors, but with a few exceptions. Age estimates of moraines may be made which are accurate to ±10 per cent given careful attention to methodology and field procedure (Bickerton and Matthews, 1992; Matthews, 1994).

Winchester, V. and Harrison, S., A development of the lichenometric method applied to the dating of glacially influenced debris flows in southern Chile. Earth Surf. Process. Landforms, 1994,19, 137–151.

Jonasson, C., Kot, M. and Kotarba, A., Lichenometric studies and dating of debris flow deposits in the high Tatra Mountains, Poland. Geogr. Ann. , Ser. A, 1991, 73, 141–146.

Climate Change and Disasters in the Himalayan Realm

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The Himalaya represents an area of rapid change in geomorphic, climatic and meteorologic attributes in space *i.e.* along x-, y- and z axis. The unlithified sediments of rapid lateral and vertical variability indicate the episodic nature of sedimentation. The stocks of such sediments entrapped into the unstable slopes further provide ideal conditions ready to be mobilized by an event such as the Leh Cloud burst 2010. Valleys in the region contain volumes of trapped glacigenic and colluvial sediments susceptible to be moved under an episode of warm-humid climate (rainfalls), an event such as cloud burst or the glacial lake outbursts. An assessment of microclimatic zones, the mass and attitudes of entrapped sediments and the mass flow pathways within the valley-mountain set up of the Himalayan region is warranted both on fundamental tunes and as socio-economic measures.

This photo showing the damage in Saboo village due to the 2010 Cloud Burst (Photo taken by author immediately after the event).

Identification of the past records of mass flow dynamics, asigning them as an event and projecting the response of the location for future events is quite a chalanging issue for Quaternary Field Geologists.

Photo taken by the author showing a dynamic mass flow condition that can be asigned either to a normal glacial drift or an event like lake outburst or the cloud burst with detailed study.

The new age Quaternary field geologists need to be more quantitaive in his observations.

The events like 2010 Leh Cloud burst and the 2013 Kedarnath floods are to be studied in great details with reference to impacts, response and inputs from the mountain-valley setups in the region.

This will enable to predict the amount and style of mass transfer besides identification of stable geomorphic surfaces for settlement and infrastructural developments in the Himalayan region.

Review of Holocene palaeoclimate of Northeast India based on pollen records

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The North-eastern India is one of the regions broadly under the influence of SW Monsoon. This region has a range of climate from sub-alpine, temperate, sub tropical to tropical due to its altitude, influence of foot hills of Himalaya, Tropic of Cancer, Bay of Bengal and the South-west monsoon winds. The average annual precipitation ranges from approx. 2000 mm to 4000 mm and around 11000 mm of highest rainfall record at Cherapunji (Deka et al., 2011). The undulating topography, high precipitation and extreme temperatures craft mixed vegetation in the region which is known to have varied flora and fauna that comprise some of the most exotic forest covers in India. Thrash and burn techniques for agricultural practices also known as 'Jhum' was of common practice in the region.

Holocene records of climate vis-à-vis vegetation variations and human impact due to agriculture or other anthropogenic activities are found in the few available pollen records from different parts of northeastern India. To understand the changes in climate vis-à-vis vegetation cover based on pollen records we further divide the records into a 3 temporal segments namely Late, Mid and Early Holocene- Late Pleistocene periods.

Late Pleistocene-Early Holocene (20k B.P. – 8k B.P.) pollen records: Few records available from northern parts of West Bengal and the Lower Assam region indicated that the climate was cold and dry from about 20k B.P. to 18k B.P (Sharma and Chauhan, 1994). The climate began to ameliorate till 12k B.P when this region was covered with oak forests. It again became cold and dry till 10k B.P when the broad leaved vegetation started to replaced the arboreal and the climate was warm temperate and humid. Other records from Lower Assam (Bera, 2003, Dixit and Bera, 2012a, b) around 14k B.P. indicate cold and dry climate along with periods of fluvial activities until Early Holocene. Events such as Younger Dryas (YD) are also evident in some of the pollen records (Dixit and Bera, 2012a, b) from the lower Assam region.

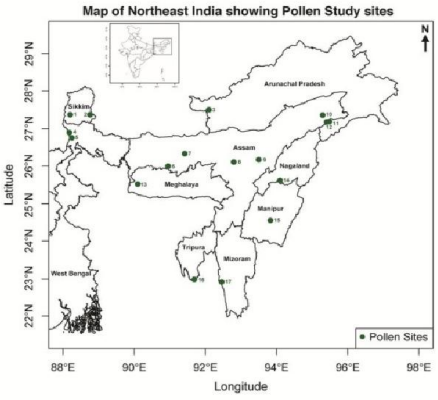

Fig. Map of North-east India showing locations of pollen study sites. 1. Khechipiri Lake, Sikkim (Sharma and Chauhan, 1999); 2. Kupup Lake, Sikkim (Sharma and Chauhan, 2001); 3. Paradise Lake, Aru¬nachal Pradesh (Bhattacharyya et al., 2007); 4. Jore-Pokhari, Darjeeling (Chauhan and Sharma, 1996); 5. Mirik Lake, Darjeeling (Sharma and Chauhan, 1994); 6. Deosila Swamp, Assam (Dixit and Bera, 2011); 7. Chayagaon Swamp, Assam (Dixit and Bera, 2012b); 8. Dabaka Swamp, Assam (Dixit and Bera, 2012a); 9.Mikir Hill, Assam (Bera, 2003); 10. Jeypore Reserve Forest, Assam (Bera and Dixit, 2011); 11. Dangrithan, Assam (Bera et al., 2011a); 12. Mothabeel, Assam (Bera et al., 2011a); 13. Garobadha Swamp, Garo Hill, Meghalaya (Basumatary and Bera, 2010); 14. Dzuko Valley, Nagaland and Manipur Boundary (Bera et al., 2011a); 15. Loktak Lake, Manipur (Nautiyal and Chauhan, 2009); 16. South Srinagar, Tripura (Bhattacharyya et al., 2011) and 17. Demagiri, Mizoram (Chauhan and Mandaokar, 2006).

The vegetation cover was dominated by tropical tree savannahs till 12k B.P. which were replaced by mixed deciduous arboreal such as Syzygium cumini, Dillenia pentagyna and Lagerstroemia parviflora. Dixit and Bera (2012a, b) indicated short spell of weakening of the summer monsoon during the YD.

Mid Holocene (8k B.P. – 5k B.P.) pollen records: Records from Lower Assam, Mirik, Darjeeling, and Tripura are available. The lower Assam records mark the fluvial activity during early Mid Holocene preceded by warm and humid climate (Dixit and Bera, 2012a, b). Fluvial taxa such as Ludwigia octavalvis and Botryococcus followed by tropical mixed deciduous taxa like Shorea robusta and Lagerstroemia parviflora were reported in the pollen records from region. During 10,810-7680 cal B.P. Dixit and Bera (2012b) reported some cereal type pollen which might be an indication of beginning of human impactin the Western Brahmaputra flood plains of Assam. Another record from Mikir hill Assam (Bera, 2003) is noted for semi arid phase during the Mid Holocene when the region was covered with open savannah forest. Sharma and Chuahan (1994) reported a warm temperate and humid climate during the mid Holocene in the Mirik region of Darjeeling (Northern West Bengal). Bhattacharyya et al., (2011) attributed the presence of >50µ grass pollen from around 5.7 kyr B.P. in Srinagar Tripura, to the beginning of rice cultivation in the region.

Late Holocene – Recent (5k B.P. – 600k B.P.) pollen records: This period in North-east has seen dramatic shifts in vegetation and climate. The records from northern ends on North-east India record a shift towards warmer and relatively less dry conditions in early Late Holocene (Sharma and Chauhan, 2001; Bhattacharyya et al., 2007; Bera and Dixit, 2011; Bera et al., 2011a). The climate ameliorated to warmer and moist conditions in most parts of Arunchal Pradesh (Bhattacharyya et al., 2007), Lower Assam (Dixit and Bera, 2011; Dixit and Bera, 2012a, b), Nagaland (Bera et al., 2011b), Manipur (Nautiyal and Chauhan, 2009), Northern West Bengal (Chauhan and Sharma, 1996; Sharma and Chauhan, 1994), Meghalaya (Basumatary and Bera, 2010), Mizoram (Chauhan and Mandaokar, 2006). There were though episodic drifts from warmer to cooler conditions and peak periods of warm conditions corresponding with global events such as Little Ice Age and Medieval Warm Period evident in the pollen records from Sikkim (Sharma and Chauhan, 2001), Arunachal Pradesh (Bhattacharyya et al., 2007), Assam (Dixit and Bera, 2012a,b). This depicts the impact of global temperature shifts in low latitude regions. The beginning of human impact or anthropogenic effect is reported mostly around 3k B.P. (Bera and Dixit, 2011; Dixit and Bera, 2011, 2012b), 2k B.P. (Sharma and Chauhan, 1994) and 1000yrs B.P. (Sharma and Chauhan, 1999).

Thus North-eastern India has experienced an effective variation in climate regime and monsoon patterns throughout the Holocene. This has influenced the vegetation cover due to the long warm and humid conditions in the later parts of the Holocene (Bera, 2003; Chauhan and

Mandaokar, 2006; Bhattacharyya et al., 2007, 2011; Nautiyal and Chauhan, 2009; Basumatary and Bera, 2010; Bera et al., 2011a, b; Bera and Dixit, 2011; Dixit and Bera, 2011, 2012a, b). The pollen records in some regions though report weakening of the South-west Monsoon and dryer climate during recent times (Sharma and Chuahan, 2001; Chauhan and Mandaokar, 2006; Nautiyal and Chauhan, 2009; Dixit and Bera, 2011, 2012a, b). The analogy of human impact and agricultural activity possible affected the vegetation cover during the Mid and Late Holocene which is evident in the pollen records from Northeastern India (Chauhan and Sharma, 1994; Sharma and Chauhan, 1996; Bera, 2003; Chauhan and Mandaokar, 2006; Nautiyal and Chauhan, 2009).

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Quaternary studies in the Purna Alluvial Basin, Central India: Prospects and Potentialities

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The Central Narmada, Purna and the Tapti valleys are the structural basins of Central India possessing a thick pile of Quaternary sediments. Out of these, the Purna and Tapti valley basins are poorly explored for Quaternary studies in the context of bio, litho- and chronostratigraphy and their intra-basinal correlations. The southern margin of the Central Narmada valley and northern margins of the Purna and the Tapti valleys are defined by two almost east-west trending regional faults, known as the North Satpura and South Satpura fault respectively (Tiwari, 1999). The linear Quaternary depocentres yoked with fundamental faults on either hingelines of Satpura Horst, are characterized by episodic tectonism manifested in the lithostratighraphy of Quaternary sedimentary fills (Mishra et al., 1999; Tiwari, 1999). The details pertaining to South Satpura fault, its neotectonics and basin framework has been described earlier by Adyalkar (1963 & 1975), Ravishanker (1987), Dubey and Saxena (1987), Tiwari and Mukhopadhyay (1989), Saha and Asthana (1990), Tiwari (1990), Tiwari et al. (1996) and Tiwari (1996).

The Purna basin is an east-west elongated basin, showing a slight convexity to the south structurally controlled isolated basin having the thick deposits of lacustrine and fluvial origin (Tiwari, 1999). The configuration and sedimentation of the valley is controlled by two distinct sets of faults; a) East west trending Gavilgarh fault defining the northern limit of the Quaternary sedimentary basin, and b) N-S to NE-SW trending faults defining the eastern limit of the basin. The available literature on the basin deals with Quaternary stratigraphy, tephra ash beds, geomorphology, palaeontology, archaeology, soil studies, and the basic sedimentological work including sediment characteristics and depositional environments (Bopardikar, 1985; Sonakia et al., 1990; Mukhopadhyay, 1992; Tiwari, 1996, 1999; Sonakia, 1997; Pal et al., 2001; Deotare, 2006; Chakrabarti and Roy, 2007; Raja et al., 2010, 2012, 2014; Srivastava and Kale, 2010; Srivastava et al., 2010). Tiwari et al. (2010) proposed lower and upper boundaries, and correlation with dates of the Narmada valley sediments. Their classification confirmed four formal stratigraphic formations in the basin in the order of superpositionas; the Purna Formation, the Kural Formation, the Kodori Formation and the Vaghoi Formation. The Vaghoi Formation comprises of reddish, calcareous and structureless silty sand and reddish brown calcareous clays. It is capped by deep brown clayey palaeosol with ferruginous concretion in 'B' horizon. The Kodori Formation is genetically related to alluvial fans and shows lateral lithofacies variation from boulder beds in the apical region to interlayered sequence of pebbly bed, sand and brown calcareous silt in the middle fan to brown, yellow and steel grey clays in the distal fan region. The Kural Formation consists of a coarse member overlain by a fine member. The coarse member comprises of calcareous conglomerate, grit, sandstone and sand whereas, the fine member by alternating succession of sand and silt, and light grey calcareous homogenous silty very fine sand. The Purna Formation comprises of gravel sand, and dark grey, non calcareous clays of inset terraces of present flood plain.

Chronostratigraphic Record

The only recognized marker horizon of the basin, the tephra ash beds from the Gandhigram locality, has been assigned as Youngest Toba Tephra (YTT: 74,000 ± 9,000 Ka, Shane et al., 1995; Westgate et al., 1998). The date of Kodori Formation tephra has been correlated with the Pawla tephra of Baneta Formation in the Narmada valley (Tiwari, 1999; Tiwari et al., 2010). Later, Sangode et al. (2007) based on magnetic polarity of two tephra bearing sites i.e.

Gandhigram and the Andhura, yielding a reverse polarity (pre-Brunhes age i.e. > 0.78 Ma)indicated Lower Pleistocene age for these tephra bearing sites. The recent work of Westaway et al. (2011) on Ar-Ar dating has also emphasised that the tephra sample of Gandhigram locality belongs to the Oldest Toba Tephra (OTT/ Toba eruption 'D') episode and not to the YTT, as proposed earlier by Shane et al. (1995) and Westgate et al. (1998). The different views demand a necessity for revision in the litho-stratigraphy and chronostratigraphy of various formations of the basin.

Data Gaps and the Future Prospects

The Purna alluvial basin possess a controversy regarding its lithostratigraphic and chronostratigraphic divisions. The chronostatigraphic records, so far available, do not match with each other and therefore point out towards a necessity for further detailed work on the reliable dating techniques. For this purpose, the basin has got various proxies in the form calcretes and vertebrate remains, in addition to the tephra beds. Radiocarbon dating of charcoal pieces and trace element study of soils of the associated horizons may produce additional information about the palaeoclimatic conditions of the region. In order to fulfil the information gaps on these aspects, there is a need to increase the tempo of research activity by adopting a multidisciplinary approach involving various proxies. Such interactions between the researchers belonging to different disciplines will definitely form a base for the establishment of precise lithostratigraphy and chronostratigraphy of the same basin and it's inter- and intrabasinal correlations in future.

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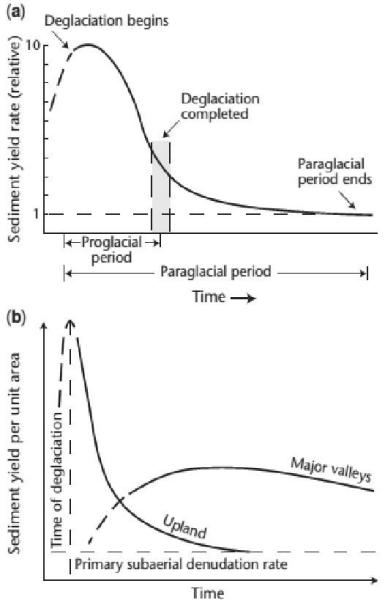
FAST FACTS

Compiled by S J Sangode-

Periglacial is an environment of frequent freeze–thaw cycles and deep seasonal freezing (encompassing about 35% of the Earth's continental surface); and/or a permafrost environment (which covers only 20%) (French 2007). The word connotes distinctive processes, landforms and landscapes (Worsley 2004).

The literal meaning of the term **Proglacial** is 'in front of the glacier', and emphasis is placed on processes and landforms in close proximity to the ice margin. The word describes distinctive processes, sediment–landform associations and landform assemblages in glacifluvial, glacilacustrine and glacimarine environments (Benn & Evans 1998). In contrast to these, the term '**Paraglacial**', defined as 'non-glacial processes conditioned by glaciation', is more contentious, as discussed in a major paper on paraglacial geomorphology (Ballantyne 2002), and does not depend either on unique processes or unique location. In fact, paraglacial environments may include both proglacial and periglacial environments, as well as fluvial and mass movement landforms and processes .



The paraglacial environment according to: (a) Church & Ryder (1972), sediment yield as a function of time since deglaciation; and (b) Church & Slaymaker (1989), the sediment wave model.

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CLASSICAL AREAS/SECTIONS OF QUATERNARY

The Leh Valley, Ladakh

S J Sangode

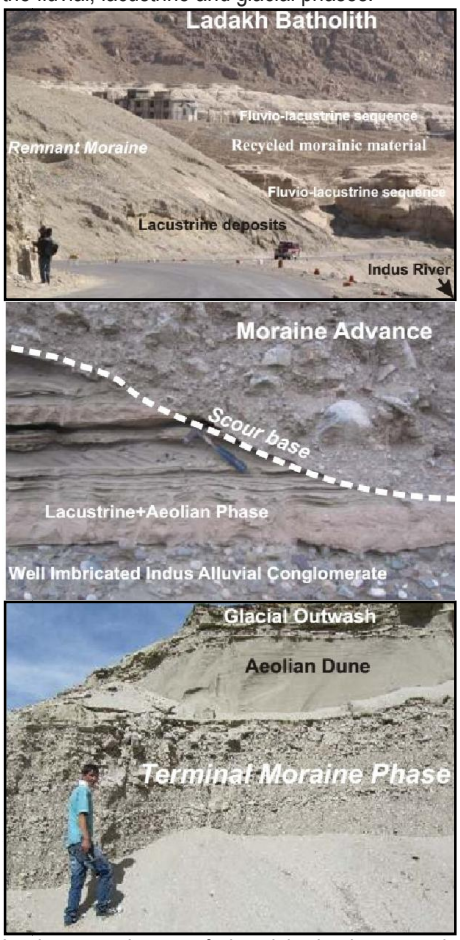
The Leh valley is an elongated and misfit valley basin of the Indus River. It show morphometric asymmetry as a result of litho-tectonic divide in the form of the folded Indus Molasse in left flank and the Ladakh batholith in the right flank. The left bank is extensively aproned by the extensive and panoramic paraglacial fans overlapped at places by younger moraines including the sporadic deposits of outwash gravels.

These paraglacial fans are explained as the records of terminal 'Indus Stage' glaciation (>430 Ka) by Owen et al., (2006).

A vertically exposed section of the Indus Paraglacial fan.

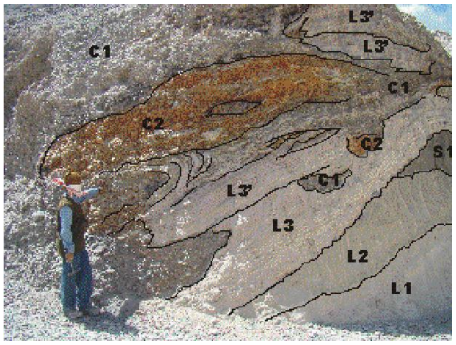
These fan terraces also show sharp toe cutting by transversely flowing Indus River. The exposed vertical profiles along the Indus River show majority of sheet geometry without any visible fan coalescence. This is due to rapid drop in fan gradient from mountainous fronts to the broad open valley basin and their coeval and episodic nature (Sangode et al 2013).

The right bank shows some of the major transverse valleys with moraines visibly approaching the valley floor from some of these. In the upstream region it shows dynamic interaction marked by litho-facies cross-cut and scouring of the fluvial, lacustrine and glacial phases.



In the central part of the right bank, a terminal moraine deposit is overlain by thick aeolian dune facies. The valley floor is notably broad in Spituk, Leh and Saboo area preserving remnant fluvio-lacustrine deposits more prominently near the right bank, and the gravelly braided fluvial deposits in the central part. Central part also display thick (>30m) fluvio-lacustrine sedimentation ending with aeolian phase at the top. The fluvio-lacustrine facies are of massive with majority of siltstone, mudstone and channel lag deposits in the vertical profile.

In northern (downstream) part of the valley appear to have episodically produced significant damming effects for the Indus River as reported in Sangode et al (2011).



A paleo- glacial lake outburst deposit in Leh valley reported by Sangode et al 2011.

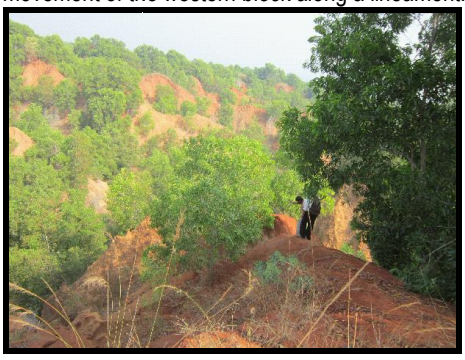
Thus, the Leh valley is an easily accessible treasure of Quaternary deposits in the Ladakh Himalaya.

Red Sands of Bhimuni

S J Sangode

Along the coastal tracts of Bhimunipatnam, north of Visakhapattnam on east coast of India, Quaternary red sand deposits occur overlying the Precambrian Khondalitic gneisses. The coastal red sands of Bhimuni are ~30 m thick unique deposition in a restricted basin of ~10 km^2 exposed over the older wave-cut platforms and adjoining foothill slopes of Precambrian Khondalitic gneisses. These red sand deposits are homogeneous and exhibit characteristic reddish color. Since garnet from the khondalite gneisses becomes highly leached out, it is anticipated that the chemical weathering of Khondalites can result in the release of iron, coating the sands.

The earliest observations on the Bhimuni red sands goes back to King (1886) suggesting these red beds formed as the denudational remnants of great sand bank of post Pliocene time or the isolated banks formed around the then sunken hills. Mahadevan and Sathpathi (1949) first suggested the mix of aeolian and fluvial origin for these deposits. Madabhushi (2003) reported the grain size range from 1.69Φ to 1.99Φ, and documented the cone structure and calcretes. He suggests that the iron derived from the Khondalites got precipitated around the sand grains. Previously Madabhushi (1995) observed that the changes in the dips of sandstone, siltstone and pebble beds are suggestive of drag in the dips due to downward movement of the western block along a lineament.



A detailed account on the morphostratigraphy and evolution of the red sand deposits of Bhimuni was produced by Nageswar Rao et al (2006). They report a wave-cut platform exposed in one of the gullies at ~968m inland and at +12m height with ~10^0 inclination towards the sea. They document the layer of flat pebbles over the wave- cut platform suggesting the action by waves. Sea levels at +7m to +11m are reported by previous workers in this area (Mahadevan and Sathapathi, 1949; Bhaskara Rao and Vaidyanathan, 1975; Prudhvi Raju et al., 1993). Occurrence of a prominent duricrust layer with lateritic gravel prompted Nageswar Rao et al (2006) to propose the valley-in-valley geomorphology. According to Nageswara Rao et al (2006) the duricrust layer separates the lower reddish brown concretion- bearing sand member with the upper brick red sand unit. The red sands rests upon the Khondalite basement except at places shore-word it is seen overlying the moderate brown colored coarse to medium grained sandstone of fluviatile origin (Nageswara Rao, 1988). Madhubhashi (1995) detailed this unit into a thickness of 4.5 m categorizing as Pleistocene sedimentaries. Nageswar Rao et al (2006) divided the entire stratigraphy into four broad units.

The genesis of red coloration and the overall origin of the deposit is not known. The role of tectonics, climate and sea level changes is therefore unclear in the context of origin of these red beds. Whether these red beds can be correlated with other coastal red sedimentation in east and west coast needs to be investigated aided by chronometric approach. Petrography and micromorphology of the red sands and calcretes is not yet attempted. The subsurface architecture, stratigraphy and variability from geophysical profiling, bore hole data and sediment cores need attention. Overall the red sediments are relatively homogeneous with indistinct stratigraphic markers/units in the exposed sections. Their depositional environment and morphology is not clear and have been variously attributed to aeolian, fluvial, beach or mixed environments.

Message to Policimakers

Monsoon is the backbone of Indian agriculture and hence the Indian economy. A continuous of three bad years of monsoon leading to draught may shake the economy of the country; and the records of past have shown such occurrences in general (e.g., see the rainfall instrumental data for last >100 years from IITM). Climatologists may be struggling for better prediction of monsoon beforehand as the monsoon itself shows spatial variability every season. While the agriculture scientists and biotechnologists may prioritize to find ways of optimum utilization of water and moisture by developing advanced methods of agricultural practices. Ironically, we keep updated with the Smart Phone technology but we are decades behind the agricultural technology in comparison to the western world. As a result some smaller countries with less surface area and climate unsuitable for agriculture compared to India are leading many of the food grain and food production and export. Whereas Indian farmers struggle with uncertainties leading to suicides (we can call the 'climate change suicides'). We need to condition our economy on permanent sources of water with annual recharge to be used effectively and efficiently during the bad monsoon years with organized farming practices and technology. The other major issue is of drinking water. Excessive withdrawal in localized area made the situation worst and the solution may be to follow the natural rule of 'migration of the civilization' at sustainable location. This demands mobilization and migration practices of infrastructure and settlements abandoning the old and congested cities to replenish for say next 50 years. It is time to develop new towns with critical evaluation of the natural resources sustenance in the area. The entire climate change problem revolves around the water resources and hence the water management becomes the most eminent issue for every science, society and government.

-S J Sangode

Teachers Must Refer this Book-

Reconstructing Earth's Climate History: Inquiry-based Exercises for Lab and Class: By Kristen St John, R. Mark Leckie, Kate Pound, Megan Jones, Lawrence Krissek; April 2012, ©2011, Wiley-Blackwell; textbook with key data and published case studies of past climate change for paleoclimate reconstruction. Using foundational geologic concepts, wide variety of topics, including: marine sediments, age determination, stable isotope paleoclimate proxies, Cenozoic climate change, climate cycles, polar climates, and abrupt warming and cooling events, students are invited to evaluate published scientific data, practice developing and testing hypotheses, and infer the broader implications of scientific results.

Important Web resources for Quaternary studies

http://www.inqua.org/ International Union for Quaternary Research. promoting improved communication and international collaboration in basic and applied aspects of Quaternary research -- is achieved mainly through the activities of its commissions and committees. Quaternary International, INQUA's international journal, is devoted largely to publishing the proceedings of INQUA-related conferences, symposia, and workshops, with each issue normally focused on a thematic or disciplinary topic of current interest. It runs two publications 1). Quaternary Perspectives is the INQUA newsletter. 2) Quaternary International, is the journal devoted to publishing the proceedings of INQUA, with each issue normally focused on a thematic or disciplinary topic of current interest.

http://www.noaa.gov/

National Oceanic and Atmospheric Administration, USA. An agency in the Department of Commerce that maps the oceans and conserves their living resources; predicts changes to the earth's environment; provides weather reports and forecasts floods and hurricanes and other natural disasters related to weather. This site also contains the three data centres 1) NODC : National Oceanographic data Centre 2) NCDC : National Climatic Data Centre and 3) NGDC : National Geophysical data Centre.

http://www.pages-igbp.org/

PAGES is a core project of the International Geosphere-Biosphere Programme (IGBP) and is funded by the U.S. and Swiss National Science Foundations, and the National Oceanic and Atmospheric Administration (NOAA).

http://www.futureearth.info/

Future Earth is the global research platform providing the knowledge and support to accelerate our transformations to a sustainable world. Bringing together existing programmes on global environmental change, Future Earth will be an international hub to coordinate new, interdisciplinary approaches to research on three themes: Dynamic Planet, Global Development and Transformations towards Sustainability.

Meetings and Seminars

XIX INQUA Congress: Quaternary Perspectives on Climate Change, Natural Hazards and Civilization @ Nagoya, Japan during 27.07 - 02.08.2015. Website: http://inqua2015.jp/index.htm

3rd ICES/PICES/IOC International Symposium on the "Effects of climate change on the world's oceans" 23.03 - 27.03.2015 Santos, Brazil

One Planet, One Ocean - 2nd International Ocean Research Conference 17.11 - 21.11.2014 Barcelona, Spain http://www.iocunesco-oneplanetoneocean.fnob.org/

The Big Picture: Archaeology, Society and Environment Conference 07.11 - 09.11.2014 nicola.whitehouse@plymouth.ac.uk

Deltas in times of Climate Change 24.09 - 26.09.2014 Rotterdam, Netherlands http://climatenl.m10.mailplus.nl **In the Bog:** The ecology, landscape, archaeology and heritage of Peatlands 03.09 - 05.09.2014 christine@hallamec.plus.com

On-going DST, MoES Projects on Quaternary

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Some Classical Papers

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Recent Ph D Thesis

Late Quaternary landform evolution: Role of climate and Tectonics in the Great Rann of Kachchh, Western India. By N. Mamata Devi under Supervision of Dr. M.G.Thakkar, Institute- Department of Earth and Envitonmental Science, K.S.K.V. Kachchh University-Bhuj-Kachchh-Gujarat.

Geochemical study of loess-paleosol Quaternary sediments of Karewa Basin with reference to paleoclimate of Kashmir Valley, J&K, India by Mr. Ishtiaq Ahmad awarded Ph. D. in Geology from University of Kashmir, Srinagar in June, 2013 under the supervision of Dr Rakesh Chandra, Department of Earth Sciences, University of Kashmir, Srinagar, J&K, India.

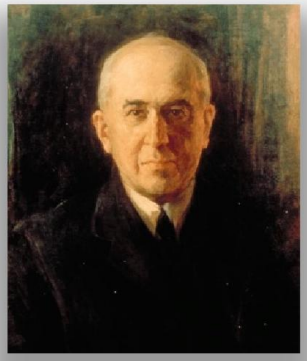
Tectono-geomorphic study of loess-paleosols in the Himalayan intermontane Karewa Basin of Kashmir Valley, J&K, India by Mr. Reyaz Ahamd Dar submitted Ph. D. Thesis in Geology to University of Kashmir on the topic in March, 2014 under the supervision of Dr Rakesh Chandra and Prof. Shakil Ahmad Romshoo, Department of Earth Sciences, University of Kashmir, Srinagar, J&K, India.

Palaeoclimatic changes using varves deposits around Baralacha Pass, Great Himalayan Range, NW Himalaya by Ms Archana Bora under the supervision of Prof. B.S. Kotlia, Centre for Advanced Study in Geology, Kumaun University, Nainital, India. Thesis awarded 2011.

Geochemical and Carbon isotope studies on the surface and subsurface sediments of Cauvery Delta, South India. By Srikanth Doradla (Awarded April 2013) under the guidance of Dr. Pramod Singh.

Geochemical and Isotopic Studies of sub-surface sediments from Cauvery Delta, South India by Malik Zbair Ahmad (Awarded Nov. 2013) under the guidance of Dr. Pramod Singh. From Department of Earth Sciences, Pondicherry University.

Remembering Quaternary Scientists



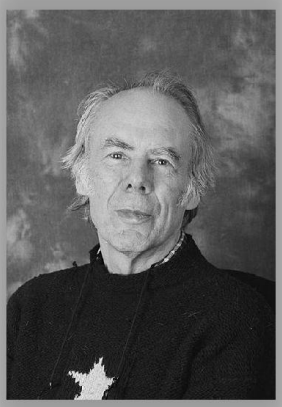
Milutin Milankovitch

(1879-1958)

Milutin Milankovitch was a Serbian engineer and meteorologist - born in 1879 he attended the Vienna institute of technology graduating in 1904 with a doctorate in technical sciences. He then went on to work in the University of Belgrade where he spent time working on a mathematical theory of climate based on the seasonal and latitudinal variations of solar radiation received by the Earth.

Milankovitch proposed that the changes in the intensity of solar radiation received from the Earth were affected by three fundamental factors. The first is called eccentricity; a period of about 100,000 years in which the nearly circular orbit of the Earth changes into a more elliptical orbit. The next factor is called obliquity, a period of about 41,000 years where the Earth's axis tilt varies between 21.5 and 24.5 degrees. The final factor is called precession, a period of approximately 23,000 years where the Earth's axis wobbles like a spinning top.

Milankovitch proposed that these regular cycles of the Earth, as they changed the Earth's relationship to the Sun, had an effect on the Earth's climate, driving hot and cold cycles, to include the ice ages throughout ancient history.



Nicholas Shackleton

23 June 1937—24 January 2006

Professor Sir Nicholas John Shackleton FRS was an English geologist and paleoclimatologist who specialised in the Quaternary Period. He was the son of the distinguished field geologist Robert Millner Shackleton and great-nephew of the explorer Ernest Shackleton.

Educated at Cranbrook School, Kent Shackleton went on to read natural sciences at Clare College, Cambridge. In 1967 Cambridge awarded him a PhD degree, for a thesis entitled "The Measurement of Paleotemperatures in the Quaternary Era".

Shackleton was a key figure in the field of palaeoceanography, publishing over two hundred scientific papers. He was a pioneer in the use of mass spectrometry to determine changes in climate as recorded in the oxygen isotope composition of calcareous microfossils. Shackleton also found evidence that the Earth's last magnetic field reversal was 780,000 years ago. He became internationally known, in 1976, with the publication of a paper, with James Hays and John Imbrie, in Science entitled "Variations in the Earth's orbit: Pacemaker of the ice ages". Using ocean sediment cores, Shackleton, Hays and Imbrie demonstrated that oscillations in climate over the past few million years could be correlated with variations in the orbital and positional relationship between the Earth and the Sun.(From Wikipedia)