Abstract Volume

National Geo-Research Scholars Meet 2016
WIHG, Dehradun, India
June 1 – 4, 2016

WADIA INSTITUTE OF HIMALAYAN GEOLOGY
(An Autonomous Institute of Department of Science & Technology, Government of India)
33, General Mahadeo Singh Road, Dehradun - 248 001
Uttarakhand (India)
EPABX : 0135-2525100, Fax : 0135-2625212
Web : http://www.wihg.res.in

वाडिया हिमालय भूविज्ञान संस्थान
(भारत सरकार के विज्ञान एवं प्रौद्योगिकी विभाग का एक स्वायत्तशासी संस्थान)
३३, जनरल महादेव सिंह मार्ग, देहरादून - २४८००१ (उत्तराखण्ड)
WADIA INSTITUTE OF HIMALAYAN GEOLOGY
(An Autonomous Institution of Dept of Science & Technology, Govt of India)
33, Gen. Mahadeo Singh Road, Dehra Dun - 248001 (Uttarakhand)

प्रो. एस. के. टंडन, FTWAS, FNA, FASc, FNASc
अध्यक्ष, शासी निकाय
Prof. S.K. Tandon, FTWAS, FNA, FASc, FNASc
Chairman, Governing Body

Dated 23rd May 2016

MESSAGE

I have great pleasure in sending you my best wishes for the National Geo-Research Scholars Meet 2016 being conducted by the Wadia Institute of Himalayan Geology from June 1-4, 2016. This is an important event that will allow participants from all across our country to not only present their findings and perspectives on Earth Science related issues, but enable them to obtain a more comprehensive understanding of the research scenario in the Earth Sciences in India.

With the increasing adoption of various technologies in the Earth Sciences including satellite technology, the scope of the subject has expanded considerably besides becoming strongly inter-disciplinary. Therefore, it is important for young entrants in this field to have opportunities to learn about the work of fellow scientists, and to be able to develop collaborations with colleagues that will make their own work more meaningful.

I believe that this is the first such initiative in the country in the area of Earth Sciences; and eagerly look forward to fruitful deliberations as well as the beginning of several research collaborations amongst the young Earth Scientists of our country.

I take this opportunity of complimenting the organizers of this meeting for taking the lead and conceiving this new initiative that is youth-centric.

Professor S K Tandon

वाडिया हिमालय भूविज्ञान संस्थान
(भारत सरकार के विज्ञान एवं प्रौद्योगिकी विभाग का एक स्वायत्तशासी संस्थान)
३३, जनरल महादेव सिंह मार्ग, देहरादून - २४८००१ (उत्तराखण्ड)
WADIA INSTITUTE OF HIMALAYAN GEOLOGY
(An Autonomous Institution of Dept of Science & Technology, Govt of India)
33, General Mahadeo Singh Road, Dehra Dun - 248001 (Uttarakhand)

प्रो. अनिल कुमार गुप्ता
निदेशक
एफ एन ए एस सी, एफ ए एस सी, एफ एन ए, एफ टी डब्लू ए एस
जे.सी. बोस नेशनल फैलो
Prof. Anil K. Gupta
Director
FNASc, FASc, FNA, FTWAS
J.C. Bose National Fellow

Director's message

The Wadia Institute of Himalayan Geology strives continuously to unravel the geological truth related to mountain building of the majestic Himalaya with an aim to improve our understanding of the geodynamic processes, climate-tectonic interactions, evolution and extinction of life, climate and health of glaciers, changes in fluvial systems, seismicity and processes of ore formations.

I am glad that the Wadia Institute of Himalayan Geology (WIHG) is organising National Geo-Research Scholars Meet-2016 (NGEOSM-2016) during 1st to 4th June 2016, dedicated to the research scholars who are working on various aspects of Geosciences in our country. The idea of this National conference which is the first of its kind, came to my mind when I was discussing with two young scientists of the Institute as how WIHG can encourage young talents and drive their interests towards new realms of geosciences. Realizing the importance of this cause, it was decided to organise a conference at National level solely for young researchers providing them a platform to share their ideas and pristine thoughts. I am extremely happy to learn that the response to the Conference is overwhelming.

The Wadia Institute of Himalayan Geology is the best place to organize such an event of this magnitude as the Institute has state of art laboratories wherein more than 40 research scholars and research associates from different streams of geosciences are working under one roof. The WIHG campus is always abuzz with a plethora of activities and has become a dynamic venue where brilliant minds of young researchers from all parts of the country converge and grow to serve to the Nation. It is an attempt to harmonize diverse thinkers and budding minds. I believe that the conference will be able to find a future road map to meet the challenges in the field of geosciences by the country. I congratulate the team of WIHG scientists who are striving to make our dream true.

I wish the organizers of this conference a great success.

Date: 01.06.2016

Anil K. Gupta

Prof. Anil K. Gupta
Director
(Chairman Organizing committee)

Contents

The climatic and tectonic events during Neogene: results from ODP Hole 730A, NW Arabian Sea

Arumugam Yuvaraja[1,2,3], Anil K. Gupta[1,2], M.K. Panigrahi[1]
[1]Indian Institute of Technology, Kharagpur 721302
[2]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[3]Anna University, Chennai 600025
agl.yuva@gmail.com; anilg@gg.iitkgp.ernet.in; anilg@wihg.res.in

The Indian southwest (SW) monsoon system is an important climatic feature influencing fauna and flora in the South Asian countries. This monsoon system is mainly driven by the land-ocean temperature contrast in the region. The impact of SW monsoon winds is more over the northwestern Arabian Sea. In this study, the multiproxy record was used from marine sediments of ODP Hole 730A, NW Arabian Sea to examine the paleoclimatic, paleoeanographic and major tectonic changes during Neogene. The comparative study of our planktic and benthic foraminiferal faunal abundances, total organic carbon and oxygen and carbon isotopes of *Cibicides* spp. suggests that the present day Indian southwest monsoon system developed in the late middle Miocene and strengthened since the late Miocene.

Abrupt changes in Indian summer monsoon variability during the Middle - Late Holocene

Saravanan, P[1]*, Anil K. Gupta[1,2], M.K. Panigrahi[1], Prakasam M[2]., Santosh K. Rai[2]
[1]Dept. of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721302
[2]Wadia Institute of Himalayan Geology, Dehra Dun 248001
**geosaran.jan26@gmail.com*

The Indian summer monsoon (ISM) brings annual rainfall more than 80% to the Indian peninsula. The West Coast of India is delimited by the vast water of the Arabian Sea, which is considered as one of the highly productive sea in this world. It exhibits seasonally reversing of wind direction i.e. southwest (SW; summer) and northeast (NE; winter) monsoon winds, and it makes one of the world's most fertile area for the fauna. In this present study, we used marine sediment cores from SE Arabian Sea to understand the summer monsoon variability and its upwelling induced productivity during Middle - Late Holocene. We studied 243 marine sediment samples from site SK-291/GC-13 (14° 42.5'N, 74° 00.82'E, 25mbsl) to see the ISM variability since 6 kyr BP. The AMS ^{14}C dates of 6 samples (*Mixed planktic*) obtained from Woods Hole Oceanographic Institution, USA. The SW Indian monsoon variability was well documented in numerous studies using by multi proxy records from sea sediments, speleothems, lake records etc., In this study we used multiproxy records such as relative abundances of benthic and planktic foraminifera, $\delta^{18}O$ of *A. gaimardii*, and Total Organic Carbon (TOC) to understand the aired/cold phase of ISM and associated sedimentation history, productivity, fluvial input of detritus etc. These proxy records of core SK-291/GC-13 indicates abrupt change occurred ~2.8 to 2.5 kyr BP and 1.0 to 0.8 kyr BP which indicates the arid/cold phase of the ISM. The abrupt change occurred ~2800-2000 BP and 1500 BP is well established in the previous workers. Our multiproxy records suggest that the several intervals of weak ISM especially 2.7 ka event coincides with the cold phase of North Atlantic climatic record. The abundance of benthic foraminiferal faunal data shows similar trend, particularly *A. gaimardii* (%), *A. beccarii* (%) abundance indicates high organic supply and brackish to shallow, inner neratic

environment with high productivity and *Nonion cf. asterizans* (%), shows continuously increasing trend ~6.0 to 0.5 kyr that maintained a high abundance along with opportunistic species in this region. The high TOC (wt. %) shows better preservation potential of organic matter produced by enhanced surface paleoproductivity. The high TOC % indicates that high biological productivity, in this area the TOC content fluctuated between 4.1 % (3.1 kyr) to 2.4 % (0.1 kyr).

Speleothem: proxy for Indian summer monsoon variability

Sonu[1]*, Anil K. Gupta[1, 2], Somdutt[1]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur
**sonu.6382@wihg.res.in*

Speleothems are the mineral formation deposited in the cave, typically in karstified horizon, most commonly as the stalagmite, stalactite and flowstone. Speleothems hold a great potential for preservation of significant paleoclimatic signals, by captured signature in the form of isotopic properties, lamination, and elemental variation (Fairchild et al., 2004). The speleothem $\delta^{18}O$ records from India have provided the remarkable insights into Indian summer monsoon variability from annual to millennial scale and also its different forcing mechanisms (Neff et al., 2001; Wang et al., 2001). Additionally recent studies, suggest that the cave records from Asia also reflect change isotopic composition of the source regime, change in moisture source, change in the fractionation at the source and process taking place along the transport pathway (Yuan et al., 2004; Pausata et al., 2011; Dutt et al., 2015).

Dutt, S., Gupta, A.K., Clemens, S.C., Cheng, H., Singh, R.K., Kathayat, G., Edwards, R. L., 2015. Geophysical Research Letters, 42.
Fairchild, I.J., Frisia, S., Borsato, A., Tooth, A.F., 2006. Blackwells, Oxford.
Neff, U., Burns, S.J., Mangini, A., Mudelsee, M., Fleitmann, D., Matter, A., 2001. Nature, 411, 290-293
Pausata, F.S.R., Battisti, D.S., Nisancioglu, K.H., Bitz, C.M., 2011. Nature Geoscience, 4,474-480.
Wang, Y.J., Cheng, H., Edwards, R.L., An, Z. S., Wu, J.Y., Shen, C.C., Dorale J.A., 2001. Science, 294, 2345-2348.
Yuan, D., Wang, Y.J., Cheng, H., Edwards, R.L., Dykoski, C.A., Kelly, M.G; Meiliang, Z., Quing, J., Lin. Y., Wang, Y., Wu, J., Dorale J.A; Zhisheng, A., Yanjun, C., 2004. Science, 304, 575-578.

Sedimentary diatoms based tropic status of Renuka Lake, Himachal Pradesh, India

Pranaya Diwate[1, 2], Narendra K. Meena[1]*, Sumedh K. Humane[3]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Department of Geology, University of Jammu. Jammu
[3]Department of Geology, RTM Nagpur University, RBD Laxminarayan Campus, Nagpur 440001
**naren@wihg.res.in*

Everglade Renuka lake is located at the foothills of the Himalaya (lat $30^0$36'36" N long.$77^0$27'45" E, 635 msl) in Sirmour district of Himachal Pradesh, India. The catchment of the lake constitutes Krol and infra Krol Formation rocks of Proterozoic to neoproterozoic age (Srikantia and Bhargava, 1998). The lake received water from catchment through streams as well as ground water

seepage. Most of the water influx contributes from monsoon rainfall. Therefore, Renuka Lake provides ideal site for paleoclimate studies. In this study, we have analysed fossil diatoms and grain size on top 126 cm sediment sequence from Renuka Lake in order to reconstruct tropic state and paleoclimate of lake. The diatoms assemblages with the characteristics of different salinity regimes and pH have been identified and grouped from the bottom to the top of the core. On the basis of morphology the species are classified as Genus *Cymbella neocistula* and *Rhopalodia gibba* (Benthic) (Hall and Smol, 1999). This genus grows in alkaline water condition. The diatoms from the top part of core suggest that the Renuka Lake was alkaline and mesotrophic during the past few decades.

Hall, R.I., Smol, J.P., 1999. eds. Stoermer, E.F. and Smol, J.P. Cambridge University, Cambridge, 128-168.
Srikantia, S.V., Bhargava, O.N., 1998. Geol. Soc. Ind. sp. Pub.

Variability of Indian Summer Monsoon (ISM) during 313 - 260 ka: implication of stalagmite oxygen isotope ($\delta^{18}O$)

Jooly Jaiswal[1,*], Anil K. Gupta[1], Somnath Kundal[2]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Department of Geology, university of Jammu, Jammu Tawi (J&K)
**jooly1991@gmail.com*

The Indian Summer Monsoon (ISM) is one of the earth's most dynamic features interacting with the atmosphere, hydrosphere and lithosphere (Clemens et al., 1991). Its intensity has varied greatly during the Quaternary (Raymo et al., 1997). Historically, abrupt changes in the ISM have been implicated to the growth and displacement of ancient civilizations in the South Asian region (Gadgil et al., 2005). ISM strength is highly sensitive to mean latitudinal position of Inter-Tropical Convergence Zone (ITCZ) and controls $\delta^{18}O$ of stalagmite significantly (Fleitmann et al., 2007). The present study reveals variability in the ISM on centennial to millennial time scales using high resolution and absolutely dated (U-Th dating) stalagmite oxygen isotope ($\delta^{18}O$) proxy record from Bhiar Dhar cave in the northwestern (NW) Himalaya. Result of U-Th dating suggests that BH-3 deposited during 313 to 260 ka having temporal resolution ~310 years. The studied stalagmite (BH-3) is the first oldest stalagmite record from the Indian subcontinent. The isotopic analysis of BH-3 shows that $\delta^{18}O$ varies between -12.21‰ and -4.15 ‰. An abrupt decrease in $\delta^{18}O$ (-7.29 ‰) during 291 to 285 ka was observed which suggests strengthening of the ISM and northward displacement in the mean latitudinal position of ITCZ. Additionally, we correlates our results with previously available global data (marine, ice core, speleothem and insolation) to understand the variability of ISM and its connection with solar forcing during 313-260 ka.

Clemens, S., Prell, W., Murray, D., Shimmield, G., Weedon, G. 1991. Nature, 353(6346), 720-725.
Fleitmann, D., Burns, S.J., Mangini, A., Mudelsee, M., Kramers, J., Villa, I., Neff, U., Al-Subbary, A.A., Buettner, A., Hippler, D., Matter, A., 2007. Quat. Sci. Rev. 26(1), 170-188.
Gadgil, S., Rajeevan, M., Nanjundiah, R., 2005. Curr. Sci. 88(9), 1389-1400.
Raymo, M.E., Oppo, D.W., Curry, W., 1997. Paleoceanography, 12(4), 546-559.

Trace fossils and palaeoenvironment of the Baisakhi Formation, Jaisalmer Basin, Rajasthan

Kantimati G. Kulkarni, Sohan N. Salunkhe*, Shweta S. Gurav
Biodiversity & Palaeobiology Group, Agharkar Research Institute,GG Agarkar Road, Pune 411004
**ssalunkhe@aripune.org*

Trace fossils are signatures of animal-sediment interaction, preserved in the form of biogenic sedimentary structures which include dwelling and feeding burrows, crawling and grazing trails, resting traces, borings, etc. They vary with changes in the substrate and the depositional environment. Thus, trace fossils form an important tool to understand changes in depositional environments as well as fluctuations in sea-level. The current work deals with scrutiny of trace fossils from the Baisakhi Formation, Jaisalmer Basin to understand the changes in palaeoenvironment. The Baisakhi Formation is broadly divided into three units based on their lithology, viz. lower unit, middle unit and upper unit. The lower unit consists of intercalations of compact, buff coloured, fine grained, sandstone with gently dipping cross beds and concretions and, grey to off-white, friable claystone; the middle unit is dominated by medium to coarse grained brown sandstones exhibiting gently dipping cross beds, asymmetrical ripples and syn-sedimentary deformation structures; while the upper unit is characterised by gently dipping cross bedded siltstones grading into fine grained sandstone associated with fossiliferous horizons yielding ammonoids, nautiloids and gastropods. Trace fossils are recorded from various sections exposed in vicinity of Rupsi, Chaudhariya, Kahala, Kala Dungar, Kathori and Lanela villages. Five ichnofacies have been identified in the sandstone dominated lithology of the Baisakhi Formation where the ichnogenera are listed in decreasing order of abundance. The ichnoassemblage within the lower lithounit comprising of *Rhizocorallium jenense*, *Planolites beverleyensis*, *Palaeophycus tubularis*, *Taenidium cameronensis, Rhizocorallium commune, Zoophycos* isp*, Cosmorhaphe* isp., *Nereites imbricata*, and *Nereites cambrensis*, indicate *Zoophycos* to Archetypal/ Distal *Cruziana* ichnofacies and represent deposition in shelf to lower/upper offshore settings, respectively. The middle lithounit displays a diverse ichnoassemblage with *Ancorichnus anchorichnus*, *Taenidium cameronensis*, *Gyrochorte comosa*, *Palaeophycus tubularis, Teichichnus rectus*, *Rhizocorallium commune*, *Asterosoma ludwigae*, *Thalassinoides suevicus*, *Rosselia socialis*, *Skolithos linearis* and *Gyrolithes nodosus* assignable to Archetypal *Cruziana* to *Skolithos* ichnofacies. This transition in ichnofacies suggests shift in environment of deposition from upper offshore to lower shoreface. The upper lithounit preserves an ichnoassemblage comprising *Gyrochorte comosa*, *Taenidium cameronensis* and *Rhizocorallium commune* representing Archetypal *Cruziana* ichnofacies. An upper offshore environment of deposition is interpreted for this lithounit. Spatio-temporal analysis of ichnofacies in the Baisakhi Formation indicates a transition from *Zoophycos* ichnofacies (lower lithounit) through *Cruziana* to *Skolithos* (middle lithounit) suggesting a regressive phase and a shift in depositional environment from shelf to lower shoreface. While the transition from the *Skolithos* ichnofacies (middle lithounit) to *Cruziana* ichnofacies (upper lithounit) indicates a transgressive phase with a shift in palaeoenvironment from shoreface to upper offshore.

Inferring Paleo-environmental Conditions Using Geochemical Signatures: Manasbal Lake, Kashmir, India

Aasif Lone[1]*, Babeesh Balan[1], Hema Achyuthan[1], Rakesh Chandra[2]
[1]*Department of Geology, Anna University Chennai 600025*
[2]*Department of Earth science, University of Kashmir, Srinagar 190006*
**geoaasif@gmail.com*

The present study was conducted on the Manasbal Lake (34°14'N & 74°40'E) to assess the geochemical characteristics of the lake floor sediments, its environmental implications and response to the local catchment. The work described in this study tracks the spatial distribution of grain size, geochemical analysis, Carbon/Nitrogen ratio, $CaCO_3$ and Organic matter content expressed as loss on ignition of the lake floor sediments. It is observed that the clay fraction (49.79 %) is predominant in the lake floor sediments followed by silt (35.88 %) and sand (14.33 %) fraction and also reveales a positive correlation with the water depth. Among major oxides SiO_2 and CaO were the most abundant oxides. CaO content is high occurring above the UCC and PAAS values due to the limestone lithology being dominant in the catchment. This relation is also confirmed by the PCA correlation. Sulphur and chlorine were dominant amongst the trace elements indicating high intensity of anthropogenic detritus input into the lake. Carbon/Nitrogen ratio (15.48) of sediments indicates a mixture of both autochthonous algal matter and land derived plants contributing organic matter to the lake. The OM (16.85%) and $CaCO_3$ (14.04%) in the lake floor sediments is attributed to high organic activity within the lake, contributions from the flora and fauna around the lake and the predominance of fine sized sediments, which have the tendency to accumulate the organic matter as exhibited by the PCA analyses. This study reveals that the deteoriation of the Manasbal lake environment is due to the natural and anthropogenic activity like quarrying and subsequent weathering of catchment Triassic Limestones, tourism, construction, sewage and domestic waste. Agricultural run-off in terms of agricultural practices such as use of chemical fertilizers has further resulted in the ingress of various trace elements and organic load into the lake.

Stable isotopic investigation of coral porites from Minicoy island, Lakshadweep

A. A. Fousiya[1], S. Chakraborty[2]*, H. Achyuthan[1], Naveen Gandhi[2], Nitesh Sinha[2], Amey Datye[2]
[1]*Department of Geology, Anna University, Chennai, India*
[2]*Indian Institute of tropical meteorology, Pune, India*
**supriyo@tropmet.res.in*

Stable isotope analysis has been performed on a coral *Porites* collected from the Minicoy Island to investigate its potential as a proxy for southwest monsoonal variability. An X-Ray image of *Porites* coral revealed about 24 annual bands corresponding to years 1989-2013. The mean annual extension over this period is ca. 7.7 mm/year. Stable carbon ($\delta^{13}C$) and oxygen isotope ($\delta^{18}O$) analysis of these bands reveal that the isotopic composition is controlled by kinetic fractionation. There is a drop of $\delta^{18}O$, ca 1‰ relative to the mean value during 1998 indicating anomalous warming of the sea surface.

Response of coral reefs due to Thermal Stress: An Indian scenario

Mohit Arora*, Ashwin Gujrati, Nandini Ray Chaudhury
EPSA, Space Applications Centre, ISRO, Ahmedabad
**mohitarora@sac.isro.gov.in*

Coral reefs are major features of tropical coastal environments between the 30° N and 30° S latitudes and coincide with Sea Surface Temperature (SST) ranging from 16° C to 30° C. A positive SST anomaly index is one of the major stresses to coral reefs. The warming of tropical sea surface temperature increases the level of thermal stress and therefore causes coral bleaching. The major coral reef formations in India are in Gulf of Kachchh (GOK), Gulf of Mannar (GOM), Lakshadweep, Andaman and Nicobar Islands. Remote sensing, from satellite is the most efficient approach for monitoring the stress on coral reef ecosystems. It measures environmental parameters like SST, solar radiation, wind speed, salinity, suspended sediment and chlorophyll-a at pixel level. SST is most important parameter for predicting coral bleaching. For this study, SST data was acquired from two different sources i.e. Indian Meteorological Satellite (INSAT-3D) and Hadley Centre Sea Ice and Sea Surface Temperature data set version 1 (HadISST1). HadISST1 monthly data was analysed for the period of 1950 to 2015 for SST and SST Positive anomaly calculations and INSAT-3D (L3B) daily data was analysed for January 2015 to December 2015 for SST calculation. Coral bleaching tends to occur when sea surface temperature exceeds climatological maximum monthly mean temperature. From the present study, it has been found that the Indian coral reef regions have different warmest months and variable thermal stresses. The warmest month for the GOK region is found in the month of June with Maximum Monthly Mean (MMM) temperature of 29.18° C (±0.32), for the GOM and Nicobar regions, it is found in the month of April with MMM temperature of 29.75° C (±0.37) and 29.65° C (±0.32) respectively and for the Andaman and Lakshadweep regions MMM temperatures of 29.81° C (±0.31) and 30.08° C (±0.37) are found in the month of May. Out of all the five regions, the warmest MMM temperature was found in Lakshadweep.

Evidences of Holocene glacial advances in the Kosa basin, Dhauliganga valley, central Himalaya, Uttarakhand, India

Pinkey Bisht [1]*, S. Nawaz Ali[3], Naresh Rana[1], Sunil Negi[1], Y.P. Sundriyal[1], Navin Juyal[2]
[1]*Department of Geology, HNB Garhwal University, Srinagar 246174*
[2]*Physical Research Laboratory, Navrangpura, Ahmedabad 380009*
[3]*Birbal Sahani Institute of Paleobotany, Lucknow 226007*
**p01bisht@gmail.com*

Understanding the pattern of glaciations is essential to establish the linkages between local, regional and global climate changes. Despite the fact that impressive successions of moraines in Central Himalaya are present, palaeoglacial reconstructions and the chronology of glacier fluctuations in the region are lacking. Towards this, the present study is an attempt to reconstruct the palaeoglacial changes on the basis of geomorphology, field stratigraphy and optical dating of moraines in the monsoon dominated Kosa basin of Dhauliganga valley, Central Himalaya. The study provides evidences of four events of glaciations in the valley, the oldest of which, is Rajbank stage (RBS-1) which occurred during 12.7 ka, implying the younger dryas cold event. This was followed by the RBS-2 glaciation that occurred during the early to mid Holocene (6 ka) and is manifested by the presence of a prominent latero-frontal moraine. The RBS-3 is dated to mid Holocene (4-5 ka) and

RBS-4 is corresponding to Neoglacial (2-1.5 ka). Besides these, mounds of unconsolidated morainic sediments present in front of the present glacier snout can be related to the LIA. The study provides some important insights about the dynamics and evolution of the Holocene glaciations suggesting decreased temperature to be the major driver of glaciations during the Holocene.

Characterization of Chemical Weathering in Khondalites: A case study from the Khurda area, Odisha

Asmita Maitra*, Aditi Chatterjee
Geology and Geophysics Department, IIT Kharagpur, Kharagpur 721302
**asmita.maitra@gmail.com*

Khondalite is a quartz-garnet gneiss with graphite and sillimanite as common associates. It is known to be highly susceptible to weathering. The integrity of a rock is particularly affected by the nature of the bonds or cement between particles within a specimen. Generally, rocks appear to lose strength when exposed to moisture, and mechanical anisotropy is another important factor controlling the extent of weathering. Khondalite is susceptible to both factors, and consequently is easily weathered. In spite of this inherent weatherability, khondalites form high topography in several areas of Eastern Ghat Mobile Belt (EGMB). These topographic highs appear to directly contradict the idea that khondalites are inherently susceptible to weathering. In order to understand the nature of the weathering products of khondalite, weathered and unweathered samples were collected from the vicinity of hot spring locations in the district of Khurda in Odisha. The hot spring present in the area serves as a 'fast forward mechanism' to study the weathering process. Water also substantially influences rock strength and is known to influence the molecular structure of mineral surfaces. Interaction between the heated meteoric water and the surrounding rock increases the rate of weathering. In this process several changes in hot spring water chemistry are also noticed. Mg and HCO_3 concentrations show a negative relationship with increasing water temperature whereas Ca, Na and Cl concentrations show a positive relationship with water temperature. These differences in water chemistry can be directly co-related with the weathering of khondalites. As the rock is highly weathered, the weathered products / minerals cannot be recognized in thin sections. Therefore, the weathered products were identified using FTIR and VNIR spectroscopy. The weathered rock is seen to comprise mostly kaolinite, goethite, and hematite, according to the results from FTIR and VNIR spectroscopy. The weathering process was also theoretically modelled. By thermodynamically calculating the stable phases produced by weathering, and also a quantitative modeling to estimate the weathering rate. Geochemical modeling of the weathering process was carried out using the Geochemist's Workbench (GWB). The modeling results indicate that the weathering process culminates with the production of kaolinite, which is the weathering product of garnet, sillimanite and feldspar. Khondalites are dominantly quartz - garnet rocks. A theoretical modeling calculation of weathering rates of khondalite was conducted for hypothetical rocks with varying proportions of quartz and garnet. Counter-intuitively, the weathering intensity is seen to be higher when the proportion of quartz is higher. As khondalite is a strongly foliated rock, increasing thickness of the quartz layers results in thin garnet layers weathering easily and rapidly. Progressive weathering of garnet results in greater porosity, which depends on the four variables - weight fraction of quartz, almandine which weathered and kaolinite and goethite retained out of the total moles of these minerals produced by weathering of almandine. This helps water to percolate through the rock, thereby increasing the rate of weathering.

A temporal study of land surface temperature and precipitation: An evaluation of glacier mass balance and glacial lakes using earth observatory techniques

Ashim Sattar[1]*, Ajanta Goswami[1], Anil V. Kulkarni[2]
[1]Department of Earth Science, Indian Institute of Technology, Roorkee
[2]Divecha Centre for Climate Change, Indian Institute of Science, Bangalore
**ashim.sattar@gmail.com; anilkulkarni@caos.iisc.ernet.in*

Himalayan glaciers contribute about 40,800 km^2 of the global glacier coverage, the largest of alpine type glaciers on the globe. The mass balance record of the Himalayan glaciers has been significantly limited in order to understand their behaviour to seasonal and climate changes over the entire Himalayan cryosphere. The Himalayan arc can be divided according to the major river basins of north, central and eastern India, viz., Indus basin, Ganga basin and Brahmaputra basins, respectively. Glaciers tend to behave differently according to the conditions prevailing over these basins throughout the year. The biasness of mass balance estimates is towards the northwest Himalaya with 58 studied glaciers (1979-2014) and just 7 glaciers (1998-2014) in the Brahmaputra basin towards east gives us a rather enormous scope for further studies. Glaciers react to climate change either by losing or gaining mass and therefore considered as an important climatic response variable. The loss of mass from a glacier eventually adds up over the years to form glacial lakes under favourable conditions. Climate change is defined by sudden change in atmospheric variables like temperature, precipitation, moisture, etc. Therefore, to understand climate change, the study of glacier lake dynamics is of foremost importance and its relation with climatic parameters will be attempted as a part of this research. Glaciers are the proxy to climate change as their dynamics helps us to understand the extent of variability of the environment. Most often glaciers react to climate change by changing their mass, to attain a steady state to the new imposed conditions of the surroundings. Here, the precipitation trends over the Indus and the Ganga basin were studied over a span of 15 years using TRMM daily data products with spatial resolution of 0.25°*0.25°. The temperature trends are derived using MODIS 8 day data product over a span of 15 years from 2000-2015. An attempt to understand the temporal temperature and precipitation variations over these major basins and their impact on glacial mass balance and growth of glacial lakes is the prime objective.

Relative chronological shift of the geomorphic processes across the Sone megafan in the Southern Ganga plain: An evidence from fluvial geomorphology

Aditya K. Verma*, Pitambar Pati
Department of Earth Sciences, Indian Institute of Technology-Roorkee, Roorkee
aditya.verma.geo@gmail.com

The alluvial megafans at the base of Himalayan foothills have been the main focus of recent researches in the last few decades. These large depositional features in the distal parts of the Gangetic plain have so far been paid less attention. The Sone river channel dynamics and development of the megafan have been described but the chronology of geomorphic evolution of the Sone megafan has not been studied till date. In the present work, parts of the Sone megafan have been studied for its relative chronological development and it has been compared with the northern adjacent areas i.e. with the Gandak megafan whose development and dates are already known. The present study

identifies the relatively older and younger plains of the Sone megafan and presents the megafan development as a 3-stage event. Various geomorphological signatures such as development, preferred alignment/orientation and relative size and shapes of natural ponds distributed to the East and West of Sone River, soil characteristics (solum thickness and soil development), identification of active and palaeochannels of the Sone River and remote sensing and GIS techniques have been used to describe the order of building stages of the Sone megafan. As the Gandak megafan and Sone megafan rest on the same tectonic block between East Patna Fault (EPF) and West Patna Fault (WPF). Their similar characteristics, within considered parameters for this study and similar response of the Gandak River and the Sone River to the tectonic tilting could be affirmatively used in the present study to compare the OSL dates from different parts of Gandak megafan with the respective parts of Sone megafan.

The integrated approach utilised to temporally differentiate plains of the Sone megafan has led to the conclusion that the oldest plain of the Sone megafan (western part) was developed with the first eastward shifting of the Sone River in response to tectonic tilting of the host tectonic block. This leads abandonment of the palaeochannels and associated fluvial geomorphic features of first generation in the western plains. During the second phase of the megafan building, the half graben between EPF and WPF has undergone uplift in the southeastern parts along EPF and subsidence in the northwestern parts along WPF which caused the Sone River to swipe back towards west and formed the younger plains of Sone megafan currently located to the east of Sone River. The last or third phase of megafan building is the current floodplains of the active channel of Sone River.

Late Quaternary climatic and tectonic perturbation through Bhuki River deposits at back limb of Kachchh Mainland Hill Range, Western India

Madhavi D. Dabhi*, Rakesh M. Bhagora, Gaurav D. Chauhan,
Kaustubh J. Sane, S. Bhandari
Department of Earth and Environmental Science, K.S.K.V. Kachchh University, Bhuj-370001
** madhavidabhi@yahoo.in*

Tectonism and climate, the two different factors which can change the landscape can be recognized with the aid of Geomorphology and Sedimentology. The geomorphic setup of the Bhuki River along with the study of morphometric parameters like Longitudinal Profile, Stream gradient length ratio indicates the river to be tectonically active. On the other hand the deposition of sediments in the river valley over the bedrock indicates the role of climate. Patchy valley fill deposits have been documented in Bhuki River. Overall four units of fining upward sequences have been recorded with gravelly bed at the bottom followed by course sand with fine sand resting on the top indicating extreme hydrological conditions. Two units of weakly pedogenized horizon in between the exposed sections can be related to periods of quiescence. These events are also supported by the geochemical data raised from these sediments which showing alternate arid and wet period. With the help of the data generated we are able to reconstruct the climatic conditions during the Late Quaternary in the Kachchh region and associated fluvial response.

Synergistic manifestation of climate and tectonic activity: a evolution of Khari River epigenetic gorge in central mainland Kachchh, Western India

Kaustubh Sane*, Gaurav Chauhan, M.G. Thakkar
Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj-Kachchh
**kaustubh186@gmail.com*

Kachchh region in western India falls in an arid climatic zone, which is the southwestern extension of arid belt of NW India. Epigenetic gorges in the tectonically active landscape are recognized by bedrock geometry and its valley pattern which are habitually coupled with Paleo-Channel containing sediment succession. In present work it is assumed that the paleo-river course was abandoned due to extensive fluvial aggradations as well as subsequent episodic uplifting of either side of palaeo-river. As a result of it, the river was forced to occupy the epigenetic gorge. Therefore, it can be suggested that Paleo-channel and gorges are the product of the climate-tectonic interaction. The current study is hence undertaken of Khari River gorge in the tectonically active Kachchh basin to understand the role of climate and tectonics in their evolution. Initial observations in Khari River indicate that an epigenetic Khari gorge is structurally restricted. The Khari River rises from Katrol Hill Range and flows northward on largely Cretaceous sandstone terrain exposed as the early Quaternary erosion bedrock. The study location west and NW of Bhuj town exhibits 10-15 m deep incised bedrock river gorge striking NE-SW. The epigenetic gorge exhibits six generations of Staircase terraces where T1 being the oldest and T6 the youngest and placed at the active gorge axis to the bottom. Chronology of the paleo-river channel indicates early aggradation phase while latter stage is governed by tectonic episode which may have caused abandoned the palaeochannel with concurrent development of epigenetic gorge. This is followed by the dominant climatic phase to form T3 and T4 erosional terraces having numerous pot holes and flutings with NE-SW trend consistent with present day flow direction. Large accumulation of potholes indicates the humid climate with high discharge rate and energy conditions. A set of depositional terraces downstream containing coarse grain, non-lithified and unstratified sand facies with angular fragments of the sandstone-the country rock that formed the bedrock surface have been correlated and indicates the prolonged wet phase. A strong tectonic phase after it uplifted the terrain to incise the epigenetic gorge to the level of T4 and T5 with distinct strath surface on the older ones and subsequent formation of hanging valley downstream cutting much younger deposition terraces. The most recent deposits in the lower reaches of valley are indicative of weak climatic condition during the middle to late Holocene.

Impacts of sea level rise (SLR) on the coastal aquifer in Thiruvananthapuram district, Kerala

Remya R.*, D.S. Suresh Babu
National Centre for Earth Science Studies (NCESS), Akkulam, Trivandrum 695011
remyaremadevi1992@gmail.com

Sea level is the base level for measuring the elevation and depth on Earth. MSL varies from place to place, and at each place it also varies over time. According to the Intergovernmental Panel on Climate Change (IPCC), sea level is currently rising at an increased rate. Global Sea level, as measured at various tide gauges around the world, appears to have risen by 12-15 cm this century. A small change in the sea level may lead to extensive flooding of coastal areas which are densely populated. This is not limited to sea coast, but also rise can contaminate groundwater supplies due to

landward and upward movement of sea-water in coastal aquifers. This may result the shift in the position of the freshwater-saltwater interface. The principal aim of the present study is to understand the impact of sea level rise on the coastal aquifers, especially in the coastal areas of Thiruvananthapuram district of Kerala in terms of hydrogeochemical evaluation, and possible fluctuations in the elevation of water table. The methodology includes aquifer mapping, hydrogeological surveys, water table monitoring, water quality analysis, resistivity surveys, radon measurements and assessment of submarine groundwater discharge. Groundwater models reflecting different scenarios of sea level rise will be computed by integrating archival data, field observations and laboratory investigations. This presentation reports the status of information available and collated so far in the assessment of stress on coastal aquifer of study area.

Palaeoenvironmental studies of Quaternary sediments from Gulf of Kachchh, Gujarat, India

Sangita M. Pachkhande*, C. Rajshekhar
Nowrosjee Wadia College, Pune
**sangi.geo@gmail.com*

The intertidal sediments of Gulf of Kachchh have immense potential to unravel the climatic as well as the environmental history and evolution since Late Quaternary. The Gulf of Kachchh has unique marine environment. Benthic forams are very useful proxies for palaeoenvironment because specific taxa and assemblages have distinctive distributions relative to proximity to shore, water depth, productivity, and dissolved oxygen (Leckie, 1987). The present work differs in being the first work on the micropalaeontology of the subsurface sediments and attempt is made here for the first time to study the Taxonomy (Classification) of foraminifera, Grain size analysis, CHN Analysis & TOC. The present study will signify the sea level changes, transgressive and regressive phase occurred in late Quaternary period. Objectives of the study are to know in detail the Taxonomy (Classification) of foraminifera present in surface and subsurface sediments and to reconstruct the Late Quaternary palaeoenvironment of Gulf of Kachchh using foraminifera as proxy. Methodology includes Sample Collection, Sample Processing, Preparation of Microfaunal Slides, Taxonomy of Foraminifera, SEM (Scanning Electron Microscope), CHN (Carbon Hydrogen Nitrogen) Analysis and TOC (Total Organic Content), Grain Size Analyses & Radiocarbon Dating of Subsurface sediments.

Evaluation of the coastal boulder deposits from the Saurashtra coast, Western India: Testing numerical models for high energy marine wave events

Kushal Chavare*, Nilesh Bhatt
Department of Geology, Faculty of Science, M. S. University of Baroda, Vadodara 390002
**chavare29@gmail.com*

The presence of Supra-littoral boulders at certain altitude distant onshore from mean sea level indicate high energy marine wave event's deposition which are observed and reported at various places. The dimensions, characteristics and morphology of these boulders were studied with the help of different numeric models to explain the nature of wave event. Numeric models include submerged, sub-aerial and joint bounded boulder scenarios which were combined with the local controlling

variables like roughness coefficient, slope of platforms, fractures, shoaling etc. Study of these models indicate significant role of local controlling factors in boulder dislodgment, transport and final emplacement on shore platform. A dataset form the Adari coast, near Veraval in Saurashtra, Gujarat is reported here for the said application and discussed in detail. It appears that these boulder deposits are result of high energy marine wave events like tsunami or super storm.

Controls on grain size distribution along the rivers of Dehra Dun

Sukumar Parida*, Vimal Singh, Harshit Tandon, Rahul Patel, Nitin Singh
Department of Geology, Chhatra Marg, University of Delhi, Delhi - 110007
**paridasukumar@gmail.com*

The distribution of grain-size along a river depends on the sediment supply, and available stream power in a particular reach (Curran, 2007). The grain-size distribution and their sorting reflect the dynamics of the processes operating in a fluvial system. In the context of the Frontal Himalaya, it can be used as a tool to study the influence of hill-slope processes and the characteristics of tributary-trunk confluences. In this study, we have measured the sediment size and their lithology along three rivers (Song, Asan and Jakhan Rao) in Dehra Dun, a structurally controlled intermontane valley in the NW Himalaya. These gravel-bed rivers are ephemeral in nature and maximum flow is observed during the ISM. For this study, we have processed sediment samples ranging from around 200 to 400 kgs at 18 different sites. These sediments are collected from pits (size: ~18 inch*18 inch *18 inch) dug on the surface of bars having least anthropogenic activity. They have been sorted into five classes using sieves with mesh sizes 2 cm, 4 cm, 6 cm, and 8 cm and weighed separately. The results show that the weight percentage of grains greater than 8 cm is higher in sites with greater mass wasting processes in the upstream. Similarly, the sites which lie immediately to the downstream of the mountain exits also show a higher percentage of coarser grains. A decrease in coarser sediments is observed after tributary confluences. In both Song and Asan rivers the weight percentage of coarser sediments decreases from the middle reaches to its distal reaches, but the grain size increases from the exit to the middle reaches. In contrast, results of the Jakhan Rao show that the distribution of coarse grains increases from the middle reach to the lower reach. Further, we observed that the weight percentages of the class representing sediment sizes greater than 8 cm, and less than 2 cm show inverse relationship in all the 18 sites. The middle reaches show relatively homogenous sorting; in contrast, the upper and lower reaches, show a unimodal grain size distribution, where the stream power is relatively very high and very low, respectively.

Dynamic response, mass balance and the state of Dokriani Glacier, Garhwal Himalaya from 1992-2015

Bhanu Pratap[1]*, Jairam Singh Yadav[2]
[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001*
**bhanuglacio@gmail.com*

Dokriani is a NNW (North-northwest) exposed glacier in the Bhagirathi basin, Garhwal Himalaya, India. The glacier has been monitoring since 1992 and contains most reliable time series observations on the mass balance and length change. The work is presented under an analysis of the

direct response (i.e. annual balance and mass balance gradient) and indirect response (e.g. length changes) of Dokriani Glacier measured during the first decade of the 21st century (2007-2015) and compares with the previous observations of the 1990s (1992-2000). The spatial variability in the mass balance gradient profile of the two different periods shows consistency, but shifted upwards in the recent period. From 1992 to 2015 (14 yrs of observations) the glacier has continuous negative annual balances with monotonically negative cumulative mass loss of -4.46 m w.e with an average loss of -0.32 m w.e a^{-1}. Ablation zone of the glacier has faced average annual ablation of -1.85 m w.e.a^{-1} as compared to residual accumulation of 0.44 m w.e. a^{-1}. In spite of the high order ablation rate compared to less accumulation rate, the glacier has only -0.32 m w.e. a^{-1} of surface mass loss. This can be attributed to the 30% of the total glacier area faced ablation process. This also shows that Dokriani Glacier is losing mass as a result of stronger summer ablation, particularly due to the exposition of WSW direction of the lower ablation zone.

In the recent decades due to substantial melting from last decade (1990s) glacier is now showing its response towards climate change by increasing debris-covered area, length reduction and narrowing glacier surface area. This may also be related to the survival of glacier by increasing debris-covered area to protect underneath ice towards the recent warming. Likewise the continuous negative annual balances, Dokriani Glacier has also continued recession rate from 1992 to present. Snout ascended by 125 m from an elevation of 3870 m a.s.l. in 1992 to an elevation of 3995 m a.s.l. in 2015. The recession rate of 20 m a^{-1} during 2007-2015 is slightly higher than the retreat rate of 18 m a^{-1} during 1992-2000 and 16 m a^{-1} during 2000-2007. In addition, the state of Dokriani Glacier based on accumulation-area ratio (i.e. AAR*n* and AAR0) suggests that glacier to be in disequilibrium state and decreasing its accumulation area. The progressive retreat rate and continuous negative mass balance of the glacier affects its extension and volume, and cover by continuous enhancement of debris over the ablation zone.

Spatio-temporal variability of air temperature in the Dokriani Glacier catchment, Central Himalaya

Jairam Singh Yadav[1]*, Bhanu Pratap[2]
[1]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Wadia Institute of Himalayan Geology, Dehra Dun 248001
**jai.au08@gmail.com*

Himalayan cryospheric system is controlled by various meteorological factors, among them temperature interplay a key role on processes (e.g. melting, precipitation change and sublimation) influencing snow and glacier ice in high elevation catchments. Temperature is extensively used as an input variable in many glacier-models that concern with land- surface-atmosphere interaction. Even though this significance, Spatio-temporal heterogeneity of temperature is poorly understood in the Himalayan catchments due to being lack to generate reliable data set. This study presents monthly, seasonal and annual characteristics of near surface air temperature and lapse rate (NSTLR) variation in the Dokriani Glacier catchment, based on 5 years (2011-2015) records of air temperature at three meteorological stations. The daily NSTLR have been calculated using daily temperatures of two nearest meteorological stations. The temperature is strongly controlled by elevation and has direct relationship with altitude. To look into this relationship, the temperature at each 100 m elevation was determined by extrapolating the near surface temperature at each station using simple regression method for all years and individually for each season. To investigate seasonal variability, each of the

study year is divided into four seasons, namely, winter (DJF: December, January, February), pre-monsoon (MAM: March, April, and May), monsoon (JJAS: June, July, August, September), and post-monsoon (ON: October and November). Besides this, intra-seasonal variability has been estimated as the variability that arises between years and seasons. In addition, we attempt to quantify the zero degree isotherm and temperate sustainability of Dokriani Glacier. Zero degree isotherm is the threshold value of temperature (near 0°C) that control the melt and phase of precipitation of glacier. Based on four entire years observations, the Dokriani Glacier ablation zone is facing 4-5 months having >5 °C air temperature. This significantly contributes in the melting of snow and ice as well as the phase change of precipitation (solid to liquid). The results show that the average NSTLR measured in lower reaches of catchment for all years was found to be ~5.8°C km^{-1}, have notable differences from that of upper reaches (~6.6°C km^{-1}), which is different from the environmental lapse rate (6.5 °C km^{-1}). Furthermore, Air temperature-elevation relation was significantly found to be linear. The seasonal cycle of the near surface temperature lapse rate demonstrate distinct pattern, i.e. steepest in pre-monsoon (range: 6.3-7.5 °C km^{-1}) and shallowest in summer (correspond to the warm, rainy and humid season) (range: 5.3-6.5°C km^{-1}) in the whole catchment. This signifies that monsoon lowers the temperature lapse rate in mountainous region due to presence of moisture in air and owing to sublimation processes. In contrast, cooling effect magnify the NSTLR during pre monsoon and winter season. On diurnal scale, NSTLR variability is strong in all seasons except monsoon, with steeper in daytime hours and shallower in night.

Geochemical investigation of sediment evacuation pattern in glacerized and non glacerized catchment of Himalaya

Tanuj Shukla[1,3]*, Manish Mehta[2], D.P. Dobhal[1], H.C. Nainwal[3]
[1]Centre for Glaciology, *Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2] *Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[3]*HNB Garhwal University, Srinagar, Garhwal 246174*
* *tanujshukla.geo001@gmail.com*

Deposition of sediments is subjected to physical and chemical process that determines the nature and mechanism of sediment disintegration. Sediment deposition in lake bed altered through its distance from source, climatic condition of catchment; while the suspended particulate matter of meltwater streams are entrained aggregates of supraglacial transport pathways of glacier. Studies suggest that more erosion occurs in glaciated region than non glaciated basins. To investigate this fact we attempted a geochemical study on suspended sediment evacuated through Chorabari glacier and the sediment deposited in a moraine dammed periglacial lake of Chorabari glacier catchment. We have aimed this study to understand the geochemical process operating in glacerized and non glacierized basin of same lithology.

The X-Ray Fluorescence (XRF) analysis has been done on parent rocks, lake stratigraphy and suspended sediments of Chorabari glacier. A geochemical mass balance approach has been applied for both the systems to measure the percent change in elemental concentration and degree of weathering with respect to parent rock composition. The elemental normalization has been done with the concentration of titanium (Ti) present in fresh parent rocks because of its low solubility and its presence in several stable primary minerals. Mass balance calculations for degree of alteration shows highest value for clay component of lake sediments (0.04) while the sand (-0.05) and courser sand (-0.04) show negative values which indicates less alteration of rocks during the deposition of sand

and courser sand size grains whereas the clay deposition reflects the progressive alteration. Meanwhile, the suspended sediments evacuating through subglacial pathways shows less negative values (closest to 1) which also indicates the high element loss during dissolution of primary minerals, transport of material and ion exchange on various minerals. The geochemical behaviour of major and trace elements like Mn, Cr, V, Fe, Be, Co, Cu, Rb, Sr which is dependent on redox conditions has been investigated through the correlation matrix plot in both lake stratigraphy and suspended sediments of glacier and the redox transformation interpret here to set the limits on the oxidation state of weathering suite. The integrated weathering history has been estimated through chemical index of alteration proxy which indicates the lowest chemical weathering in sediments evacuated through subglacial pathways (55) and highest for the clay composition of lake (61). These results are primarily used to link the climate and topography of glaciated and non glaciated regions.

Fluvial transfer of molybdenum in tropical humid river and estuarine systems, west coast of India: constraints on marine molybdenum budget

Gurumurthy G.P.[1]*, Tripti M.[2], Riotte J.[3,4], Prakyath R.[5], Balakrishna K.[5]

[1]Manipal Centre for Natural Sciences, Manipal University, Manipal 576104, India

[2]Centre for Earth Sciences, Indian Institute of Science, Bangalore 560012, India

[3]Indo-French Cell for Water Sciences, Indian Institute of Science, Bangalore 560012, India

[4]Geosciences Environment Toulouse (Universite de Toulouse, CNRS, IRD), Toulouse, France

[5]Department of Civil Engineering, Manipal Institute of Technology, Manipal University, Manipal, India

**gurumurthygp@gmail.com*

The study presents the seasonal and inter-annual monitoring of molybdenum (Mo) distribution and variability in humid tropical riverine and estuarine systems (Nethravati, Gurupur and Mandovi estuary), west coast of India. The study was intended to understand the geochemical behaviour of Mo in the riverine and estuarine environment, and their ultimate discharge fluxes. The riverine flux of dissolved Mo (DMo) to the Nethravati and Gurupur estuary is 1.8x 103 mols yr^{-1} (4.88 mols day^{-1}) and 195 mols yr^{-1} (0.53 mols day^{-1}) respectively, and the particulate Mo (PMo) flux to Nethravati estuary is 10.8 x 103 mol yr^{-1}. DMo in the riverine environment is being lost to particulates by reversible scavenging under oxidized acidic water. Assuming the linear relationship between silicate weathering flux and DMo, the adsorptive loss of DMo is estimated at 30-40% of total DMo. This has implications in marine DMo budgeting as the reversible scavenged oxidized particles (produced in the river) may release Mo on its entry to the sea. In the lower salinity reaches of the studied estuaries, DMo is found to be sequestered during premonsoonal season. The DMo sequestration in the estuary is estimated at ~2 mols day^{-1} in the Nethravati estuary and is about 1.9 mol day^{-1} in the Mandovi estuary. The DMo sequestration in the estuary is higher than the riverine supply, indicating the sequestration of both marine and river borne DMo. However, the mechanisms involved in the removal process are distinct in these estuaries viz oxidative adsorption process in the Nethravati-Gurupur estuary and biological utilization in the Mandovi estuary. At higher salinity (>20psu) region, there is a systematic gain in the DMo (~1 to 37nML^{-1}). Mo release from river borne particulate Mo could contribute up to 3nML^{-1} to 4nML^{-1}, which is not sufficient to balance the observed Mo excess. On the other hand, the reductive Mo remobilization from bottom sediments (Mo=4 mg kg^{-1}) during sediment diagenesis and subsequent tidal activity could release up to 14 to 28 nML^{-1} of DMo to the estuarine water. Mo release to water column is supported by the gradual enrichment of DMo with depth in the estuary. Therefore, diagenetic release of DMo could be the potential source of DMo excess in the estuary.

Tectono-sedimentary and climatic setup for Dhosa Sandstone member (Chari Formation) of Ler dome, Kachchh, Western India

Asma Amjad Ghaznavi[1]*, M. Masroor Alam[2], A.H.M. Ahmad[1]
[1]Department of Geology, Aligarh Muslim University, Aligarh 202002
[2]Department of Civil Engineering, ZH College of Engineering and Technology, Aligarh Muslim University, Aligarh 202002
**ghaznavi.asma@gmail.com*

Petrographical studies of the sandstones exposed in the river section near Ler Village, south of Bhuj district, Kachchh, were carried out to analyse the petrofacies, tectono-provenance and paleoclimate. The dome named after the nearby village as Ler dome holds a well exposed Dhosa Sandstone Member. The Dhosa Sandstones are composed dominantly of monocrystalline quartz with an abundance of common quartz and variable amount of polycrystalline quartz with recrystallized metamorphic quartz dominant over stretched metamorphic quartz. Potassium and plagioclase feldspars, heavy minerals, micas as well as meta-sedimentary rock fragments are also present in variable amount. There is a dominance of quartz in these rocks. They can be categorized as mainly belonging to sub arkose. However, some of the samples fall in the quartz arenite field followed by a few in the lithic arenite field. The average petrofacies recognized are Qt90.5F6.9L2.6, Qm86F7Lt7, Qp74Lv00Ls26, Qm92.5P2.0K5.5. The identified petrofacies suggest a hybrid continental block-cum recycled provenance comprising granite-gneiss with metamorphic supra crustals, exposed in the craton interior. The source rocks were exposed in the early stage of thermal doming prior to incipient rifting and drifting associated with Gondwanaland breakup. Paleoclimate studies suggest a humid-semi humid to temperate climate. The overall detrital mineralogy and paleoclimatic condition testifies short transportation of sediments under moderate relief condition complying with the climatic setup of this region during the Jurassic times.

Petro-chemical study of the Punagarh Group sandstones, Punagarh Basin, Aravalli Craton: Implications for paleoweathering, tectonic setting and provenance

Tavheed Khan*, M. Shamim Khan
[1]Department of Geology, Aligarh Muslim University, Aligarh 202002
**khan.tauheedgeo23@gmail.com*

The Punagarh basin of trans-Aravalli is divide into two groups i.e. Sojat Formation and Punagarh Group. Later, Punagarh Group is further divided into three distinct formations i.e. Bambolai, Khamal and Sowania.The Punagarh Group sandstones composed of highest abundance of quartz as compared to the other detrital modes. In the Punagarh Group, there is general decrease of common quartz, mica and plagioclase from Bambolai to Sowani aassociated with concomitant increase of polycrystalline quartz, K-feldspar and chert. The clasts of the Punagarh Group are angular to sub angular except lower beds of Sowania shows well rounded clasts. The petrographic characters of Punagarh Group suggest proximal source. In the petrofacies diagrams like Qt-F-L and Qm-F-Lt the samples of the Punagarh Group are displaced in the recycled orogen field, which suggest that Punagarh Group acquired their debris from palpitating orogenic sources (collision orogen).On the basis of the SiO_2/Al_2O_3 ratio the Punagarh Group sandstones are compositionally mature. In association with the petrographic constituents the major oxides of the sandstones suggest a quartz

arenite type classification of the sandstones. Weathering indices CIA, CIW, PIA and A-CN-K plot for the sandstones of the Punagarh Group suggest low to moderate chemical weathering. Major element discrimination diagrams, trace element ratios Th/Sc, Zr/Sc, Cr/V and Cr/Th and bivariate plots La/Sc versus Th/Sc, Th/Sc versus Cr/Th and Co/Th versus La/Sc suggests that the sandstones of the Punagarh Group are derived from a mixture of felsic and mafic rocks. K_2O/Na_2O versus SiO_2/Al_2O_3 and Ti/Zr versus La/Sc scatter plots and Th-Sc-Zr/10 and La-Th-Sc diagrams indicate active continental margin setting for Punagarh Group which is also attested by the chondrite normalized REE ratios e.g. $(La/Yb)_n$, Eu/Eu^* and REE abundances.

Factors controlling detrital mineral composition of sandstones of Khardeola Formation (Meso-Neoproterozoic), Chittourgarh, southeastern Rajasthan, India

Shahnawaz[1]*, Abdullah Khan[1], M. Masroor Alam[2]
[1]Department of Geology, Aligarh Muslim University, Aligarh 202002
[2]Department of Civil Engineering, Aligarh Muslim University, Aligarh 202002
**shahnawaz.khanazmi@gmail.com*

The Khardeola Formation (~200m) crops out in the southeastern parts of Rajasthan as linear patches in the North-South continuation. The petrographic data reveal that the Khardeola Sandstone comprises, quartz (72%), as dominant framework mineral, with subordinate amounts of feldspar (12%), and rock fragments (6%) with some opaque and heavy minerals. The presence of medium to fine, moderately to poorly sorted and subrounded to subangular detrital mineral suggests that the sediments have not been subjected to prolonged transport and reworking, resulting in only a moderate level of maturity.

Diagenetic features observed suggest early cementation, porosity reduction during early compaction by the rotation and readjustment of detrital grains and formation of line contacts during mechanical compaction as well as dissolution and replacement of feldspar and lithic fragments. The petrofacies in Qt-F-L and Qm-F-Lt ternary diagram suggests that these sandstones mainly belong to the Continental block, recycled orogeny and rifted continental margin tectonic setting. Thus, the study indicates that detrital mineral compositions are not affected by the paleoclimate, transportation, distance, and by the source rock composition. The Khardeola Formation sediments were derived from the Banded Gneisses Complex (BGC) and metasediments of present day Aravalli Super Group.

Heavy minerals and tectonic provenance of Surma Group of rocks in and around Nungba, Tamenglong district

A. Sangeeta Devi*, N. Pandey
Department of Earth Science, Assam University, Silchar 788011
**sangeetakonnect@gmail.com*

A thick sedimentary succession belonging to the Surma Group (Miocene) is well exposed along the road section (NH-53) in and around Nungba, Tamenglong district, Manipur. The Surma sediments have been analyzed for their heavy mineral suite following heavy liquid seperation

technique. The research results reveal the dominance of transparent varieties over the opaques. The diagnostic non-opaque variety includes zircon, garnet, tourmaline, phlogopite, schorlite, rutile, anatase, chondrodite, glauconite, kyanite, staurolite, chloritoid, sillimanite, epidote and pyroxene in decreasing order of abundance. The heavy minerals suite is characterised by the presence of euhedral/ sub-hedral as well as rounded to sub-rounded varieties, indicating a mixed provenance for the Surma sedimentation. Among the opaque variety iron-oxide is the most abundant. The value for ZTR Index has been calculated to be 85 indicating a high mineralogical maturity for Surma sediments.

Facies analysis and depositional environment of Kajrahat Formation, Vindhyan Supergroup, Son Valley, India

Akanksha Singh*, B. P. Singh
Centre of Advanced Study in Geology, Institute of Science, B.H.U. Varanasi 221005
**aakankshasinghbhu@gmail.com*

The Kajrahat Formation of the Vindhyan Supergroup is exposed along the southern flank of the Vindhyan basin in and around Son Valley, India. The present work is concerned with the depositional environment of the Kajrahat Formation based on facies analysis and carbonate mineral phases present in the carbonate succession. The whole succession has been divided into three lithofacies, namely alternating thinly and thickly bedded dolomite facies containing slump breccia and convolute lamination, thickly-bedded dolomite facies, and horizontally laminated limestone-shale alternation facies. All these facies are characterized by grey to brown colour and are mostly calcitic to dolomitic in composition. Elephant skin weathering and stylolites are the dominant mega-features throughout the succession. Stylolites show various patterns, some are parallel to the bedding plane, while others are cross-cutting conjugate to vertical in their orientations. It is presumed that the horizontal stylolites parallel to the bedding planes were formed earlier than the vertical and oblique ones. The stylolites parallel to bedding plane were formed due to overburden while conjugate ones were originated under tectonic activities. Slump breccia and convolute beddings are confined to the 8.65 m thick succession of the rhythmic alternations of thinly and thickly bedded dolomite facies in the lower part of the studied succession and categorized as the soft-sediment deformation structures. In the thinly and thickly bedded dolomite facies thickness of the thinly bedded carbonates gradually increases upward, suggesting repetition of the same conditions and cyclic sedimentation. Thickness of the individual shaly intervals varies from 30 cm to 1.2 m in the studied succession. Petrography of the Kajrahat Formation exhibits algal mats, fenestral fabric in micritic carbonate, crinkle and wavy laminations and micritized pellets that suggest deposition in quite-water coastal environment. The fenestral fabric suggests its formation in the intertidal zone. Contrary to these, the occurrence of slump breccias and convolute laminations and their restricted occurrence suggest that they developed along the continental slope. However, we cannot rule out their seismogenic origin during Kajrahat Limestone sedimentation. Majority of the stained thin sections show that the samples are dolomitic in composition, contrary to the X-ray diffraction patterns which shows calcite as the dominant mineral phase present. This indicates that the dolomite formed is secondary in origin and formed through the replacement of the precursor calcium carbonate.

Banerjee S., Bhattacharya S.K., Sarkar S., 2007. Journal of Asian Earth Sciences, 29, 823-831.
Bose P.K., Sarkar S., Chakrabarty S, and Banerjee S., 2001. Sedimentary Geology, 142, 395-419.
Sharma M., and Kumar S., 2010. The Palaeontological Society of India, 1-121.

Depositional conditions and source of rare earth elements in carbonate strata of the early Paleogene succession, Jaisalmer basin, Rajasthan, India

A. Patra*, B. P. Singh
Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi 221005

Major, trace and rare earth element (REE) concentration of the Eocene limestones, Jaisalmer basin, Rajasthan, India are analysed to reconstruct the depositional conditions and to identify sources of REEs. Among the major oxides, CaO is dominant followed by SiO_2 in the studied limestones. Trace element Ba dominates over other trace elements and it shows negative correlation with CaO. The Sr, occurring in small concentration, shows positive correlation with CaO. Other trace elements such as V, Zr, Sc, Y, Rb, Ni, Pb Co, Cu, and U occur in small concentrations. The limestones possess sea-water like shale-normalized REE+Y pattern with light REE depletion, slight Gd enrichment, slightly positive La anomaly, positive Y anomaly, positive Eu anomaly, negative Ce anomaly and superchondritic Y/Ho ratio from 23.12 to 28.57. The dominance of CaO and low percentage of MgO suggest that mineral phase is calcite and there is absence of dolomitization. The occurrence of SiO_2 and Al_2O_3 in appreciable percentages may be because of the siliciclastic input during the limestone precipitation. The low concentration of Uranium (0.4-3.7) and authigenic Uranium (Average Total U-Th/3 value = 0.74) indicate that the studied limestones were precipitated in oxic condition from seawater. The depletion of LREE suggests that the limestones were precipitated from the seawater. The positive correlation of ΣREE with Al_2O_3, Fe_2O_3, Ni, Th, Sc, and Y and negative correlation with CaO suggest an input of siliciclastic sediments from the land during limestone precipitation. The low values of the Y/Ho ratio (23.12 to 28.57) in the studied limestones suggest some modification of the seawater by the input of freshwater in a coastal environment. The REEs of the studied limestones are correlable with the shallow sea water REEs with exception of a few elements. We envisage a coastal/shallow marine depositional environment where mixing of the continental material in sea water appears feasible.

Alexander, B.W., Bau, M., Andersson, P., Dulski, P., 2008, Geochim. Cosmochim. Acta, 72, 378-394.
Alibo, S.D., Nozaki, Y., 1999, Geochim. Cosmochim. Acta, 63, 363-372.
Barnes, U.C., Cochran, J.R., 1990, Earth and Planetary Science Letters, 97, 94-101.
Bau, M., 1991, Chemical Geology, 93, 219-230.
Condie, K.C., 1991, Geochim. Cosmochim. Acta, 55(9), 2527-2531.
De Baar, H.J.W., Bacon, M.P., and Brewer, P.G., 1985, Geochim. Cosmochim. Acta, 49, 1943-1959.

Diagenesis and deformation of the metagreywacke-argillite suite (Goa Group)

G.Q. Fernandes[1], K. Mahender[1], S.D. Iyer[2]
[1]Goa University, Taleigao, Goa, India
[2]CSIR-National Institute of Oceanography, Dona Paula, Goa

The paper discusses the diagenetic and depositional aspects of the metagreywacke-argillite association of rocks of the Goa Group exposed along the coast of Goa from Pernem to Mormugao Taluka and in the hinterlands of Tiswadi Taluka, to assess the magnitude of mineralogical change and textural reorganization, which has been observed at large and has implications for understanding rates and mechanisms of element cycling through the crust. The framework components of metagreywacke-argillite association are angular to sub-angular with abundance of matrix of clay to

silt-sized detrital matter consisting of clay minerals with a variable amount of comminuted quartz, biotite, muscovite, chlorite and calcite. The abundance, composition and size of the framework grains along with the matrix components and cement type, greatly controls the texture of metagreywacke. Relict detrital rock fragments within the matrix are also identified.

The metagreywacke-argillite association has undergone various diagenetic processes prior to metamorphism, which include compaction, cementation, fracturing, dissolution, and replacement that affected the texture and composition of the sediments after their deposition until the early metamorphism. Compaction of quartz-rich materials occur at a slower rate than more ductile lithic-rich materials. The brittle crushing of mineral grains of quartz and feldspar identified can be recognized due to compactional mechanism. The pressure solution exhibited by quartz is greater than those due to feldspar. Pressure solution is consistently more in sandstones bearing argillaceous matrix such as greywackes and some arkoses than the pure varieties. But pressure solution is minimal in sandstones in which quartz grains are devoid of coating of clay bearing minerals. Cementation occurs as precipitation of mineral within primary intergranular pore spaces. This is seen with nucleation of quartz on the surfaces of some existing minerals. Cementation occurs in a localized manner. The rate of quartz cementation is faster in fine grained detrital materials than the coarser materials as the surface area of fine grained particles is larger. Observation of the pitted texture on the detrital minerals such as quartz and orthoclase owes its occurrence to surface-controlled mechanism of dissolution during diagenesis. Replacement occurs locally at the locus of dissolution. Late diagenesis at elevated temperatures, precipitating an authigenic phases induce the dissolution of an adjacent pre-existing phase. Detrital feldspars in greywackes and argillites are subject to dissolution and replacement during late diagenesis. Precipitation and dissolution may be essentially simultaneous. Fracturing leading to brittle and ductile tectonic deformation seems to occur during the late diagenesis stage. The microfractures and fractures are filled by authigenic phases due to cements and grain replacement.

Further, due to burial and metamorphism the framework composition of the clastic sequences is significantly altered. The association of metagreywackes and argillites shows low grade metamorphism of greenschist facies indicated by the characteristic minerals that are product of partial metamorphism. Metamorphic processes readily alter shales to argillites and greywackes to metagreywackes. Recrystallization of detrital quartz imparts a major reorganization in texture related to grains, cement and the interstitial pores space elimination. Hence, the extent to which the minerals are modified due to diagenesis is difficult to visualize due to metamorphism.

Compositional variability of Mesozoic glauconites in response to depositional conditions

Udita Bansal
Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400076
uditabansal.geo@iitb.ac.in

Glauconite is abundant in Mesozoic, possibly because of warm seawater condition and existence of wide shallow shelf. This study explores the relationship between chemical composition of Mesozoic glauconites and depositional setting on the basis of detailed petrography, mineral chemistry, trace element and REE analysis. Glauconite samples are investigated in their stratigraphic context, from Karai Shale Formation (Albian-Middle Turonian), onshore of Cauvery Basin, Ukra

Member (Aptian) of Kutch Basin, Bryozoan Limestone Member of Bagh Group (Albian-Campanian) and Lameta Formation (Maastrichtian) of Narmada Basin. In all these examples, glauconite occurrences coincide with major transgressions related to second order esutatic sea level rise. While glauconite in the Karai Shale formed in outer shelf that in the Ukra Member originated in middle to inner shelf environment; it formed in littoral condition in the Bryozoan Limestone Member and the Lameta Formation. Glauconite usually occurs as an altered form of fecal pellets and K-feldspars, as infillings within bioclasts, and as vermiforms, replaced after degraded micas. Our study indicates that maturation of glauconite, usually inferred on the basis of K_2O content, not only depends on sedimentation rate, but also on the substrate composition. Although the average K_2O content of all glauconites suggests an 'evolved' stage of maturation, the least 'evolved' glauconites in the Karai Shale indicates predominant control of substrate on maturation. The K_2O content of glauconite is, therefore, found to be directly linked to the composition of substrate, and unrelated to sedimentation rate as envisaged earlier. The K_2O contents of the Lameta (av.7.56%), Bryozoan Limestone (av.7.01%) and Ukra glauconites (av. 7.01%) are higher than that of the Karai Shale glauconites (av.6.28%). This is attributed to their formation in K-feldspar and fecal pellet substrates. K_2O content of glauconite is high in K-feldspar and fecal pellet substrates, while it is low in glauconites formed within bioclast and degraded micas. The total Fe_2O_3 content of glauconite in the Karai Shale (av. 25.03 %) and Ukra (av. 24.25%) are much higher, than that in Bryozoan Limestone (av. 15.06%) and Lameta (av. 16.69%). Redox condition of the depositional setting possibly influenced the total Fe_2O_3 content, as reducing pore water is more favourable for the mobility of Fe. The least content of total Fe_2O_3 found in glauconites within the Bryozoan Limestone Member and the Lameta Formation suggests relatively more oxidizing conditions during the formation of glauconite in shallow marine environment. The highest Fe_2O_3 total content of glauconite in the Karai Shale Formation is possibly related to slightly reducing conditions. Ce anomaly data corroborates the slightly more anoxic condition for the Karai Shale compared to other cases. This study, therefore, demonstrates the relationship between glauconite composition and depositional environment and indicates that mineral chemistry of glauconite may be useful for understanding depositional conditions.

Sedimentation dynamics in Kolhan basin

Smruti Rekha Sahoo
Department of Geology and Geophysics, IIT Kharagpur, Kharagpur 721302
smruti@iitkgp.ac.in

The Paleoproterozoic Kolhan ensemble constitutes the youngest lithostratigraphic 'outlier' within the Singhbhum Archaean craton. It unconformably overlies the Singhbhum granite and represents a typical sandstone-shale (+/- carbonate) sequence, and characterized by the development of thin and discontinuous patches of basal conglomerates draped by sandstone beds. The Iron Ore Group (IOG) fault limits the western 'distal' margin of the Kolhan basin.

The assumption of a tectonic setting for the NE-SW trending Kolhan basin possibly relates to the basin opening to the E-W extensional stress system that prevailed during the development of the Newer Dolerite dykes. The Kolhans show progressive change towards greater textural and mineralogical maturity in their upbuilding. The trend of variations in different mineralogical and textural attributes, however, exhibits inflections at different lithological levels. Petrological studies collectively indicate that the sandstones were dominantly derived from a weathered granitic crust

under a semi-dry climatic condition; provenance-derived variations in sandstone compositions are therefore a key in unraveling the regional tectonic histories. The basin axis controlled the progradation direction which was likely driven by climatically induced sediment influx and the incongruent shift and increased sediment supply permitted the rivers to cross the basinal deep.

The sedimentation pattern in the Kolhan reflects a change from a fan-delta to a lacustrine type. The channel geometries and the climate exerted a major control on the processes of sediment transfer. The marked variations in the thickness of the fan-delta succession and the stacking pattern in different measured profiles reflect the overriding tectonic controls on fan-delta evolution. Such a fan-delta could be a stratigraphic response of the connected rift basins at the early stage of extension.

A strong asymmetry in the vertical basin architecture is presumed to have developed in an elongated trough during the initial basin rifting stage, while the later stage is marked by the progressive overlaps and coalesces of the facies builtup. The sedimentation in the lacustrine fan-delta probably took place in a NE-SW elongated continental rift basin, compartmentalized by N-S and E-W trending intrabasinal faults. The basin-fill architecture was probably determined by tectonic evolution, as well as by inherited characteristics of the source area.

New insights into the comparison of tidalites in siliciclastics and carbonate systems: An outstanding example from Proterozoic Simla basin, western Lesser Himalaya, India

Tithi Banerjee*, Ananya Mukhopadhyay, Alono Thorie, Priyanka Mazumdar
Department of Earth Sciences, Indian Institute of Engineering Science & Technology, Shibpur
**tithi.geol@gmail.com*

Significant progress has been achieved in the research of tide-dominated environments in the past two decades. These studies highlight both the importance and diversity of tidal deposits. Development of better tools for recognizing tidalites (e.g., tidal bundles and tidal rhythmites) has also revealed that such deposits are much more common and extensive than previously thought (Eriksson., 2012). Several examples of ancient tidalites have been reported from all over the globe in previous literatures (Fan *et al.*, 2004; Yang *et al.*, 2008). But comparison of ancient tidalites recorded in both siliciclastics and carbonates has not commonly been sited this far. The Proterozoic Simla Basin, Lesser Himalaya serves a unique example in this regard. An attempt has been made in the present work to differentiate sedimentary facies and architectural elements of tidalites in both siliciclastics and carbonates recorded in the Simla Basin. Lithofacies and microfacies analysis led to identification of 11 lithofacies and 4 architectural elements from the siliciclastics, 6 lithofacies and 3 architectural elements from the carbonates. The most diagnostic features for comparison of the two tidalite systems are sedimentary structures, textures, and architectural elements. The physical features such as flaser-lnticular bedding, mud/silt couplets, tidal rhythmites, tidal bundles, cross stratified successions, tidal bars, tidal channels, microbial structures are common to both the environments. The architecture of these tidalites attests to sedimentation in shallow subtidal to intertidal flat facies, affected by intermittent reworking by open marine waves/storms (Fan *et al.*, 2004; Yang *et al.*, 2008). The seventeen facies attributes were categorized into two major facies belts (FA1 and FA2). FA1 represents a prograding muddy pro-delta deposit whereas FA2 bears the signature of an inner-mid carbonate ramp deposit. Facies distribution indicates development of

highstand systems tract (HST). The aggradational to progradational bedsets record the history of slow rise in sea level.

Eriksson, K. A., Simpson, 2012. Eds. pp. 397-420, Springer, Heidelberg, Germany.
Fan, D. D., Li, C. X., Wang, D. J., Wang, P., Archer, A. W., Greb, S. F., 2004. Journal of Coastal Research, 43, 23-35.
Yang, B. C., Gingras, M. K., Pemberton, S. G., Dalrymple, R. W., 2008. Geology 36, 39-42.

Anatomy of a thinly bedded distal turbidite: insights from a Proterozoic fan delta system, Simla Group, western Lesser Himalaya, India

Priyanka Mazumdar*, Ananya Mukhopadhyay, Tithi Banerjee, Alono Thorie
Department of Earth Sciences, Indian Institute of Engineering Science & Technology, Shibpur
**priyancam8@gmail.com*

Turbidites have captioned a lot of attention of sedimentologists during the last decades. However, their relationship to delta systems still deserves further attention. This paper addresses example of fine grained turbidite from a pro-deltaic sub-environment of a Proterozoic fan delta system exposed in the surroundings of Rahana village of the Chhaosa Formation of the Simla Basin. Detailed process-based facies and paleoenvironmental analysis of the study area have led to identification of more than 150 m thick coarsening-upwards deltaic successions composed of fine grained turbidites overlain by delta slope deposits. Erosional features are locally common at the base of turbidite beds and still more widespread at the top. The complete sequence has nine sub-divisions that are here termed T_1 to T_8. "The lower subdivision (T_1) comprises a massive graded unit with a sharp, scoured base, internal parallel-lamination and cross-lamination. The overlying sequence shows textural and compositional grading through alternating silt and mud laminae (T_2). T_2 is overlying by T_3 which is characterised by climbing ripple and cross lamination. Parallel laminae are the predominant facies attributes of T_4 which caps the T_3 unit. T_5 has a loaded scour base and is mainly characterized by laminated silt. The topmost three divisions, graded mud (T_6), ungraded mud (T_7) and laminated mud (T_8). The proposed sequence is analogous to the Bouma (1962) structural scheme for sandy turbidites. The repetition of partial sequences represents deposition from different stages of evolution of a large, muddy, turbidity flow Detailed facies analysis of the study area reveals that the sediments of the turbidites developed during normal regression at the stage of stable or marginally rising sea level. The thin bedded turbidites were deposited predominantly by turbidity currents in the relatively shallower part of the Simla basin. The fine grained turbidites are developed by resedimentation of delta-front sands and slumping of upper pro-delta muds.

Badalini, G., Kneller, B., Winker, C., 2000. Deep-Water Reservoirs of the World, GCSSEPM Foundation 20th Annual Research Conference pp 16-34
Bouma, A.H., 1962. Elsevier, Amsterdam pp. 168.

Reminiscence of algal activities (Microbially influenced sedimentary structures/MISS) from a storm-wave influenced Proterozoic siliciclastic tidal flat, Kunihar Formation, Simla Group, Himachal Pradesh

Alono Thorie*, Ananya Mukhopadhyay, Priyanka Mazumdar, Tithi Banerjee
Department of Earth Sciences, Indian Institute of Engineering Science and Technology, Shibpur
**allan_thr@yahoo.com*

Considerable imprints of algal activities in the form of microbially influenced sedimentary structures (MISS) have been documented alongside siliciclastic tidal flat deposits in the upper part of Proterozoic Kunihar Formation, Simla Group, Himachal Pradesh. MISS have been recorded from five major siliciclastic facies - (i) wave influenced sandstones (FA1), (ii) storm dominated sandstone-siltstone facies (FA2), (iii) tide dominated sandstones (FA3), (iv) heteroliths (FA4) and (v) laminated siltstones (FA5). Exertion of Periodic wave and storm activities are manifested by sedimentary structures such as hummocky cross stratifications, flaser-lenticular bedding, mud/silt couplets, herringbone cross-bedding, oscillation and interference ripples (Thomson et al., 2014). These structures indicating storm-wave influence reflects deposition in supratidal to intertidal domains. MISS structures such as gas domes, gas dome collapse structures, wrinkle structures, kinneyia ripples, palimpsest ripples, sand chips, patchy ripples, etc. are prevalent in these siliciclastic tidal flat. Extrusion of gas from decaying organic matter from the base of algal mats gave rise to gas domes and dome collapse structures. Water absorption and subsequent dessication of microbial mats, gas build-up and wave current, from mat decay stimulated the emergence of wrinkle marks on sandstone surfaces (Gerdes et al., 2000; Banerjee & Jeevankumar, 2005). Limited sedimentation and insignificant erosion produced palimpset ripples (Schieber et al., 2007). Wave activity deposited lags of rounded to sub-rounded sand chips (Gerdes et al., 2000). Alteration of first generation ripples by second generation ripples fostered the development of patchy ripples. Limited dessication cracks resonates insignificant exposure to air associated with cohesive microbial mats on sediment surface (Schieber et al., 2007). Rampant load casting in several pockets reflect synsedimentary deformations (Owen and Moretti, 2010). Development of MISS structures was provoked by development of resistant substratum, favourable energy conditions, consistent water supply and low terrigeneous input in a tidal flat environment where low sediment input between depositional episodes gave sufficient time for algal activities to flourish (Seilacher et al., 1998). The MISS bearing siliciclastic tidal flat deposits of Kunihar Formation with associated signatures of storm-wave activities reveal the ongoing processes and energy conditions in tidal domains during Proterozoic eon.

Banerjee, S., Jeevankumar, S., 2005. Sedimentary Geology 176, 211-224.
Gerdes, G., Klenke, T., Noffke, N. 2000. Sedimentology 47, 279-308.
Owen, G., Moretti, M., 2010. Sedimentary Geology 235, 141-147.
Schieber, J., Bose, P.K., Eriksson, P.G., Banerjee, S., Sarkar, S., Altermann, W., Catuneau, O., 2007. Atlases in Geosciences. Elsevier, Amsterdam, p. 311.
Thomson, D., Rainbird, R. H., Dix. G., 2014. Sedimentary Geology 299, 119-138.

Thickness of sedimentary sequence and basement configuration in Wagad uplift, Kachchh basin, northwestern India

Virender Kumar Choudhary, Mehul Nagar, Dilip Singh, Mahendar, Pruthul Patel, G. Pavan Kumar, Kapil Mohan
Institute of Seismological Research (ISR), Raisan, Gandhinagar 382007

The Kachchh basin is an east-west oriented peri-cratonic Mesozoic-Tertiary rift basin on the western margin of the Indian shield (Biswas, 2005). The Wagad region is one of the uplifted hilly terrains of the basin showing intense seismic activity and vertical/lateral deformations comprising a thick pile of Mesozoic sediments. The Mesozoic and Tertiary sediments in the basin are potential sources for not only petroleum resource but also for seismic hazard in which the ground motion is significantly amplified in sedimentary basins compared to hard rock environs. To map the thickness of the sedimentary sequence and basement configuration of the Wagad uplift, a magnetotellurics (MT) survey has been carried out along an 60 km long ~N-S profile cutting various faults during Nov. 2015 - Jan. 2016. MT data of 4 days recording duration at 18 sites are recorded using ADU-07e [Metronix, Germany] recording system. Pb-$Pbcl_2$ electrodes and induction coil magnetic field sensor (MFS-06e) are, respectively, used for measuring electric and magnetic components of the secondary electromagnetic (EM) fields. MT impedance tensors of broad frequency range (0.001-1000s) are computed after preprocessing of the data using MT processing package MAPROS (Friedrichs, 2003).

Dimensionality analyses by Groom-Bailey technique (Groom & Bailey, 1989), phase tensor approach (Caldwell et al., 2004) and Becken and Burkhardt method (Becken & Burkhardt, 2004) suggest that one dimensional (1-D) approximation can be made for the data at least up to 10 s. A 10 km deep resistivity section after combining all the 1-D results of the 18 sites using the Occam inversion technique (Constable et al., 1987) shows a conducting layer of approximately 1.2-2.0 km thick with less than 20 Ω.m representing the presence of sediments all along the profile underlain by the fractured basement of resistivity 100-200 Ω.m. A high resistive block of resistivity >500 ohm.m is observed in the middle portion of the profile might represent the mafic intrusion from the lower crust. However, detailed 2-D/3-D modelling of the data can resolve the nature of the resistive block. The findings of the study could be useful for estimating the seismic hazard of the study region.

The record of base-profile changes in the upper terrestrial division of the early Cretaceous Bhuj Formation, India

Amlan Koner*, Subir Sarkar
Department of Geological Sciences, Jadavpur University, Kolkata 700032
**amlankoner@gmail.com*

The topmost terrestrial division of the Early Cretaceous Bhuj Formation, Kutch, India is up to 60 m thick in its eastern exposures and further divisible in five discrete stratigraphic intervals, superposed one above another. The 13 m-thick basal interval is of poorly sorted, coarse to medium-grained and generally cross-stratified sandstone depicting vertical stacking of three fluvial channel belts and thereby implies overall rise in the base profile. Architectural element consortium, channel pattern and other hydraulic parameters underwent significant changes temporally implying unsteady nature of the rate of this course of rise in base profile. The next younger ~ 8.3 m-thick interval is of

comparatively finer-grained and planar laminated sandstone of putative crevasse splay origin occasionally intervened by thin bodies of rootlet-infested mud of possible flood-plain origin. Evidently aggrading this interval developed in the background of base profile rise at a rate higher than before. Drop in the rate of weathering and sediment leaching at the mid-level of this interval indicates fluctuation in the rate of base profile rise even in this phase of aggradation. The third interval, ~ 2.5 m thick, is of mudstone, locally encasing small and isolated channel sandstone bodies. Being interpreted as amalgamated flood-plain deposit locally encasing anastomosed channel sandstone this interval is indicative of significantly enhanced rate of base profile rise. High rainfall rate ensured lush growth of vegetation, presumably of C_3 category as indicated by $\delta^{13}C_{org}$ in the range between -22.7 to -26.8‰ PDB. Enhanced rate of organic carbon preservation within the 3rd interval with respect to the 2nd interval is consistent with this contention of enhanced rate of base profile rise in the 3rd interval. The upward succeeding 4th interval, ~ 18 m thick, is, however, of stacked channels once more indicating a significant fall in the rate of base profile rise. The rate of fall further increased as the interval passed upward into an aeolian succession of dune-interdune alternations measured up to 16 m. Excellent preservation of aeolian dunes indicates significantly high sediment budget.

Mass flows from the Paleo-proterozoic Bayana sub-basin; decoding rheology, grain-support mechanism and depositional style

Sagnik Basu Roy*, Priyabrata Das
Department of Geological Science, Jadavpur University
**sagnikiitkgp1985@gmail.com*

Subaqueous gravity-induced flows are common and integral component of marine deltaic settings. In Precambrian, provocation for aggressive rate of denudation in the presence of greenhouse climatic condition, abundance of steeply sloping ephemeral streams and flashy river-discharge in absence of land vegetation allowed excess availability of coarser clastics at river mouths. As a result, excess sediment load and high pore-fluid pressure triggered frequent slope failures and generated gravity induced mass flow events in deltaic settings. In addition to the above mentioned factors, high rates of accumulation and mass failures can also be initiated by tectonic instability in a basin or they may be a result of a combination of all above mentioned reasons. The present study documents gravity flow products from Paleoproterozoic Bayana sub-basin in North Delhi fold belt and focuses on operative flow processes and thus highlight role of mass flow processes in subaqueous mass transfer in a rift-fill basin setting.

The ~1300 m thick, NW-SE striking, weakly metamorphosed Nithar Formation of the Alwar Group overlies Pre-Delhi metapelitic basement and records initial deposition history of the Bayana sub-basin. While the lower part of the Nithar Formation is represented by multiple cycles represented by fluvial to shallow marine transition; amalgamated volcanic layers with limited interleaved sedimentary cycles comprise the upper part. The present study takes into account the upper part of the Nithar Formation, where a series of thick, laterally restricted, polymictic conglomerate horizons interleave with parallel-bedded, poorly sorted, coarse grained pyroclast rich sandstones deposited immediately after the termination of major phase of volcanic eruption.

The present study attempts a process-based sedimentological analysis in a ~2 km long NE-SW trending stretch across the Sita village reservoir section in the upper part of Nithar Formation in order to delineate genetic processes involved in origin of conglomerates. Ten genetically different

conglomerate/ coarse-sandstone litho-facies types were delineated from three different stratigraphic levels. The litho facies are a) disorganised clast-supported (boulder) conglomerate; (b) inverse- to normal-graded clast-supported (boulder) conglomerate; (c) stratified conglomerate with sandy matrix; (d) single-train cobble-pebble sheet conglomerate; (e) massive granular sandstone; (f) plane laminated granular sandstone; (g) crudely stratified fine grained sandstone; (h) Cobble-pebble bearing cross bedded sandstone; (i) massive/normal graded sandstone; and (j) Pyroclastic rich thinly laminated sandstone. A wide range of flow rheology and grain support mechanisms spanning between laminar, cohesive to turbulent/ dispersive non-cohesive characters are interpreted, which include debris flow, bipartite hyper-concentrated flow, sustained high-density grain flow, and turbulent flow.

Operation of a wide variety of subaqueous mass flows having a wide spectrum of rheological character is commonly described from deltaic settings, particularly in case of hyperpycnal deltas where accumulation of voluminous sediment at the delta mouth trigger intermittent sediment shedding in form of mass flows with varying sediment-water content and rheology. Further, movement of mass flows along steeply dipping slopes of delta can cause transformation of mass flows into bipartite flows and flows of varying rheology while travelling. Repeated cycles comprising deposits ranging from rock fall to non-cohesive turbulent flow suggests unstable deltaic condition operating in the upper part of Nithar depositional history.

Significance of trace fossils from Bhuj Formation (Cretaceous) exposed in Mainland Kachchh, Western India

Suruchi Patel[1], Bhawanisingh G. Desai[2]*, Darshit Padiya[3]
[1]Department of Earth and Environmental Science, Kachchh University, Bhuj, Kachchh
[2]School of Petroleum Technology, Pandit Deendayal Petroleum University, Gandhinagar
[3]Department of Geology, R. R. Lalan College, Bhuj Kachchh
**bhawanigd@gmail.com*

The Kachchh paleorift basin is a classical basin situated in western India. It comprises of syn and post rift sediments belonging to Jurassic and Cretaceous age. The complete Mesozoic sedimentary package shows a transition from initial continental environment to marine environment and finally to fluvio-deltaic environment. These sediments are well exposed in six tectonically uplifted islands namely Kachchh Mainland, Patcham, Khadir, Bela, Chorar and Wagad. The youngest Mesozoic sediments belonging to Early Cretaceous post rift sedimentation is well known as Bhuj formations. The Bhuj Formation is well exposed in Kachchh mainland especially in in Northern Hill and Katrol Hill Ranges. Bhuj formation is interpreted to be deposited under deltaic environment. Bhuj formation was studied for its integrated ichnological and sedimentological aspect to understand the significance of trace fossils assemblage and ichnofabric in delineating various depositional processes. A closely spaced sections belonging to Guneri Member of Bhuj Formation exposed in the Katrol hill range was studied. The sections comprises of shale and sandstone alternations with coarsening upward sequence and fluctuating bioturbation. The coarsening upward sequence shows well preserved sedimentary structures with most of the structures are well preserved in layers where the bioturbation is minimum. Trace fossils show low to moderate diversity of trace fossils represented by recurring traces of dominantly suspension feeding organisms are present and include *Diplocraterion sp*, *Palaeophycus tubularis*, *Psilonichnus isp; Skolithos linearis*. However bioturbated horizons show variation from Bioturbation Index 1 to Bioturbation Index 6. There are

cycles of high bioturbation (BI-5 to BI-6) alternating with low bioturbated beds (BI-0 to BI-2). Trace fossils shows diagenetically enhanced trace fossils showing simple tier and multiple-colonization. The diversity of trace fossils is low to moderate. These bioturbated horizons are cross cutted by rooted horizons which indicates overall environment shift. Systematic analysis of the integrated ichnology and sedimentology like cyclic bioturbation, rooted horizons indicates several episodes of deltaic lobe progradation and abandonment processes as a result of variation in hydrodynamic energy conditions, fluctuation rate of sedimentation and sea level fluctuations.

Facies characteristics and sedimentation model of the Lower Siwalik Group of southeastern Uttarakhand, India

Tanuja Deopa*, Pradeep K. Goswami
[1]Centre of Advanced Study, Dept. of Geology, Kumaun University, Nainital 263002
**deopa.tanu@gmail.com*

Systematic lithofacies and palaeocurrent analyses have provided detailed information about the Middle Miocene fluvial sequence the Himalayan foreland basin in south-eastern Uttarakhand state. Three distinct lithofacies associations, each representing a specific depositional setting, have been identified and named as 'Facies Association A', 'Facies Association B' and 'Facies Association C'. Each of these associations consists of one or more of eight distinct lithofacies. The sandstone dominated lithofacies association 'A' suggests deposition mainly by 0.09-2.0 m/s flowing traction currents in braided streams. The sandstone-mudstone dominated lithofacies association 'B' suggests deposition by 0.1-1.0 m/s flowing traction currents as well as suspension fallout in meandering streams and adjoining overbank areas. The mudstone dominated facies association 'C' is characteristically pedogenically altered and disassociated with any major channel sandstone body. It represents reworking of pre-deposited sediments by ephemeral sheet and shallow channelized flows in the upland interfluve regions. The regional radial outward palaeoflow pattern indicating convex-up transverse surface profile, dominance of fine to medium sized sand and general absence of coarser extrabasinal clasts suggest that this distributive fluvial system of meandering and braided streams was located in the middle-distal part of a megafan.

Clay mineral assemblage of the Lower Siwalik Nahan Formation in the type area Nahan, northwestern Himalaya

A.R. Chaudhri, Rajesh Ranga*
Department of Geology, Kurukshetra University, Kurukshetra 136119
**rajeshranga333@gmail.com*

Clay mineralogy of the Middle Miocene Nahan Formation of the type area, northwestern Himalaya, India, has been investigated to understand the palaeoclimatic and palaeotectonic conditions in the frontal Himalayan terrain. The clay minerals were investigated by X-ray diffraction analysis. Study of the oriented aggregates of 35 representative clay samples of the Nahan Formation of the type area reveals that illite is the most dominant mineral followed by kaolinite, vermiculite, and chlorite and mixed layer clay minerals. The distribution of the clay minerals in the three measured sections of the Nahan Formation, namely the Shambhuwala - Nahan section, the Renuka - Nahan section and the Sataun - Rajban section is nearly uniform suggesting thereby the prevalence of

similar sedimentation environments in the Himalayan foreland basin. The presence of illite and kaolinite suggests their derivation from crystalline rocks containing feldspar and mica as also from pre-existing soils and sedimentary rocks. Further, the palaeoclimatic conditions were moderate. Vermiculite has been mainly formed by weathering and transformation of biotite. Warm and humid climatic conditions prevailed for a major part during the deposition of the detritus which favored weathering and transformation of minerals.

Palynofacies analysis *vis-a-vis* environment of deposition of Subathu Formation of Nilkanth area, Uttarakhand

R. Panwar*, O.P. Thakur, N.N. Dogra
Department of Geology, Kurukshetra University, Kurukshetra 136119
**rashmipanwar2009@gmail.com*

The present paper deals with palynofacies analysis of Subathu sediments of Nilkanth area, District Pauri Garhwal, Uttarakhand. The samples having yielded the present palynofacies spectrum were collected from the Subathu Formation outcropping along Nilkanth-Parvati temple road. The samples collected from this area were processed with standard processing techniques of treatment with HCl followed by HF to recover the dispersed organic matter, for the palynofacies analysis serve as a valuable tool for meaningful interpretation of the depositional environment of any basin. In the present sediments, the moderate to rich organic matter is recovered which is dominated by grey amorphous organic matter followed by biodegradable terrestrial, black debris, fungal remains, structural terrestrial, spore/pollen and structural aqueous organic matter in decreasing order. The frequency variation pattern of the palynofacies documented in these sections reflect dominant reducing/anaerobic conditions in the area. In addition, microbiota recovered in the present studies from these sections comprising dinoflagellates, acritarchs and foraminiferal linings infer marine influence into the area along with anoxic conditions during the sedimentation/deposition of Subathu horizon.

A Coconut Like Fruit Fossil from the Palaeocene Sediments of Barsingsar Lignite Mine, Bikaner Basin, Western Rajasthan, India

Sikander*, O.P. Thakur, N.N. Dogra
Department of Geology, Kurukshetra University, Kurukshetra
**skhan602@gmail.com*

A fossil fruit resembling extant *Cocos sp.* of the family Arecaceae is reported for the first time from the Palaeocene Palana Formations at Barsingsar Lignite Mine, Bikaner, Rajasthan, and Western India. The Palana Formation comprises Glauconitic silts clay, Lignite with intercalations of carbonaceous clay, variegated clay, and medium to coarse grained ferruginous sandstone in the ascending stratigraphic order. The present fossil specimen has been recovered from the variegated clays during the field trip undertaken in the month of April, 2014. The occurrence of coconut fruit in the Palana Formation of this region indicates coastal-deltaic conditions prevailing at the time of its deposition in contrast to the present day arid to semi-arid climate. In addition to the coconut like fruit, Arecaceae pollen and significant amount of Resin has also been documented from the lignite samples of this mine and are additional supporting evidences towards its depositional environment i.e. Coastal-deltaic to marginal marine.

Distribution pattern of REE in surficial sediments from the tropical estuary in northern Kerala, India and their significance

B. S. Praseetha*, T.N. Prakash
National Centre for Earth Science Studies (NCESS), Akkulam
**praseethabs@gmail.com*

The present study attempts to define the trend and concentration of Rare Earth Elements (REEs) and heavy metals in the sediments of Beypore estuary, northern Kerala, India. Beypore is a tropical estuary situated in the northern part of Kerala, South-West coast of India. The estuary receives inputs from Chaliyar River. The Chaliyar River is the third largest river in Kerala along with its tributaries contributes water to the estuary. For the present investigation 16 estuarine sediment were collected during pre-monsoon and mosoon seasons of 2015 (April, 2015 & Sep., 2015).

A Rare Earth Element (REE) is one of the set of seventeen chemical elements, specifically the fifteen lanthanides, as well as scandium and yttrium. The rare earth elements like La, Ce, Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm, Yb, Lu, and heavy metals like Cu, Cr, Co, Zn. Mn, Fe, V,U ,Th were analyzed using standard Perkin Elmer SCIEX (Model 6100 ELAN DRCII) ICP-MS at the National Geophysical Research Institute, Hyderabad, India. MESS-3 is used as the reference material for the REE analysis. The post-Archean Australian Shale composition was used to normalize the rare earth elements. The concentration of REE in the upper estuarine sediments are found to be lower than that in the lower reaches of the estuary. Shale normalized pattern indicated dominance of LREE over HREE. Earlier studies in the nearby area reported that the NASC normalized values signify one tenth reduction of lanthanide concentration in the estuarine sediments compared to the shales. The geochemical attributes also show a characteristic spatial patterns, where the samples in the downstream region (towards sea) have relatively higher concentration, while the samples from the upstream region have lower concentration. A clear increasing trend is observed from upstream to downstream region of the estuary. REE concentration increase downstream suggesting the additional supply from the nearby region. The Ce anomalies of the studied area varies from -0.0215 to 0.039. Ce- anomaly is positive in stations ST-1, ST-3, ST-5, ST-7, and ST-8 shows the predominance of toxic environment except few stations. Majority of the sediment shows positive Eu anomaly indicates that the REE originated may be from a feldspar dominant terrain.

Grain size analysis and characterization of sedimentary environments along Harnai to Ladghar coast, central West Coast of Maharashtra, India

Milind A. Herlekar*, Prafull Kamble, Jayant Shinde
Department of Geology, Savitribai Phule Pune University, Pune 411007
**milindk@unipune.ac.in*

The sediments of the beaches along the Central West Coast of Maharashtra from Harnai to Ladghar were studied for their textural parameters. 62 sediment samples collected from Foreshore, backshore, raised beach and dune of different microenvironment were analysed. The sand that are found on beaches in coastal settings provides a wealth of information about transport pathways and the history of energy delivery at coastal places. The sedimentary environment is significantly composed of textures having very fine sand to medium sand, well sorted to moderately sorted, symmetrical to very skew and leptokurtic to mesokurtic. Abundance of the medium to very fine sand

shows the prevalence of comparatively moderate to low energy condition in the Harnai to Ladghar area. Frequency distribution curves for all along the coastal sediments differ in their modal class showing unimodal to bimodal trend. Symmetrical skewed sediments distributions on the majority of coast indicate slow rate of deposition whereas negatively to positively skewed sediment distribution indicate strong winnowing and deposition. Gradual decrease in mean grain size from Harnai (north) to Ladghar (south) beach indicates the direction of movement of sediments towards south and southwest of the Panchnadi.Linear Discriminant Function Analysis (LDF) of the samples indicates a shallowmarine environment origin for majority of samples. These results show thatreworked sediments, submerged during the Holocene marine transgression, arebeing deposited on present-day beaches by waves, currents and rivers in the studyarea.

Folk R.L., and Ward W.C., 1957. Journal of Sedimentary Petrology, 27(1), 3-26.
Friedman G.M., 1961. Journal of Sedimentary Petrology, 31(4), 514-529.
Friedman G.M., 1979. Sedimentology, 26(1), 3-32.
Mislankar P.G., and Antao F.B., 1992. Indian Journal of Earth Science, 19 (2-3), 70-78.
Sahu Basanta K., 1964. Jour. of Sed. Petr., 34(1), 73-83.

Architectural elements and paleohydraulic analysis of fluvial part of Sandhan Formation, Western Kutch, India

Shubhendu Shekhar*, Pramod Kumar
Department of Geology, Center for Advanced Studies, University of Delhi, Delhi 110007
**shekhar.shubhendu.gmail.com*

The deposition during relative sea-level fall produces a distinctive sedimentary package known as *falling stage systems tract* (FSST), which is the logical counterpart to the transgressive systems tract (TST). The FSST lies above and basinward of high stand systems tract (HST). It is characterized by strata offlap, however rarely recorded due to subsequent subaerial or transgressive ravinement erosion. The unique setup is recorded in the terminal Cenozoic succession of western Kutch (Sandhan Formation) where the HST is bounded at the top by the basal surface of forced regression, characterized by abundant fluvial channel lags occurring at top of the beach barrier complex followed by various fluvial architectural elements culminating towards the top into a thick regional paleosol indicating an upper sequence boundary. Thick poorly sorted fluvial sediments of braided nature deposited above the HST due to sudden/rapid relative sea-level fall are regarded as FSST. The siliciclastic dominated Sandhan Formation is well exposed along cliffs and banks of the Kankawati River. Its (type section) is characterized by a lower marine part (135m) and an upper fluvial part (157m). The aim of architectural element analysis is to identify and understand the type of fluvial system (Miall, 1985). Six architecture elements of fluvial system are identified: Channel element CH - stacked sheet sand bodies, Sandy Bedform SB - tabular sand bodies dominated by planar laminations and tabular crossstratification, Downstream Accretion Element DAE - consists of cosets of trough crossstratified sandstones interspersed with coarse grained gravel deposits, Compound Bar Element CBE - amalgamation of unit bars dominated by coarse troughcross sandstones finingup to tabular sand bodies, Overbank Fines OF - represent fine sediments deposited on top of bars and banks, Gravel Bars and bedforms GB - represented by troughcross stratified and planar crossstratified gravel. Paleohydraulic analysis was carried out to understand the flow dynamics and energy condition at the time of deposition. The steep slopes observed in the area might have been the manifestation of local tectonics that led to local uplift and fall in base level resulting into the formation of a steep sloped braided fluvial system with high flow dynamics which can easily

explain the dominance of ill sorted, gritty, gravel bedforms, gravity flow patterns and coarse clasts. The upper part of the Sandhan Formation is interpreted as a FSST of high energy braided deposits. The architectural element analysis of upper part of the Sandhan Formation suggests intermittent high energy braided fluvial system. The paleohydraulic analysis suggests a high slope and thus a high energy braided river system. The occurrence of braided river system over shallow marine HST indicates an abrupt fall in relative sea-level or base level fall which triggered the initiation of fluvial system. The forced regressive FSST led tothe final withdrawal of marine condition from onland part of Kutch, eventually shifting the depositional milieu westward (i.e. present continental shelf of Arabian Sea) and closing the onland sedimentation/basin.

Clay mineralogy of a Chambal River section, central India

Rohit Kumar, Vimal Singh*
Department of Geology, Chhatra Marg, University of Delhi 110007
**vimalgeo@gmail.com*

The Cratonic Rivers provide significant sediment flux to the Himalayan foreland. Out of all the cratonic rivers, the Chambal River is comparatively largest. Due to incision by the Chambal River, a highly dissected topography - also called as the Chambal badlands - has developed. The badlands bound the southern margin of the Indo-Gangetic Plains and are unique landforms in the region. For long, due to unfavourable conditions not many studies have been carried out in this region. In this study, we investigate the sediments from the banks of the Chambal River and attempt to interpret the paleoclimate. The present study area lies in the lower Chambal valley around Dholpur city. The lower Chambal valley mainly comprises of Vindhyan Super group, Aravalli super group, Gwalior Group and alluvium. We have investigated two sequences in this study - one along the Chambal River and other in the interfluve at the margin of the Chambal badlands. The main clay mineral assemblage of the Chambal River bank section near Dholpur consists of Vermiculite, Chlorite, Kaolinite and Mica. The clay mineral weight percentages distribution at Dholpur are Chlorite (26-68%), Vermiculite (35-62%), Kaolinite (4-11%) and Mica (6-11%). On the other hand, the major clay mineral assemblages at the margin of the badlands in the interfluve include Chlorite, Mica and Kaolinite. One sample (S2) shows some percentage of Vermiculite as well. The weight percentage of clay mineral at Raihna Devi Temple section comprise of Chlorite (11-27%), Mica (5-18%) and Kaolinite (9-17%). Analysis of the results suggest that the area has undergone at least three cycles of wet and arid periods. The basal unit in the bank section is rich in Vermiculite whereas another sample from same unit collected from higher elevation shows interlayering of Vermiculite-Chlorite, indicating a change in climate from wet and humid, to cold and arid. The gravel unit above the basal unit does not contain any dominant (>50%) clay mineral; the clay minerals present in it are mainly transported. The sandy fluvial unit above gravel beds is relatively rich in Vermiculite and Kaolinite indicating wet period. Noticeable decrease in Vermiculite and Kaolinite, and relative increase in Kaolinite is observed as we pass in to the overlying overbank deposits indicating a change from wet to arid period. Sample collected from a bed separated by few tens of meters in adjoining area and at nearly same elevation dominantly consists of Smectite indicating strong arid period. The samples collected from the interfluve section mainly show mineral assemblages (Chlorite and illite/Mica) representative of arid period. But there are few samples that show increased Vermiculite and Kaolinite content. As these are mainly found in the lacustrine facies, we surmise that these samples are mainly derived from older beds. Hence, we cannot infer much climatic information about these beds.

Molasse type sediments of Nubra Valley and their implications for the tectonic evolution of Shyok Suture Zone (SSZ), Ladakh Himalaya and Karakoram, India

Mujtuba Rashid*, Rakesh Chandra
[1]*Department of Earth Sciences, University of Kashmir, Hazratbal, Srinagar 190006*
**amrzubin@yahoo.co.in*

The subduction, collision and accretion of the Indian Plate along the southern margin of the Eurasian Plate resulted in a collage of terrains and the formation of Indus fore-arc basin and Nubra-Shyok back-arc basin. More than 50 km long molasse sediments of the Nubra-Shyok Valley accumulated in the north of Ladakh Magmatic Arc in response to India-Asia collision. The Nubra-Shyok back-arc sedimentary basin, which lies in the Ladakh Trans-Himalaya to the north of Leh city across Khardung La (5602m) is comprised of different lithological units sandwiched between Ladakh Batholith in the south and Karakoram Batholith in the north. The sedimentary sequence of SSZ is an important unit of its litho-tectanostratigraphy. It overlies the volcano-sedimentary sequence of Khardung belt in south of the valley with a north dipping thrust. The lower part of the sedimentary sequence consists of highly metamorphosed flyschoidal sediments, believed to be pre-orogenic in nature. The recrystallized limestone horizon exposed in the KhalsarDokNallah section yields a rich assemblage of Bryozoan fossils, identified as *Cheilostomata* of Late Jurassic age (Chandra et al., 1999). The Saltoro molasses of Nubra-Shyok Valley is a linear belt resting unconformably over the Saltoro Flysch and Shyok Volcanics at different places. All the lithological units of SSZ are thrusted to each other, the Saltoro Molasse is in thrust contact with ShyokOphiolitic Melange to its north and in the south it is thrusted with Shyok Volcanics and Saltoro Flysch. The distribution of molasse sediments shows variation in lithological characters, structure and their thickness across the Shyok Suture Zone (SSZ). The deposition of Saltoro Molasse sandstone and overbank silt and shale is caused by braided river system. The action of depositing the coarser bed load initiated mid-channel bar formation such as sandstone beds of sedimentary sequence. The bed forms are generally plane and few scouring at their bases. The sedimentary structures such as mud cracks and rain imprints suggest sub-areal and shallow marine environment. The molasse displays an overall decrease in pebble size in conglomerate and decrease in percentage of pebbles in groundmass

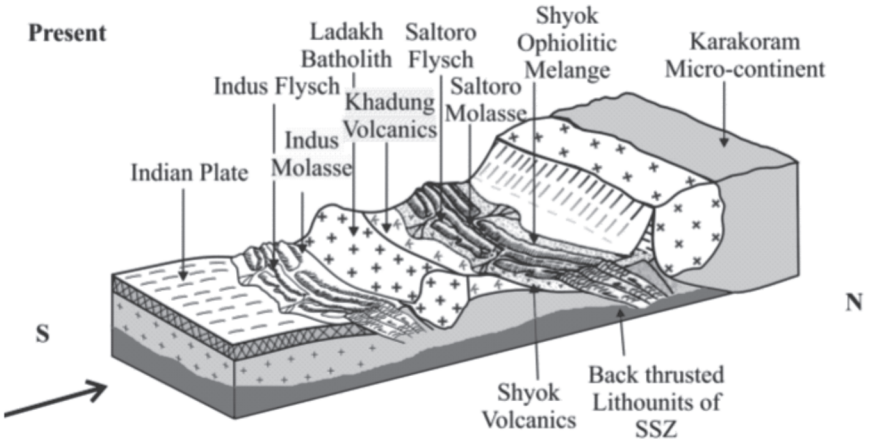


Fig. 1. Diagrammatic illustration showing the present position of Nubra-Shyok back-arc sediments of Shyok Suture Zone, Ladakh Himalaya. (Not to the scale)

away from the southern contact suggesting the initial deposition was adjacent to the Ladakh magmatic arc. Petrographic study of sediments reveals the presence of rhyolite and andesite pebbles in abundance, contributed by Khardung Volcanics. The presence of Khardung Volcanics of 52Ma age (Bhutani et al., 2009) suggests that the molasse sediments of Nubra-Shyok Valley are younger among the lithological units of SSZ and deposited during the Late Eocene. Tectonically, the sediments represent the back-arc sediments of Ladakh Arc resulted by the subduction and collision along Indus Suture Zone (ISZ). Due to the continuous northward movement of Indian plate the different lithounits of Shyok Suture Zone stacked and resulted in the further thrusting of the rock units (Fig.1). The Molasse sequence of Saltoro is almost vertical and dip around 75° due north at some place.

Chandra, R., Upadhyay, R. and Sinha, A. K., (1999) Paleobotanist, 48, 183-209.
Bhutani, R., Pande, K. and Venkatesan T.R., (2009) Jour. Asian Earth Sci., 34,168-177.

Structural studies in the Main Central Thrust Zone of the Munsiari area, eastern Kumaun Himalaya

A.K. Verma
Centre of Advanced Study in Geology, University of Lucknow, Lucknow 226007
akvgeo@gmail.com

The Main Central Thrust (MCT) is an important geotectonic element of the Himalaya along which the Central Crystalline Zone of the Greater Himalaya is thrust over the Sedimentary Belt of the Lesser Himalaya. A segment of the MCT has been studied in details in the area around Munsiari falling in the Pithoragarh District of Eastern Kumaun Himalaya. An area of about 400 sq km has been geologically and structurally studied. The study area exposes in two litho-tectonic subdivisions Kumaun Himalaya: (a) Central Crystalline Zone (CCZ) to the north and (b) a part of the Inner Sedimentary Belt of Kumaun Lesser Himalaya. The contact of the CCZ with the sedimentary belt is defined by the MCT. The CCZ of the present area has been subdivided into three units on the basis of lithological assemblage. Unit-I constitutes the physical base while Unit-III the physical top of the crystalline sequence. The sedimentary belt of the Lesser Himalaya has been subdivided into two rock units (formations): a lower calcareous unit conformably overlain by an arenaceous unit which is impersistently developed along the MCT. The rocks of this unit show prominent effects of recrystallization and faint development of foliation towards the MCT.

In the study area, the MCT is a moderately northward-dipping thrust with dips varying from 250 to 500. The foliations of the rocks of the CCZ persistently dip northwards, thus suggesting a homoclinal structure. The rocks of the sedimentary belt also dip northwards. As such the megascopic structure of the area can be described as homocline. The rocks of the area show a variety of mesoscopic and microscopic structures such as mylonitic foliation, S-C structures, grain-shape foliation, micro-folds and rotation microstructures. These structures progressively become stronger towards the trace of the MCT thus suggesting their formation as a result of progressive shear deformation. Dynamic recrystallization, feldspar recrystallization, grain boundary migration, polygonisation, diffusional mass transfer, pressure solution, crystal-plastic deformation and boudinaging are common micro-mechanisms of rock deformation that have operated in the mylonites of the MCT zone. Dynamic recrystallization is the most dominant mechanism of strain softening that gave rise to the formation of mylonites in the vicinity of the MCT, both in the up-thrust and sub-thrust blocks. In the rocks of Unit III the scatter of lineation orientation is very high up to about 700 or even more but gradually falls down to

100 in the vicinity of the MCT. This progressive reorientation of lineation orientation can be ascribed to progressive increase in the ductile shear strain towards the MCT.

The MCT can thus be described as a ductile thrust developed at great depth and has risen up in the crust due to movement along the thrust. Further, a number of neotectonic features have also been observed in the vicinity of the MCT suggesting that the MCT is still active.

Petrography and heavy mineral analysis of Barail sandstones, Zubza village, Kohima district, Nagaland, India

A. Ramamoorthy*, S. Ramasamy, R.C. Patel
Department of Geology, University of Madras, Guindy Campus, Chennai
Department of Geophysics, Kurukshetra University, Kurukshetra
**ramgeo.in07@gmail.com*

In this paper petrographic and heavy mineral account of the Barail sandstones of Zubza village area is presented. The sandstones are dominated by Quartz arenite. Few other petrographic types are Argillaceous Siltstone, Laminated Siltstone, Micaceous Quartz Arenite and Lithic Glauconitic Arenite. The modal composition reveals that the percentage occurrences of different constituents of these Barail sandstones range as Quartz (39.85% to 64.10%), Feldspar (5.27% to 8.25%) and rock fragments (4.53% to 14.25%). However the rich monocrystalline quartz implies their derivation from intrusive igneous rocks. The predominance of unit quartz and undulose quartz collectively corroborate the dual sources of low rank metamorphic, and plutonic sources of variable pressure effects. QFL triangular plot infers the derivation of the sandstones from recycled orogenic sources. QmFRt triangular plot shows that the provenance of these Barail sandstones were mainly of mixed and dissected arc types. However, few of them also show their derivation from quartz arenite recycled origin. Heavy mineral study reveals that the Barail sandstones contain both opaque and non -opaque minerals. The non-opaque minerals include zircon, tourmaline, rutile, sillimanite, kyanite and staurolite. ZTR maturity indices vary from 82.059% to 96.082% with an average 88.538%. ZTR triangular diagram points out the predominance of tourmaline and zircon which further infers the derivation of the Barail Sandstones from both metamorphic and igneous sources.

Re-validation of the Jajiya Member of the Jaisalmer Formation, Rajasthan

Jitendra Sharma[1]*, Dhirendra K. Pandey[1], Matthias Alberti[1, 2]
[1]Department of Geology, University of Rajasthan, Jaipur 302004, India
[2]Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel,Ludewig-Meyn-Straße 10, 24118 Kiel, Germany
**jitendrageology@gmail.com*

The Jajiya Member is the youngest member of the Jaisalmer Formation in the Jaisalmer Basin, Rajasthan. It consists of rudstones and sandstones deposited in a high-energy, marine environment. Earlier it was considered as a part of the Kuldhar Member, which predominantly consists of silty marl with inter beds of mud- to packstones containing fossils, shell fragments, and golden ooids. Consequently, the Jajiya Member was separated from the Kuldhar Member due to its distinct lithology. However, the lower and upper lithological boundaries and age limits of the

member were not defined. Instead, it was assigned only broadly to the Middle Callovian to Oxfordian on the basis of ammonites such as *Lissoceratoides* (Late Callovian to Late Oxfordian), *Brightia* (*Hecticoceras*) (Late Callovian to Early Oxfordian), *Distichoceras* (Late Callovian to Early Oxfordian), *Epimayaites* (Middle Oxfordian), *Mayaites* (Middle Oxfordian), *Dhosaites* (Middle Oxfordian), and *Hubertoceras* (Middle to Late Callovian). In this context there are three fundamental problems which have to be addressed:

1. In the Mesozoic, stages/zones/subzones are demarcated on the basis of the vertical/temporal distribution of ammonites. These fossils are considered delicate time indices and are able to demarcate biostratigraphic boundaries even up to a precision of 0.5 million years. Contextually, ammonites of different stages/zones/subzones cannot occur together until there is a condensed sequence or considerable reworking has taken place. Hitherto, there is no record of a condensed sequence in the Jajiya Member.

2. In the neighboring Kachchh Basin, the Callovian and Oxfordian ammonites occur in different zones. They are separated from each other by a considerable amount of sediment, at least from the Upper Callovian to the Lower Oxfordian. Whether the depositional setting in the Jaisalmer Basin during this time interval was distinctly different is yet unknown.

3. The recent field visits of the present authors revealed that there are a number of thin beds at the transition of the Kuldhar and Jajiya members, yielding different ammonites. At times, ammonites are found loose as stray samples and somewhat hasty or amateur collecting may result in wrong interpretations. This is particularly important here because earlier workers did not give any precise information on the horizons yielding the ammonites described by them.

Contextually, it is very likely that the fossils collected earlier have been mixed up. Furthermore and in the absence of any detailed lithostratigraphy (at finest possible resolution), the boundary between the Kuldhar and Jajiya members was not known. As per the records, the Kuldhar Member is characterized dominantly by silty marlstone, whereas, the Jajiya Member is dominantly a rudstone. Although both members consist mainly of carbonate sediments, the depositional environments are considerably different.

The bed by bed collecting of ammonites and the retrieval of data from the three sections exposed west of the Kuldhar River Section (the type locality of the Kuldhar Member) suggest that the Jajiya Member is of an Oxfordian age. In the present study, the Jajiya Member has been re-described including data on its stratotype, lower and upper boundaries, and fossil diversity.

Tectono-provenance setting of middle Bhuban Formation in Aizawl town, Mizoram

Parakh Protim Phukan*, Pradip Borgohain, Devojit Bezbaruah, Bubul Bharali, Raghupratim Rakshit

Department of Applied Geology, Dibrugarh University, Dibrugarh 786004, Assam

** pcube92@gmail.com*

The present work was carried out along Bawngkawn-Durtlang Road Section of Aizawl, Mizoram where the Middle Bhuban Formation of Surma Group is well exposed. The Middle Bhuban

Formation in the study area is composed of grey and buff coloured fine to medium grained sandstones alternate with siltstone and shale. Shell limestone as lensoidal bodies with bioturbations and concretionary nodules are also reported in the field. The Middle Bhuban Formation in the entire section of the study area is about 1500 m thick.

Petrographic analysis reveals that the sandstones are composed mainly of quartz, followed by feldspar, rock-fragments and mica and are cemented in argillaceous, ferruginous and calcareous cements. Amongst the varied rock fragments, metamorphic and sedimentary rock fragments are dominating and consists 12% of the total framework constituents. The sandstones are mainly quartz wacke to sublithic arenite type and derived from uplifted terrains of recycled orogenic provinces. Diamond diagram suggests the derivation of sediments from middle and upper rank metamorphic rocks. Heavy mineral analysis also supports this interpretation. Geochemical analysis integrated with various binary and ternary plots suggests continental islands as well as active continental marginal setting of the source areas in a subducted zone and derivation of sediments dominantly from intermediate felsic type of rocks.

Physical sedimentation on a mid Proterozoic shallow basin: A case study from the Kolhan, Jharkhand-Orissa

Rohini Das
Indian Institute of Technology, Kharagpur
romiyadas@gmail.com

The pear shaped Kolhan Group in the studied sub-basins of Chaibasa-Noamundi and Chamakpur-Keonjhar is usually represented by a sequence of clastic (+carbonate) association along with development of thin and discontinuous patches of basal conglomerates draped by sandstone beds. Six lithofacies have been observed in the area. Petrological study further denotes that the Kolhan sandstones show progressive change towards greater textural maturity in its up building. This fining upward sequence along with the vertical and lateral facies variation in the Kolhan implies superimposition of retrograding shorelines on an earlier prograding alluvial fan sand complex. The IOG-fault marks the western 'distal' margin of the Kolhan basin showing evidence of passive subsidence subsequent to the initial rifting stage (Saha, 1994). The basin is thought to have evolved as a half-graben under the influence of an extensional stress regime. This assumption of a tectonic setting for the NE-SW trending Kolhan basin can be related to the basin opening as a consequence of E-W extensional stress system that prevailed during the development of the Newer Dolerite dyke. The Paleoproterozoic age of the Kolhan basin is based on the consideration of the conformable stress pattern responsible both for the basin opening, and on the development of the conjugate fracture system along which the Newer Dolerite dykes intruded the Singhbhum Archaean craton.

The half-graben development and fault growth evolved differently through time and produced different basin-filling patterns (Schlische, 1991). In the initial stage the basin evolution can be explained by detachment type half-graben filling model that incorporates a basin-bounding fault soling into a sub-horizontal detachment fault. Two types of genetic sequences reflecting variations in the generated accommodation space have been recognized within the sub-basin of Chamakpur-Keonjhar. The lower sequence is characterised by shallow braided river deposits that lack repetitive facies patterns and were deposited during a period of slower rate of fault growth and generated accommodation space. An upward increase in the generated accommodation space is recorded by

sheet sandstones encased in sand-streaked siltstones representing ephemeral flood deposits. It is suggested that the different fluvial styles in the two depositional phases. During the fault growth stage the Kolhan basin grew both wider and longer through time as the basin-bounding faults lengthen and displacement accumulated as evident in the sub-basin of Chaibasa -Noamundi. Younger strata consistently pinch out against older syn-rift strata rather than pre-rift rocks in the later fault-growth stage. The basin fill thus commonly forms a fanning wedge during fluvial sedimentation, whereas lacustrine strata tend to pinch out against older syn-rift strata. The fluvial strata progressively onlap the hanging wall block, whereas the lacustrine strata pinch out against older fluvial strata at the centre of the basin but onlap along the lateral edges. The transition from fluvial to lacustrine deposition and hanging wall onlap relationships are thoroughly observed in the sub-basins of Kolhans. The pronounced variations in thickness of the fan delta succession and the stacking pattern in different measured profiles reflect the overriding tectonic controls on fan-delta evolution. A strong asymmetry in vertical basin architecture and the linearity in the outcrop pattern of the preserved sedimentary sequence are presumed to have developed in an elongated trough during the initial basinal rifting stage, while the later stage is marked by the progressive overlaps and coalesce of the facies built-up.The basin axis controlled the progradation direction which was likely driven by climatically induced sediment influx, a eustatic fall, or both.

Saha, A. K., 1994. Memoir Geological Society of India, 2, 341.
Schlische, R. W., 1991. Basin Research, 3, 123-141.

Process based facies analysis and geochemical investigation of shale intervals from late Paleo-Mesoproterozoic Vindhyan basin: implications towards depositional motif, paleoweathering, provenance, and ocean redox state

Arvind K. Singh[1], P.P. Chakraborty[2]*, S. Sarkar[3]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Department of Geology, University of Delhi, Delhi
[3]Department of Geological Sciences, Jadavpur University, Kolkata
**parthageology@gmail.com*

This study attempts the characterization of argillaceous stratigraphic intervals from ~4.5 km thick Vindhyan Supergroup, central India spanning over >500 Ma time period in late Paleoproterozoic-Mesoproterozoic earth history. From documentation of physical and chemical attributes of shales from six different stratigraphic levels viz. Arangi, Koldaha, Rampur, Bijaygarh, Rewa and Sirbu shale up the Vindhyan stratigraphic column in both qualitative and quantitative manner, the study strived towards understanding, i) paleo-environments of deposition and identification of depositional agents including their mutual relationships in mud depositing environments, ii) mode of evolution of muddy shelf at different stages of Vindhyan depositional history with delineation of causative forcings, iii) sediment provenance and depositional tectonics with detail appreciation of source area weathering, sediment sorting and shale mineralogy, iv) Oxidation state of Vindhyan hydrosphere including its temporal change, if any.

Process-based facies and paleo-environmental analysis of shale units revealed their deposition in marine shelf domain, varying in bathymetry between inner shelf and distal shelf, often beyond storm wave base. Vindhyan shelf, irrespective of time, was storm infested and operations of both storm-generated return flow and Coriolis force guided geostrophic current are documented from

Vindhyan shelf deposits. From appreciation of facies pattern and paleocurrent, a rift-related half-graben setting is proposed for the Arangi and Koldaha Shale Formations and low-gradient stable shelf set-up, with well-defined proximal-distal energy gradient, is proposed for shale units from the Rampur Shale onward.

Appreciating roles of weathering in the provenance (CIA values), hydrological sorting and mineralogical constitution of shale units, a differentiated felsic provenance is inferred. Only in the Sirbu time mixing of supply from a mafic source is predicted from major, trace and REE geochemistry data. Consideration of paleocurrent motif and REE geochemistry allowed prediction of provenance in the south-southeast of the basin; Chhottanagpur Gneissic Complex (CGC) and/or Mahakoshals may be the probable candidates. Low molybdenum (Mo) concentration and Mo/TOC ratios allowed inference of a stratified Vindhyan sea with Sulphidic, reduced deep water and oxygenated surface water in most parts of basin depositional history that eventually became uniformly circulated with oxygenated deep water during the Sirbu time as is evident from the ~3‰ enrichment of $\delta^{13}C_{org}$ value in organic matters from the Sirbu Shale when compared with $\delta^{13}C_{org}$ values of organic matters from all underlying shale units.

Morphometric analysis of ravinous area of marginal Ganga Plain and its implication with peripheral bulge tectonics

Rupa Ghosh[1, 2]*, Pradeep Srivastava[1], U.K. Shukla[2]
[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*Department of Geology, Banaras Hindu University, Varanasi 221005*
* *rupaghosh2006@gmail.com*

The Ganga foreland basin, located between Himalaya and Tertiary Siwalik Group in the north and Bundelkhand- Vindhyan plateau in the south, formed due to down flexing of Indian lithosphere in response of thrust sheet loading along the northern margin of the Indian plate. The MGP (Marginal Ganga Plain) consists of Yamuna and its tributaries Betwa, Non and Dhasan, characterized by different fluvial landforms formed during the Late Pleistocene. Dissected ravines and deeply incised gullies along Yamuna, Betwa and Dhasan, also a characteristic feature of this region provides good opportunity to study the past depositional environment and its interaction with climate and tectonics of the forebulge. The present study area occupy the Marginal plain upland surface which is considered to be equivalent to the T_2 surface (Singh, 1996). In the present study 19 stratigraphic sequences are studied and dated using optically stimulated luminance technique aiming to understand (i) its fluvial architecture of MGP (ii) the impact of peripheral bulge tectonics on the sedimentation. All sections consist a basal paleosol unit followed by of a 2.5-4 m thick gravel. Gravel units is polymictic in nature, cross bedded, clast supported and ranging from sub angular to sub rounded and is laterally persistent for kilometer. Internally it is made up of laterally shifting bar events which are entirely cross bedded and composed of reworked calcrete and variable lithoclasts. This gravel unit also contain vertebrate fossils and molars which essentially makes this horizon biological significant. An elephant skull of *Elephas Namadicus* was recovered from the Dhasan section, the occurrence of all vertebrate fossils from this horizon shows a humid climate and strongly indicate a savannah vegetation in which large mammals become survive (Ghosh et al., in press). The OSL date of this horizon shows it span a time period between 100-56 ka, MIS-4 represent a period of moist climate when there was large influx of coarse sediments input. This horizon unconformable overlies the paleosol, making paleosol unit >100 ka, shows MIS-5 a period of floodplain aggradation

and low sedimentation. The optically stimulated luminescence dates from various sections indicate periodic aggradation between ~100 to 12 ka and the incision postdates 12 ka. The aggradation of south derived gravel unit between 100-56 ka indicates wet climate and increased relief in the peripheral bulge of the basin. Ravine erosion generally removes large volume of sediments from Marginal Ganga Plain. Topographic characteristic of ravines was derived from Cartosat-1 based DEM using ArcGIS tools and in conjunction with the chronology the rate of erosion due to ravine process was calculated for time scale of 10^4 yrs.

Grain size characteristics of suspended sediments evacuated from debris-covered Chorabari glacier, Mandakini basin, central Himalaya, India

Anupam Anand Gokhale*, Amit Kumar, D.P. Dobhal
Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001
**anupam@wihg.res.in*

Present study deals with sedimentological characterization of suspended sediments transported and evacuated from debris-covered Chorabari Glacier. Grain size characteristics of suspended sediments generated from high altitude debris-covered Chorabari Glacier were examined using Laser Particle Size Analyser (LPSA) throughout the melt seasons (2009, 2011, and 2012). Suspended sediment grain size reflects mean distribution range as 56.29% of sand-sized particles, 43.26% of silt-sized particles and 0.46% of clay-sized particles. The grain size analysis suggests dominance of medium silt to fine sand particles corresponding to 70-80% ranging between 0.0156 and 0.25 mm without any significant seasonal variations. Seasonal variations reflect evacuation patterns for each grain size, where clay particles correspond to <1%, variations in silt particles correspond to around 3% and sand-sized particles to around 4%. Textural studies were conducted by calculating median, mean size, standard deviation, skewness and kurtosis using graphical method to understand suspended sediment evacuation patterns and transport characteristics. Results show presence of coarse-grained silt to medium-grained silt, poorly sorted grains, and coarsely skewed to near symmetrically skewed distribution. Tail and the peak values are equally sorted giving mesokurtic texture to the grain size distribution. Observations from cumulative frequency curves reflects closeness to each other, reflecting poor sorting of suspended sediments. Bivariate scatter plots are prepared for empirical relationships between graphical parameters, which reveal textural variability in evacuation patterns because of snow and ice melt caused by the rise in temperature, high rainfall variability in the melting seasons. These findings suggest that debris cover over the central Himalayan glaciers acts as an important source of fine-grained suspended sediments that are entrained into subglacial traction zones and eventually drained with the glacier melt runoff in a high energy environment.

Progressive fabric overprinting: a case study from the Mahanadi Shear Zone, Eastern Ghats Belt, India

Subham Bose
Department of Geology & Geophysics, IIT Kharagpur, Kharagpur 721302
subhozzz03@gmail.com

High grade rocks in polydeformed terranes often undergo later deformation along ductile shear zones, resulting in the overprinting of earlier annealed fabrics by a later mylonitic fabric.

Textural and micro-structural study aids in determining the temperature of ductile shearing. On the mesoscopic-scale, lineations in these ductile shear zones are interpreted to be the transport direction.

The present study deals with the Mahanadi Shear Zone, Eastern Ghats Belt, India, which is an intra-province mega-lineament. This shear zone forms the boundary between the Angul and the Tikarpara domains to its north and the Phulbani domain to its south. The reported absence of the c. 550 Ma Pan-African tectonothermal overprint, separates rocks to the north of the shear zone from those to its south, suggesting that the Mahanadi Shear Zone may have major tectonic importance. Field traverses starting ~100 km north of the shear zone reveals a progressive increase in the dip of the planar elements (in quartzofeldspathic gneiss, charnockite, khondalites and associated rocks) from gentle to moderately dipping towards NE on approaching the shear zone. A lineation observed on the foliation plane plunges almost down - dip away from the shear zone; this has been interpreted as an intersection lineation based on field evidence. However, in the vicinity of the shear zone another lineation, observed (approximately down the dip of a later mylonitic foliation) has been interpreted to be the transport direction along the Mahanadi Shear Zone. Textural and microstructural studies reveal that the lineation away from the shear zone is related to an annealed fabric, typical of the granulite facies of rocks. Quartz and plagioclase crystals showing granoblastic polygonal texture (with dihedral angle of 120° between plagioclase grains in some charnockites) suggests static recrystallization at high temperatures. However, on approaching the shear zone to the south, a gradual increase in non-coaxial shearing is observed both in the outcrop and in the micro-scale. On the outcrop scale the earlier fabric has been found to be transposed by shearing in some localities. Elsewhere, sheared boudins have been observed within which strained plagioclase with deformed lamellar twinning has been detected. On approaching the shear zone, thin mylonite bands make an appearance within the annealed fabric, followed by a prominent mylonitised fabric in the vicinity of the shear zone. Lastly, the presence of ultramylonite implies that the annealed fabric away from the shear zone has been completely obliterated. Further, microstructural investigations suggest that the mylonitic fabric near the shear zone has formed at a significantly lower temperature than that of the annealed fabric, away from the shear zone.

Pseudotachylites from the base of Almora Nappe

Mallickarjun Joshi, Shilpi Rai*
Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi 221005
**shilpirai01@gmail.com*

Pseudotachylites have developed in Chara area, district Nainital, located close to the base of Almora Nappe. It is well known that the melts generated due to significant friction induced shear heating during faulting are quenched as pseudotachylites under brittle or brittle-ductile conditions of shearing. Pseudotachylites being associated with seismic slip document palaeoearthquakes. Understanding their origin and influence on slip behaviour is critical for identifying the paleoearthquakes and their significance as paleoseismic indicators. In the present case it is tempting to relate the genesis of these pseudotachylites to the Tertiary thrusting responsible for bringing the Almora Nappe to its present location from the Higher Himalaya as a consequence of Himalayan Orogeny. Agarwal et al. (2011), attributed the melt generation leading to pseudotachylites from the South Almora Thrust Zone, located upsection to the pseudotachylites being reported, to "intense deformation and friction-related heating (is) generated during the thrust sheet movement". However, both the South Almora Thrust and the Ramgarh Thrust along with the protomylonites-

mylonite - ultramylonites ensemble comprising the Basal Shear Zone of the Almora Nappe largely developed due to ductile shearing (Joshi, 1999).

Ductile shearing by itself cannot lead to melt formation as the latter requires brittle or brittle-ductile conditions. The two are highly incompatible modes of deformation, and complex mechanisms for the genesis of pseudotachylites have been suggested to explain this paradox. Thus, apparent synchronous mylonite-pseudotachylite packages are highly likely to represent two discrete time events. It is known from the previous work that such assumed contemporaneity of ductile shearing and pseudotachylite generation may be invalid in many cases. In the absence of any precise date for the highly likely Tertiary mylonites and the definitely later pseudotachylites, our best take would be either a post- mylonite brittle fault reactivation or during the brittle -ductile transition during the evolution of the Basal Shear Zone of the Almora Nappe (Joshi, 1999).

Tectonometamorphic set up of Askot Klippe, Kumaun Lesser Himalaya

Mallickarjun Joshi*, Biraja Prasad Das, Ajit Kumar Patel**
Department of Geology, Banaras Hindu University, Varanasi 221005
**joshimallickarjun@gmail.com, **birajageology@gmail.com*

Valdiya (1980) suggested similarities between the Askot Klippe and the Almora Nappe and believed both of them to be equivalents of the Almora Group of rocks. Almost till the end of the twentieth century, neither Valdiya (1980) nor any other worker realized that the Ramgarh Group of rocks, instead of being exposed only in the southern parts of the Almora Nappe, skirt all around the nappe and likely underlie the Almora Group of rocks throughout the nappe (Joshi, 1999). It thus became crucial to find out whether the Askot Klippe bears out the details delineated for the Almora Nappe by Joshi (1999) and whether it was still reasonable to consider the two as equivalents in the revised tectonometamorphic set up. The present structural and metamorphic studies in the Askot Klippe distinctly bring out a nappe-pile stack made up of two main tectonometamorphic units, viz. the lower Ramgarh Group of rocks and the tectonically overlying Almora Group of rocks and reveal marked similarities with the Almora Nappe. The Askot Klippe is also characterized by a Basal Shear Zone very much like the Almora Nappe that is piled up by means of tectonic contacts characterized by cataclastic or mylonitic rocks developed at various crustal depth. The degree of mylonitization by and large decreases up section from base of the Klippe and like the Almora Nappe the Ramgarh Thrust here too, separates the Ramgarh Group of rocks from the Lesser Himalayan sedimentaries and the Almora Thrust separates the Ramgarh Group of rocks from the overlying Almora Group of rocks which are clearly distinguishable in the area. Moreover, unmylonitized Almora Group schists and gneisses are exposed in the central parts of the Klippe. The Basal Shear Zone skirts around the Askot Klippe and is formed as a consequence of the crustal scale southward thrusting and comprises protomylonites, mylonites and ultramylonites after the Ramgarh Granite in the lower and the mylonites after the Almora Group rocks at upper crustal levels. The mylonites exposed at the base of the Klippe preserve evidence of intense shearing and high strain zones marked by the development of ultra mylonites alternating with low strain zones comprising mylonites and protomylonites, which are common near Thal and Lalghati areas in the northern flank of the Klippe and south of Ranagaon in its southern flank. A prograde metamorphic sequence beginning with the biotite zone both in the northern and southern parts of the Askot equivalent of the Almora Nappe to the K-feldspar-sillimanite zone in its central parts has been delineated. However, unlike the Almora Nappe any repetition of metamorphic isograds is yet to be identified at this stage of the work albeit the K-feldspar - sillimanite isograd does show a vague influence of NW trending folds.

Constraints in paleo - fit between eastern Madagascar and southern India and insights for "Ur" supercontinent assembly and dispersal: Evidences from the Mercara Suture Zone, southern India

T. Amaldev*, K.R. Baiju
Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Kochi
**amaldev302@gmail.com*

The Mercara Shear Zone is sandwiched between the Western Dharwar Craton (WDC) and the Coorg Block in the Southern Granulite Terrain (SGT) of India, and is marked by steep gravity gradients interpreted to suggest the presence of underplated high-density material in the lower crust (Sunil et al., 2008, Chetty et al., 2012). A recent study by Ishwar-Kumar et al. (2013) from the WDC identifies a major late Mesoproterozoic suturing event between eastern Madagascar and southern India (Karwar-Kumta-Mercara Shear Zone), which they correlated to the Rodinian suture. In contrast Rekha et al. (2014), summarized that U-Pb zircon ages and U-Th-total Pb chemical ages in monazites are identical across the proposed Rodinia suture, opposing the validity of Karwar Kumta-Suture Zone. The variation in existing zircon ages in the crustal domains across the accretion zone is similar to the variation in monazite ages obtained by Rekha et al. (2014) and therefore the Mercara Shear Zone continues into Madagascar as the <2.5 Ga accretion zone in the general location of the Betsimisaraka suture zone, between the Antongil Block and the Antananarivo Domain. In this context our study tries to elucidate the geological, petrological, geochemical and geochronological (zircon U-Pb ages) and genetic aspects (Lu-Hf isotopes) of different lithological units such as metaigneous (TTG-related gneisses, charnockite, metagabbro, mafic granulite) and metasedimentary (quartz mica schist, khondalite, garnet biotite gneiss, kyanite-sillimanite bearing metapelite) rocks from Mercara Shear Zone. Geochemical data on the magmatic suite suggests formation through subduction-related arc magmatism, whereas the metasediments represent volcano-sedimentary trench sequences. Phase equilibrium modeling of mafic granulites from the Mercara Shear Zone suggests P-T range of 10-12 kbar at 700°C to 900°C. The tightly defined ages of 3.1 to 3.2 Ga from igneous zircons in the magmatic suite suggest prominent Mesoarchean convergent margin magmatism. The timing of high grade metamorphism as constrained from metamorphic overgrowths in zircons is ca. 3.0 Ga which might mark a collisional event. Hf isotope features suggests that magma has derived from juvenile sources and the Lu-Hf model ages suggest that the crust building might have also involved partial recycling of basement rocks as old as ca. 3.8 Ga. Our study defines the Mercara Shear Zone as a terrane boundary, and possible Mesoarchean suture along which the Coorg Block was accreted to the Western Dharwar Craton. The accretion of these continental fragments might have coincided with the birth of the oldest supercontinent "Ur".

Morphotectonic analysis and influence on structural features of Tawang and a part of west Kameng districts of Arunachal Pradesh, NE India

Raghupratim Rakshit*, Chaitra Dhar Taye
Department of Applied Geology, Dibrugarh University Dibrugarh 786004
** raghupratim@gmail.com*

The Eastern Himalayan part of India is situated in one of the most seismically and tectonically active regions in the world. The collision of Indian plate with theEurasian plate gives rise to complex geological occurrences in the region. The north-western most part of Arunachal Pradesh

comprises of the higher and lesser Himalayan rock units. This study emphasizes on morphotectonic aspects along with major structural features of Tawang and a part of West-Kameng districts of Arunachal Pradesh. In the present study different morphometric parameters viz. Asymmetric Factor (AF), Transverse Topographic Symmetry Factor (T), Basin Shape Index (Bs), Stream Length Gradient Index (SL) have been calculated for the basins along the Tawang Chu River, and a part of Gang River and its main tributaries. These studied parameters are computed and the resultant values infer the activeness of the tectonic movement. Active tectonics and rapid upliftment are also evident by the V-shaped valleys and steep scarps. The lineament map and lineament density plot of the study area indicative of the relationship of active tectonic components in the area with the regional structural features of the region. The area is mostly experiencing NNE, NNW and ENE stress components as revealed from the lineament analysis. The lineaments and the regional structures show a synchronize characteristics. The relationship with the important tectonic features of the region viz. Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Indus Tsangpo Suture Zone (ITSZ) is very prominent. Moreover, correlations of regional tectonic features identified during the field work are implemented to establish the anomalous behavior of the structural and morphotectonic features in the region. Furthermore, from the study a model has been proposed and an overall relationship between morphometric behaviors of the basins with tectonic processes and different structural features is tried to achieve. This might help to identify the vulnerable zones in the studied region.

Deformation of the Lesser Himalayan Crystallines near Daporijo, Upper Subansiri valley, Arunachal Himalaya

P. Kalita[1]*, T.K. Goswami[1], M.P. Gogoi[2], P. Phukon[1]
[1]Department of Applied Geology, Dibrugarh University, Dibrugarh 786004
[2] Department of Geology, Sibsagar College, Sibsagar
**pranjit.kalita84@gmail.com*

In the upper Subansiri valley of Arunachal Himalaya, the biotite gneiss in the hanging wall of the Tamen Thrust (TT) preserves the imprints of the high strain ductile shear zone at east of Daporijo. The mylonitic quartzites and foliated metapelites within the Daporijo Gneisses bear the signatures of the Main Central Thrust (MCT) foot wall imbrications. We present here the field evidences that point towards the upliftment of the slivers of the Lesser Himalaya Sequence (LHS) followed by phases of deformation where both Daporijo Gneiss and LHS are affected. The Daporijo Gneiss, if considered as folded slab of MCT, its' grouping with the Bomdila Gneiss is ambiguous. Rather, Daporijo Gneiss represents a phase of intrusion into the earlier folded metapelites and metapsamites of the LHS. The later phase of deformation affected the granites, metapelites and metapsamites. We glean that the late phase of shearing produced shear related folds in gneisses and metapelites and quartzites being mylonitised. Away from the MCT, thus the Daporijo Gneiss could be well correlated with and equivalent to the Bomdila Gneiss or Ziro Gneiss (Kumar, 1997). MCT footwall imbrications constrained in other parts of Arunachal Himalaya are responsible for the formation of duplex structures, the tourmaline bearing leucogranites in the immediate south of Taliha are products of crustal melting in the high temperature MCT ductile shear zone. Three phases of fold and late shear related folds are well constrained in the interleaved gneisses and metapelites in the east of Daporijo. There are evidences for tectonic interleaving in the MCT zone in other parts of Himalaya where orthogneisses and pelites representing contrasting geochemical signatures are juxtaposed. Thus the tectonic interleaving of Greater and Lesser Himalayan sequences is considered to be associated with

the tectonic movement along the MCT. So, the interleaving is controlled by the thrust duplication between MCT and MBT (Saha, 2011). A transposition of the early shear related folds to shear related late folds are observed which must have nucleated close to the shear zone boundary. Thus, the shear related late folds have affected the early mylonitic foliation. In south of Daporijo the Tamen Thrust has a NE-SW trend. The asymmetric shear related early folds show a top to the NE sense of shear. The early mylonitic foliation is rotated and became unstable because of the stretching. The synthetic late shear folds show a dextral sense of shear with top to the WSW sense of movement.

Microstructural analysis of superposed deformation and associated metamorphism in staurolite-garnet bearing metapellites of the south Konkan region, Maharashtra using photomicrographic mosaics

Dashputre A. S.[1]*, Jadhav P.B.[2], Marathe T.[1]
[1]Department of Geology, Fergusson College, Pune 411004
[2]Department of Petroleum Engineering, Maharashtra Institute of Technology, Pune 411038
**dashputreamey@gmail.com*

Microstructures in deformed rocks are reliable sources to reconstruct tectonic evolution however, establishing the continuity of microstructures and integrating information for entire thin section is challenging and requires a cautious approach else it may lead to incorrect interpretations. The present work deals with study of ninety eight photomicrographic mosaics prepared by using stitching module of LAS v4 software of Leica DM 2700P Microscope from thin sections of Staurolite and Garnet bearing Metapellites belonging to the poorly attended supracrustal sequence of coastal Maharashtra, equivalent of Upper Chitradurga Group. Mineralogically, the rocks consist of staurolite, garnet, biotite, muscovite, graphite, chlorite, quartz and some feldspar.The photomicrographic mosaics have been prepared in two separate steps; the first step involves observation and capturing of the entire thin section while the second step involves fine focusing, rotation in order to re orient the thin section according to the field data and also in case of micas wherein illumination is required to highlight the extinct grains under crossed polars. Although each thin section requires more than two hours to be converted to a photomicrographic mosaic, it is seen that the generated image provides broad field of view encompassing the entire thin section. Microstructural analysis based on such photomicrographic mosaics provides a complete representation of the microstructures and aids in unbiased, immaculate and thorough observations and warrants a greater certainty for Micro, Meso and Macro synthesis. The staurolite bearing metapellite is analyzed for one region (fifteen thin sections) and garnet bearing metapellite has been studied from two different regions (all 98 thin sections).

The study of photomicrographic mosaics reveals two successive deformation episodes (D1 and D2) in the evolution of staurolite grains. They have evolved from biotite and garnet by progressive metamorphism. The syn-tectonic staurolites evolved during D1 deformation show millipede microstructure, deflection fold microstructure, textural sector zoning and re-entrant zones with feather edge structures and intergrown porphyroblasts. During D2 deformation, the new staurolite is essentially syntectonic while the earlier alumnosilicates were rotated and behaved rigidly giving rise to antithetic or synthetic microfractures. Shearing during the D2 deformation is evident from mica fish, microfracturing in the alumnosilicates and elongated quartz grains. The metamorphism associated with the D3 deformation was retrogressive manifested by evolution of garnets from staurolite. Inter-tectonic, syn-tectonic to post-tectonic garnets have evolved in all three

successive deformation episodes from biotite by progressive metamorphism. The earliest formed garnets during D1 deformation were rotated during D2 deformation and they show strain shadows while the new garnets were syntectonic. Shearing during D2 deformation is evidenced from amphibole and/mica fish and microfracturing in the garnets. The third deformation event D3 saw growth of syn-tectonic and post-tectonic garnets. Polymetamorphism and Idiomorphic Rims are common in garnets that evolved during D3 deformation. The technique of generating photomicrographic mosaics for interpretation of deformation microstructures in the present studies is found to support the field observations.

Quantification of paleostress using quartz veins in Gadag (southern India) - implications of scaling the 3-D Mohr circle to understand gold mineralization during fluid pressure fluctuation

Sivaji Lahiri*, Manish A. Mamtani**
Department of Geology & Geophysics, Indian Institute of Technology, Kharagpur 721302
**sivaji.lahiri@gg.iitkgp.ernet.in; **mamtani@gg.iitkgp.ernet*

It is well-established that gold mineralization takes place in quartz veins that form a mesh like network. This network forms due to episodic emplacement of veins during fluid pressure (Pf) fluctuation (Sibson, 1992). If veins emplace because of dilation of pre-existing fractures/anisotropy, then relative stress/Pf conditions can be evaluated by plotting 3-D Mohr circle using vein orientation data (Jolly and Sanderson, 1997). This approach was earlier adopted by Mondal and Mamtani (2013) to evaluate relative stress/Pf conditions for emplacement of quartz veins hosted in metabasalts. Many of these veins form gold lodes and it was concluded that gold separated from the fluid during phases of sudden drop in Pf. However, the previous workers did not scale the 3-D Mohr circle. Quantifying the paleostress is critical to the understanding of variations in effective normal stresses that may drive the fluid flow and separation of gold. With this objective of quantifying the paleostress and scaling the 3-D Mohr circle, the authors have analyzed 157 quartz veins in metabasalts of Gadag region. Scaling of the Mohr circle was done using estimates of highest and lowest recorded Pf from fluid inclusions preserved in quartz veins, as well as intrinsic rupture criterion that empirically quantify rock properties. The absolute magnitudes of three principal stresses are quantified for high and low Pf. It is noted that the quartz veins are dominantly NW-SE striking with a sub-maximum in NE-SW direction. It is argued that at high Pf, pre-existing fractures/anisotropy of all possible orientations dilated, thus leading to vein emplacement. However, at low Pf, pre-existing fabric elements of a limited range of orientation were susceptible to dilation and vein emplacement. Based on the scaled 3-D Mohr circle, 14 orientations are identified that were favourably placed for dilation at low as well as high Pf. These were continuously susceptible for vein emplacement during cyclic Pf fluctuation. These veins have NW-SE strike with a mean orientation of 150^{o}, which is similar to the orientation of the gold bearing quartz lodes reported in the region. Effective normal stress (= normal stress - Pf) prevalent during dilation of fracture/fabric anisotropy with 150^{o} strike is calculated for high Pf, as well as low Pf conditions. In addition, the change in effective normal stress that prevailed during Pf fluctuation and associated separation of gold from the fluid is quantified.

Autoclastic mass flow in the eastern margin of the Pranhita-Godavari Basin: An indicator of basin margin faulting

Vijay Sharma*, Pitambar Pati
Department of Earth Sciences, IIT Roorkee, Roorkee
**vijaysharmageol@gmail.com*

The autoclastic conglomerate in the limestone in the eastern margin of the Penganga sub-Basin, in the extensional Pranhita-Godavari basin uncovers the different faulting episodes in the shallow marine carbonate shelf. Along the fringe, massive cherty limestone represents the undisturbed part of the shelf deposit, whereas, the conglomeratic limestone sequences in the basinward representing the mass flow events indicates a steady rhythmic mass mobilization. Their deposition is genetically intra-basinal and effectively under the wave base possessing no affiliation with any depositional slopes like reef margins and exhibits distinct vertical assemblages with sediment gravity flow assistance displaying consistently varying facies successions directly justifies their importance. Considerably voluminous conglomerate sequence are parallel to the depositional strike, which are vertically aggradational in nature. Due to mass movement, various facies came into appearance which are correlated with gradient. Heterogeneous composition of shelf faces indicate isolated shallow-water environments separated by basin-margin horsts and grabens. The intervening stomatolite bed is a clear indicator of shallow marine environment and tectonic stability. However, the later stage basin-margin faulting is responsible for destroying the algal mats which are embedded as clasts within the mass flow deposits. The farthest conglomeratic facies possess well rounded clasts of limestone is indicative of shoreline processes. The whole facies assemblage indicates gradual recede of the sea from the margin of the Bastar craton to the interior of the basin.

Tectono-geomorphic signatures in Kachchh rift basin, Western India

Gaurav D. Chuahan[1]*, Kaustubh J. Sane[1], Girish Ch. Kothyari[2], S. Prizomwala[2], M.G. Thakkar[1], S. Bhandari[1]
[1]*Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj, Gujarat*
[2]*Institute of Seismological Research, Raisan, Gandhinagar, 382007*
**gdc_dew@yahoo.com*

Kachchh, a pericratonic Mesozoic rift basin, in Western Peninsular India displays fault-controlled first-order topography. Kachchh basin in Western India has typical geometry of a marginal cratonic rift basin (Biswas, 1982; 1987) formed in early Jurassic time and received sediments in later periods, while the Indian plate was moving to northeast after the rifting. The rifting developed along major regional E -W trending master faults such as the Nagar Parkar Fault (NPF) in the North, Island Belt fault (IBF), Kachchh Mainland fault (KMF) and North Kathiawar Fault (NKF) in the South. The basin was evolved when India's drift motion along an anticlockwise path slowed down considerably after its collision with Eurasia in Late Eocene-Miocene time and changed the stress regime from normal to reverse by the NS-compressive stress field. The E-W trending master faults were reactivated in reverse manner and gave rise to positive topography as highlands and inversion topography as large inland basins along these faults. Numbers of secondary faults were generated during the time resulting hill ranges, dissection of the ranges and scarps. The faults that dissect master faults are identified as transverse strike-slip faults. The median high of the basin is a structural high since the Middle Jurassic and had influenced the sedimentation thickness through Late Jurassic to

Quaternary and also resisted seismic waves to pass to the west during 2001 Bhuj earthquake. This high is reflected in topography as young tectono-geomorphic features. Highlands are fault-controlled first-order topography while the neotectonic features represented by fault scarps, triangular facets, alluvial and colluvial fans, unpaired Holocene terraces, displaced Quaternary sequences, hanging Quaternary paleo-channels and incised meandering and bedrock gorges. These features are largely found in the vicinity of E-W fabric faults and transverse fault system. The Neotectonic features indicate that though the major faults in the basin have been active since rifting, its activity during the Quaternary is intensified which is also reflected in seismic activities clustered along these faults. Our observation of neotectonic features along various faults in Kachchh and repeated activation of primordial faults in present stage of neotectonic cycle insist us to conclude that various faults like KMF, IBF, SWF, KHF, and transverse faults are active in Quaternary period in various degrees, hence they have potential to reactivate in future and create major seismic hazards as 2001 or 1819 earthquakes. Further, it needs detailed study on rates of uplift during different tectonic cycles on individual fault in Kachchh basin.

Tectonic control exhumation of the Higher Himalayan Crystalline along the Bhagirathi River, Garhwal, NW Himalaya: using Zircon Fission Track dating

Reena Karnwal[1]*, R.C. Patel[1], Y.P. Sundriyal[2]
[1]National Facility Lab, Dept. of Geophysics, Kurukshetra University, Kurukshetra
[2]Dept. of Geology, H.N.B.Garhwal University, Srinagar, Uttarakhand
**reenaku13@gmail.com*

The HHC is core of the Himalaya which has undergone intense deformation and exhumation during Himalayan orogeny. The detail study of the HHC is very significant to provide insight information of the Himalayan orogeny. The Bhagirathi River is important river in the Garhwal Himalaya cutting across whole of the HHC and major structures such as STDS (South Tibetan Detachment System), Jhala Fault, Vaikrita Thrust and Main Central Thrust (MCT)/Munsiari Thrust (MT). So this traverse is a critical traverse to study exhumation pattern of the complete the HHC starting from the STDS to MCT/MT. In present study, new 21 Zircon Fission Track (ZFT) data between Gaumukh in the north and Maneri in the south has been collected along this valley. The ages range between 3.1 to 11.7Ma and show systematic changes in age that record faster exhumation around VT and systematically the exhumation rate is declining away from the VT i.e. towards north and south. One possibility why there is rapid exhumation around the VT is the rapid uplift due to duplex development below the VT. It appears that the VT was passively uplifting above the duplex structure. There is no break in age trend across the MCT/MT which indicates no reactivation of MCT/MT during 3 to 6 Ma. Bird' eye view of all the ZFT ages in the Kumaon-Garhwal region i.e. new and published together show different pattern along different traverses. It might me geometry of structures above which rocks are exhuming or different kinematics along different structures in different traverses.

Paleoseismic investigations along active faults of the northern segment (south Andamans) of Sunda Andaman Subduction Zone: implications of the paleoseismicity on seismic landscape evolution and associated hazard

Gulam Rasool Bhat*, Nasir Lone, Sudem Iswary, S. Balaji
Department of Disaster Management, Pondicherry University Port Blair, Andaman
**bhatgr74@gmail.com*

The Oblique Convergence between Indian plate and Burmese micro plate is largely taken up and concentrated on two major earthquake belts reflecting two types of tectonic settings. One belt encompasses Andaman trench region i.e. outer arc-forearc domain and second belt lies in the back arc or Andaman sea region. The outer region shows attendant predominant thrust faulting which is largely taken up by several active thrust belts, while the back arc region follows normal faulting with strike slip faulting consistent with Dextral slip on N-NW striking planes of West Andaman fault and Sumatra fault system running N-S direction all along the length of the Sunda-Andaman arc. The cumulative slip on active strands of emergent thrust belt in the accretionary prism of Outer arc setting is several times greater than lateral displacement on West Andaman Fault and spreading centre in the back arc which is evident from large and great magnitude thrust faulting events in the Outer arc domain such as 2004 Great Andaman Sunda earthquake. Despite in gross patterns of faulting, the earthquake belts also share similarities in deformation style. In this Context, comprehensive paleoseismic Investigations were carried out on explicit young scarps at multiple places and on raised Holocene marine terraces serving paleo surface ruptures to infer the most recent structural and crustal deformation. The study is critical towards active fault evaluation and seismic hazard assessment of Andaman and Nicobar region where practically no active fault and paleoseismic data is available. Active deformation is expressed by distinct physiographic transition and stepped topography in the form well developed young compressional scarps, uplifted marine terraces, pressure ridges and development of young piggyback basins across the faults and displacement of late Holocene deposits. The paleoseismicity have unequivocally created an obvious signature on the geology and geomorphology of Andaman and Nicobar Islands and has sculptured the bulk topography which is defined by position of Quaternary deposits and seismic landscape and is related to order of magnitude of its earthquake potential. The paleoseismic investigations demonstrates that the emergent thrust system in the accretionary prism of Outer arc setting accommodate E-W crustal shortening and west verging i.e. towards trench and features a break forward sequence style which is consistent with recent GPS studies and Seismotectonic data. The present study suggests that the active fault zones in the accretionary prism presents a complex picture of strain partioning and share probably a common decollement surface below and bifurcates as they project towards surface producing complex fault systems and landforms at surface. Therefore, the oblique subduction and motion of Indian plate under Burmese micro plate is largely accommodated and non-uniformly distributed along active strands of emergent thrust system in the accretionary prism which involved several episodes of coseismic surface rupturing earthquakes along different fault zones.

Studies on phyllites of Narukot Formation, Champaner Group, Gujarat: a microtectonic approach

Aditya Joshi, Manoj A. Limaye
Department of Geology, Faculty of Science, The M.S.University of Baroda, Vadodara 390002

A penetrative planar feature present in the rock is called its foliation. It may be in the form of compositional variation or cleavage, schistosity, or even trace lineation occurred due to intersections of planes or micro-folds on foliation plane (Passicher and Trouw, 2005). Such foliations are proved to be very useful tool in interpreting metamorphic and deformational conditions in any area. Microstructural study on discrete crenulation cleavages in phyllites of Champaner Group has been attempted. The area under investigation is situated eastern fringe of Gujarat, where Precambrian rocks of meso-proterozoic age are enveloped by younger plutonic intrusive (i.e.) Godhra granite on its three sides (Gupta et al., 1997). The present work aims to classify the crenulations from phyllite of Narukot formation, morphologically and to appreciate mechanism of its development. This study will be helpful to evolve the area microtectonically. Moreover, an attempt has been made to correlate crenulation cleavage development with increasing deformation and temperature.
The classification suggests that the cleavages of the Narukot region can be termed as spaced foliation of anastomosing nature with discrete transition between cleavage domains and microlithons. The shape of cleavage domains is smooth with 30% in volume and possesses 3:2 ratio of spacing between them. Additionally by establishing correlation between increasing deformation and temperature, the crenulations of the study area fall under stage II of cleavage development.

Thrust and fold growth, segment linkage and morpho-tectonic evolution of the frontal Siwalik range to the south of the Chitwan intermontane valley, Central Nepal: evidences from topography and drainage development

Ananya Divyadarshini*, Vimal Singh
Department of Geology, Chhatra Marg, University of Delhi, Delhi 110007
**ananyadivya.ad@gmail.com*

The Himalayan front is marked by a linear succession of several strike parallel ranges running from NW - SE. In tectonically active regions such as the Himalaya, the development and growth of such ranges is kinematically linked to the geometry of the underlying thrust and thus they form helpful guides for understanding the structural evolution of the area (Jackson et al., 1996). In general, the Himalayan frontal ranges represent anticlines formed as a result of thrusting of Siwalik rocks over the Indo-gangetic alluvium along a blind or emergent Main Frontal Thrust (MFT) (Powers et al., 1998). The frontal Siwalik ranges are better studied along the north western Himalaya (Delcaillau et al., 2006; Singh and Tandon, 2008; Barnes et al., 2011) in comparison to the central and eastern Himalaya. Satellite images show a distinct variation in the morphology of these frontal ranges from NW to SE, which could indicate a difference in the geometry of the underlying MFT. In this study we analyze the morphology and evolution of a Frontal Siwalik Range (FSR) that is developed along the Central Himalaya. The study area is located nearly 100 km SW of Kathmandu and forms the southern boundary of the Chitwan Intermontane valley in the Central Nepalese Sub-Himalaya. The FSR in this region is locally termed as the Frontal Churia Range - FCR (Kimura, 1998) and comprises 4 distinct segments: the Western most Dumkibas Range, the South West Churia Range (SWCR), the southernmost Valmiki Nagar Range and the South East Churia Range (SECR) (Fig.1). In this study,

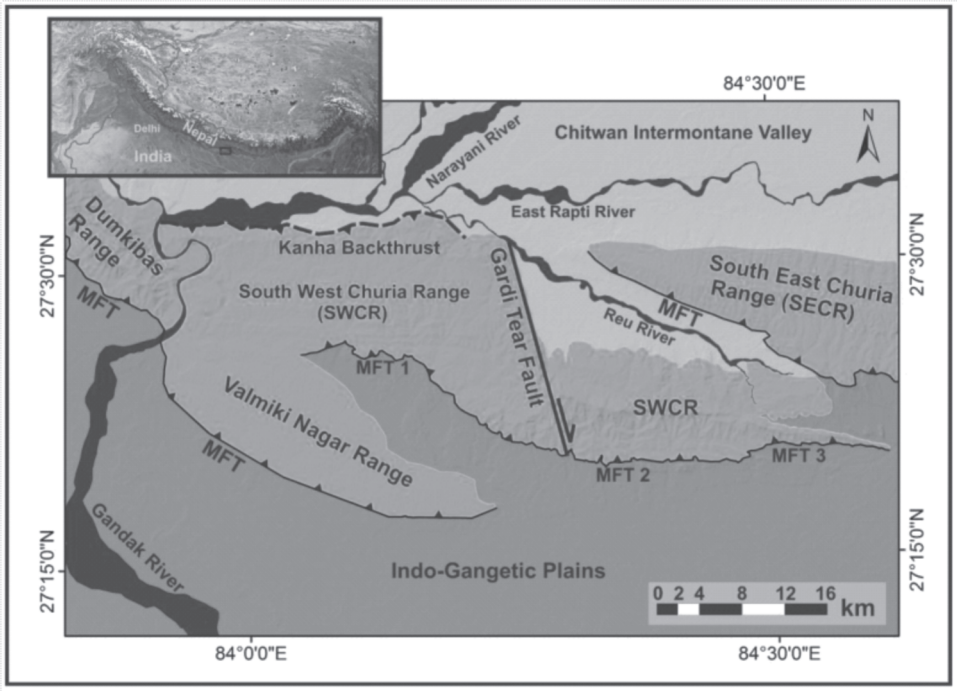


Fig. 1. Hillshade map of the study area showing different segments of the Frontal Churia (Siwalik) Range to the south of the Chitwan Intermontane valley. MFT 1, MFT 2, MFT 3, Gardi Tear Fault and Kanha Backthrust are the structures identified in this study and represent individual segments that have merged to form the SWCR.

we have focused on the morpho-tectonic evolution of the SWCR through geomorphic indices, drainage anomalies, river profiles, along and across strike topographic profiles and morphology of the catchments developed over the SWCR. Our study reveals that the SWCR is formed by the coalescence of at least 3 independent MFT segments (MFT 1 in west; MFT 2 and MFT 3 in east) that have grown towards each other (Fig.1). However, a complexity in its geometry and topographic growth is caused by the development of a NW-SE trending tear fault (Gardi Tear Fault) in the central part between the MFT 1 and MFT 2 (Fig.1). As a result, the SWCR exhibits a stair-stepped geometry where the E-W trending MFT 1 and MFT 2 are laterally displaced along the Gardi tear fault. Inferences from the regional topography, orientation of the adjacent FCR segments and drainage network suggest a dextral movement along the Gardi Tear fault, and as a consequence the eastern part of the SWCR has shifted southwards with respect to its western part. The Gardi tear fault is also marked by the development of a high topography indicating vertical movement along it. Abrupt topographic gradients at the interacting tips of the Gardi tear fault and MFT 2, suggest a huge transfer of stresses between the two segments that have caused the vertical movement along the Gardi tear fault.

Overall growth of the SWCR is more complex; there are two E-W running northern ridges (in both the western and eastern parts) that are parallel to the southern ridges developed due to the growth of MFT segments. Results show that in the western part of the SWCR, the northern ridge is formed along a south dipping back thrust (Kanha back thrust) related to the MFT 1(Fig.1). However, the development of the northern ridge in the eastern part is not clearly understood. Results of topographic profiles and catchment morphologies do not support presence of any back thrust in this part. Therefore, we surmise that the northern ridge in this region could reflect a ramp-flat geometry of

the MFT 2 and MFT 3 segments or it could also represent a separate thrust developed to the north of the MFT 2 and MFT 3 and thus requires a detailed geophysical and field investigation. But these investigations are difficult to carry out in this region as it is a protected forest area. The development of the SWCR can be divided into 3 distinct zones (Western zone, Central zone and Eastern Zone) each of which exhibit a distinctly different pattern of topographic and structural growth. A complex interaction of at least 5 fault segments i.e. the MFT 1 and Kanha back thrust in the western part, the Gardi tear fault in the central part and the MFT 2 and MFT 3 in the eastern part have resulted in the overall morpho-tectonic evolution of the SWCR.

Polyphase folding and ductile shearing in south Delhi Fold Belt: Preliminary structural analysis from Ranakpur-Kumbhalgarh area, Southwestern Rajasthan, India

Kalyanbrata Hatui
Department of Geology, University of Delhi, New Delhi 11007
kalyanbrata11@gmail.com

The Precambrian Aravalli-Delhi mobile belt has a wide variety of metamorphic rocks and they have gone through several phases of deformation. The rocks of the Delhi Fold Belt (DFB) are mostly of a metasedimentary origin and comprise gneisses and schists with very minor occurrences of quartzite, granite, pegmatite, diorite and amphibolite which indicate a metamorphic terrain multiply intruded by the igneous bodies of varying origin. The rocks of this area are generally NNE-SSW trending but the major difference between the nearby two areas is the dip direction of foliation planes. In the eastern part, near Kumbhalgarh fort, foliation planes dip towards west whereas foliations of Parashuramji cave area dip towards east. In a detail study of both parts it is noticed in many places that there are Z- and S- shaped folds present in the eastern part and western part, respectively. The plunge of the fold axes are nearly 18^0 towards 180^0. So, in the large scale it can be assumed that there is a large synclinorium. M-shaped folds are present within an almost 50m outcrop. The folds also plunges 15^0 towards 190^0. Shear zones signatures like asymmetric folds, rotation of boudins and sheath folds are observed. Three phases of deformation are interpreted clearly in the mapped area. First, an early extension was followed by compression and formation of isoclinal, tight folding is observed. Therefore the boudins are folded. Hook shaped folds (Type 3) are also seen. The fantastic structures of the region show that there is a shear zone running parallel to the axis of the synclinoriun. Some workers have suggested that this area is a major transpressional zone with development of a flower structure. The structure of North Delhi Fold belt is well known but relatively lesser data is available from Southern part of Delhi Fold belt (SDFB). This study has a potential to extract more focused structural information from the SDFB and improve the understanding of the Delhi-Aravalli orogeny.

Textural and micro-chemical analysis of pseudotachylyte from two different tectonic settings of Indian craton to understand role of frictional heating and melting of rocks on seismogenic faults

Arindam Sarkar
Department of Geology, University of Delhi, Delhi 110007
arindamsarkargeo@gmail.com

Pseudotachylyte is an ultrafine-grained glassy rock produced either by frictional heating and melting of rocks along a rapidly slipping seismogenic fault plane or by shock-induced temperature rise around a meteorite impact site (Sibson 1977; Shand 1916). The first type is considered to be a product of melting by frictional heat produced during rapid (1-10 m/sec) fault slip. Debate related to melt origin due to lack of exact amount of glass was forwarded till 19th century (Spray 1995). But occurrence of felsic minerals (alkali feldspar along with quartz grains) as refractory clasts with mafic matrix is considered to be a result of preferential melting of mafic minerals (e.g. biotite, hornblende) of the host rock by flash heating although frictional melting process is not still well understood. Rapid melting and solidification of the rock leads to domainal chemical heterogeneity which can be characterized through Scanning Electron Microscopy (SEM) and Electron Probe Micro Analyzer (EPMA). Mylonitised and cataclastic dominated pseudotachylyte veins are studied from Gavilgarh-Tan Shear zone (GTSZ) in the central India and melt dominated psodotachylyte veins are studied from Sarwar-Junia Fault Zone (SJFZ) in western part of Indian craton. Cataclastic dominated Pt veins contain angular clasts with fine grained matrix whereas mylnitised psudotachylyte veins are sheared but these pseudotachtlyte veins comprise sheath like flow structure along with sulphide droplet. Iterated boundary of angular clasts and brightness difference along the boundary of these clasts (analyzed by SEM) in Cataclastic dominated pseudotachylyte veins postulate phase transformation of mineral due to frictional heating along the boundary has taken place (Green et al. 2015). Where as the SJFZ Pt- samples exhibits spectacular melt-origin microstructure, e.g. spherulites and microlites. Radial growth of biotite and Fe-oxides (e.g. ilmenite, magnetite) laths around a relict clast (mostly quartz) commonly constitutes the spherulites. Skeletal growth of ilmenite and biotite into star-, skeletal- or spider-like microlites also supports a melt origin. Partial melting of quartz clasts has formed flow like structure. Glass phase has been determined through X-ray Diffraction (XRD) analysis of these Pt samples whereas peaks of quartz and biotite have also been identified through this analysis. Flow structures of different colors impart a banded nature to the Pt matrix. SEM and EPMA analysis show that melts of different composition, likely derived through melting of different minerals (e.g. biotite/hornblende and quartz/feldspar). This colour banding probably represents inhomogeneous mixing of melts of different compositions, and flowed through different distances depending on the respective melt viscosity.Melting or survival of a mineral grain was not only controlled by its composition (i.e. specific heat) but also by its relative position in the Pt vein (Bizzarri, 2014). Reflection of chemical heterogeneity of the Pt matrix is clearly identified in their chemical analysis. Bulk chemical analysis by X-Ray Fluorescence (XRF) shows an average composition close to that of the host rock. EPMA analysis shows wide variation in the chemical composition of different domains. Therefore, bulk chemical composition data of pseudotachylytes do not carry much genetic significance.

Analysis of river profiles across the frontal fold-thrust belt in the Dikrong river valley, Arunachal Himalaya, northeast India: Implication for fold propagation

Rajeeb Lochan Mishra[1,2]*, R. Jayangondaperumal[1], Hrushikesh Sahoo[2]
[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*Department of Geology, Utkal University, Bhubaneswar*
**rajeebmishra88@gmail.com*

The present study makes use of the normalized channel steepness index (k_{sn}) to quantify the rates of differential uplift across the fold-thrust belt in the Dikrong river valley, northeast Himalaya, India, by considering river longitudinal profiles as a proxy for the local uplift. Though the model has been earlier applied to the streams of northwest Himalayan front, we attempt to validate its application in high monsoonal areas like the northeast Himalaya. Based on field observations and analysis of drainage data from Digital Elevation Model of 1 Arc-Sec, a total number of 147 erosive channels flowing across the major structural elements: the Bomdila Thrust, Main Boundary Thrust, Tipi Thrust, Himalayan Frontal Thrust and the Simna Parvat anticline have been considered for study. With negligible lithological influence, the values of k_{sn} calculated in this study range between 22 and 199. Streams flowing across the Bomdila and the Main Boundary Thrusts yielded k_{sn} values ranging between 22 and 53, whereas, for those flowing across the Tipi and the Himalayan Frontal Thrusts, the values range from 46-186, the majority of these values falling on the higher side. This suggests that the Bomdila and the Main Boundary Thrusts are undergoing lesser degree of tectonic activity as compared to the Tipi and Himalayan Frontal Thrusts. The channels flowing across the nose of the Simna Parvat anticline yield higher k_{sn} values from 86 to 214, suggesting that the Simna Parvat anticline is propagating towards ENE direction, resulting in the gradual shifting of the Dikrong river towards east and abandonment of paleochannels.

Reckoning long-term deformation rate between the Saralbhanga and Kameng river valleys, Assam Himalaya, India

Arjun Pandey*, Ishwar Singh, Rajeeb Lochan Mishra, R. Jayangondaperumal
Wadia Institute of Himalayan Geology, Dehra Dun 248001
**rohitarj42@gmail.com*

The northeast Himalayan Frontal Thrust (HFT) shows high Holocene fault slip rate of 23.4 ± 6.2 mm/yr (Burgess et al., 2012), which contrasts with the geodetic rates of 16 ± 0.5 mm/yr (Jade et al., 2007) between the mountain front and locking line. The high geological shortening rate along frontal fold-thrust belts (Bhalukpong thrust, Balipara anticline and Nameri thrust) and closely clustered earthquake events (A.D. 1697 Sadiya, A.D. 1713 Bhutan, and A.D. 1950 Tibet-Assam earthquakes) in the northeastern Himalaya motivated us to infer the geological long-term uplift rate along the HFT between the Saralbhanga and Kameng river valleys. The study area lies west of recently reported high Holocene rate (Burgess et al., 2012). Toward addressing this issue, detailed geological field work with an aid of high resolution satellite imagery has been undertaken along HFT in the vicinity of Saralbhanga, Manas, Lokhaitora, Dhansiri, Rowta and Mansri river valleys from west to east. We mapped the disjointed geomorphic surfaces along the HFT using Cartosat imagery (with 2.5 m spatial resolution) in a 3-dimensional mode in the lab. The waypoints (i.e. coordinates) of

these geomorphic surfaces were subsequently cross-checked. Wide shear zones demarcating the HFT, various tectonic scarps and uplifted surfaces were observed at the exit of major river valleys. Detailed mapping of these surfaces and fault scarps along the HFT has been undertaken by using Real-Time Kinematic Differential Global Positioning System (RTK DGPS) and Robotic Total Station (TS). Field observations together with high resolution survey data reveals that the disjointed surfaces were uplifted by tectonic activity along the HFT. Along the Lokhaitora river valley, three levels of terraces: T1, T2 and T3 of 6, 12 and 60 m heights respectively were truncated by active faults. At the exit of the Dhansiri river valley, terraces T1 and T2 of 7 and 20 m heights respectively, are faulted. Fault scarps of variable heights (30 m near the Rowta river) and 10 m near the Lokhaitora river have been extensively mapped using RTK GPS. Sediment samples for optical luminescence dating (OSL) and detrital charcoal samples for ^{14}C radiocarbon dating by Accelerator Mass Spectrometer (AMS) were obtained from these disjointed geomorphic surfaces will help in estimating the long-term vertical uplift rate along the HFT.

Recent deformation activity along the Main Boundary Thrust in the western flank of eastern Himalayan Syntaxis, Arunachal Himalaya, India

Ishwar Singh*, A. Pandey, Rajeeb Lochan Mishra, P. S. Rao, R. Jayangondaperumal, P. Srivastava

[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*

[2]*Geological Survey of India*

**gishug@gmail.com*

The northeastern Himalayan syntaxis is very complex in terms of structure and lithology. The Dibang river that debouches into the Brahmaputra plains at Nizamghat in NE-SW direction joined by many tributaries, namely, from west to east are the Siluk Korong, the Sissar (Sessri), the Sirki, the Chisi Pani, the Iphi Pani and Deo Pani rivers respectively. Between Sissar and Nizamghat river sections, the Siwalik disappears and it has been named as the Sessri-Dibang gap (Singh and Choudhury, 1990). Here, the Main Boundary Thrust (MBT) consisting of lesser Himalayan Miri Formation in the hanging wall, directly overlies the Brahmaputra alluvial plains. In the present study, many truncated geomorphic surfaces were mapped along the frontal thrust to constrain the deformation rates at different time scales. To infer the timing of the deformation activity, sediment samples for optical thermo luminiscence (OSL) and detrital charcoal samples for ^{14}C radiocarbon dates by Accelerator Mass Spectrometer (AMS) techniques were collected from the deformed and truncated terraces as well as surfaces preserved along the major river valleys. On the right bank of Sessri river valley, the Miri Lesser Himalayan rock is faulted against the Quaternary fluvial terrace deposits and thus, the MBT forms the frontal thrust in this section. The river cliff section was thoroughly cleaned and the fault exposure was mapped with high resolution robotic Total Station (electronic distance meter). A minimum 10 m of slip along the fault has been ascertained. The OSL dates along with field observations suggest the activity of MBT post 13 ka. Detailed mapping of different levels of abandoned terraces, in conjunction with paleoseismic trenches may highlight a clear vision of the Holocene activity in this region.

Shortening rate across the Surin Mastgarh anticline, Chenab re-entrant, NW Himalaya

Aravind A[1]*, Shraddha Jagtap[1], Anil Kumar[1], Pradeep Srivastava[1], Linto Alappat[2], V. C. Thakur[1], R. Jayangondaperumal[1]
[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*Physical Research Laboratory, Ahmedabad*
**aravind.attukal@gmail.com*

The Surin Mastgarh anticline (SMA), located in the NW sub Himalaya extends continuously for ~200 km in length, between Beas River in the east and Munwar Tawi River in the west. Eventhough the anticline is extending for such a long distance, it does not have emergent frontal thrust in the forelimb, but instead a well-developed discontinuous back thrust has been mapped at several places along northern limb of SMA. In the Jammu-Reasi regions along Chenab river, a minimum geological shortening rate of SMA was inferred as 9±3.2 mm/yr. It was estimated by dating of terrace atop that lies near to the hinge of the SMA using excess area method (Vassallo et al., 2015). In the same region, they found that the Medlicott-Wadia Thrust (MWT) also absorbs minimum of 11±3.8 mm/yr shortening. Thus the total shortening rate between frontal anticline and MWT is ~20 mm/yr, which is larger than the reported total geodetic rate (i.e. 16 to 12 mm/yr).

In the present study, we estimated shortening rate at two different parts of the SMA (hinge and limb) using fold geometry methods along River Chenab that cuts across the anticline. In this method, the anticline is considered obeying Sine function. Total three sets of terraces were identified along Chenab river section. Using Real Time Kinematic GPS survey, we mapped these three levels of terraces and current river grade across the anticline. Optically stimulated luminescence samples were collected from each of these terraces. Robotic Total Station was used to get the geometry of strath contact and finally inferred the nature of the terrace deformation with respect to underlying bedrock. Using field data integrated with survey data fold structure has been reconstructed. By using the arc line method, the horizontal distance of the limb (D) was calculated and also length of the limb (L) was calculated. Subtracting the horizontal distance 'D' from the limb length 'L', we obtained deformed length of a fold. Using abandonment age of the dated terraces and deformed length, we inferred geological shortening rate across the SMA.

Rock water interaction and suitability of groundwater for various uses in a part of Vathalmalai hill region, Tamil Nadu, India

G. Gowrisankar, G. Jagadeshan, L. Elango*
Department of Geology, Anna University, Chennai
elango34@hotmail.com

Rock water interaction plays a major role on the quality of groundwater. The present study was carried out with the objective of assessing the role of rock water interaction and to determine the suitability of groundwater for various uses in a part of Vathalmalai hill region, Tamil Nadu, India. About 40 groundwater samples were collected during January 2014 and June 2014 from wells located in the area and analyzed for calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride and sulphate. This area is comprised by epidote hornblende gneiss and charnockites which are intruded by dolerite dykes. Various major ion correlation diagrams were

prepared to assess the role of rock water interaction in controlling the groundwater quality. The suitability for drinking purpose was assessed by comparing with the standards prescribed by Bureau of Indian Standards. Based on the concentration of TDS, sodium, chloride and fluoride the groundwater of January and June 2014 of a few wells was not found suitable for drinking purposes. Chemical indices like Na^{+}%, sodium adsorption ratio, residual sodium carbonate and permeability index (PI) were calculated. Most of the sample from June 2014 is not suitable for irrigation. Hence proper management strategy is required to reduce the concentration of ions present in the groundwater and salinity build up for drinking and irrigation purposes by increasing the rainfall recharge.

Impact of sea-level rise on seawater intrusion in coastal aquifer south of Chennai, India

Dhanamadhavan S., L. Elango*
Department of Geology, Anna University, Chennai
**elango34@hotmail.com, elango.annauniv.edu*

Increase in atmospheric temperature, sea level rise and changes in precipitation are the effects of climate change in the world. There is a need for assessing the impact of sea level rise on coastal aquifers as they supply water to the community. The objective of this study is to assess the impact of sea level rise in fresh water - sea water interface in the coastal aquifer of Chennai. The aquifer south of Chennai is bounded by Bay of Bengal in east and Buckingham canal in the west. The projected changes in sea level up to 1 m were considered for assessing the change in fresh water-salt water interface. The freshwater and saltwater interface on the coastal aquifer resulted in the linear increase towards land due to the projected sea level rise.

Groundwater chemistry and hydrogeochemical processes in a part of Chinnar watershed Perambalur District, Tamilnadu

S. Anbarasu, L. Elango*
Department of Geology, Anna University, Guindy, Chennai 600025
**elango34@hotmail.com*

Rock water interaction and hydro-geochemical processes play a major role in the chemical composition of groundwater. Quality of groundwater determines various usages. This study was carried out to understand geochemistry and groundwater quality in a part of Chinnar watershed located in the western part of Perambalur district, Tamilnadu, where groundwater is used mainly for drinking and agricultural purposes. Groundwater samples were collected from 43 locations and analysed for major ions to determine the drinking and agricultural use. Calcium, magnesium and potassium sulphates were present within permissible limits for drinking and irrigation. Some samples exceed the permissible limits recommended by Bureau of Indian Standard for pH, TDS, TH, chloride, sodium and bicarbonate. In the study region, carbonate weathering, silicate minerals and ion exchange process control the major ion chemistry. Chloride, nitrate, sulphate concentrations suggest the impact of agriculture activities.

Assessment of surface water and groundwater quality in the parts of the Manipur Valley, Northeast India

Laxmi Thokchom*, K. S. Kshetrimayum
Department of Earth Science, Assam University, Silchar 788011
**chan.thokchom@gmail.com*

To elucidate the present state of quality, a study on the hydrochemical parameters like pH, Temperature, EC, TDS, ORP, Fe, As, Mn, Cl, HCO_3^-, Ca, K, Mg, Na, Zn, Pb, Cu, Br and Sr of surface water and groundwater has been carried out in the parts of the Manipur Valley, NE India. The pH values indicate slight alkalinity in surface water and normal in groundwater. TDS and EC values for both surface water and groundwater show fresh quality except few in saline spring samples. Some samples exceed WHO (2011) recommended limit for turbidity in surface water. Fe, Na, K, Ca, Mg were analyzed in ICP-AES, As, Mn, Cu, Pb, Zn, Sr and Br were analyzed using ICP-MS and HCO_3^-, CO_3^{2-} and Cl^- were tested by titration method. A total of 531 samples from 59 sites in which 8 from rivers, 2 from lakes, 4 from springs and 45 from shallow aquifers (depth upto ~10m) were collected from alluvial plain, flood plain and piedmont zone of the study area. The results revealed that Cl, HCO_3, Ca, K, Mg, Na, Sr, and Br were highly elevated in all the springs and surrounding aquifers indicating existence of salt springs. Cu concentration in both surface water and groundwater confined within the recommended limit. Concentrations of Fe, Mn, Zn, Pb and As were also highly elevated in many of the samples. Fe and Mn exceed WHO limit as high as fifty times for Fe and six times more for Mn mostly in groundwater. Likewise, concentration of Zn exceeds five times more than WHO limit by mostly in groundwater. Pb concentration exceeds ten times more than WHO limit mostly in groundwater. Contamination of arsenic as high as seven times more than WHO limit in groundwater was observed during the study. Therefore, further studies on inland salinization into fresh aquifers, sources of elevated Fe, Mn, Zn and Pb and contamination of arsenic are necessary for better management and development of both surface water and groundwater in the study area.

Sources of elevated iron and manganese concentrations in surface water and shallow groundwater in and around Dimapur town, northeast India

Heizule Hegeu*, K. S. Kshetrimayum
Department of Earth Science, Assam University Silchar 788011
**heizulehegeu@yahoo.in*

Causes of elevated Fe and Mn in surface water and groundwater around Dimapur Town have been investigated. The study area is located in the tectonically active region around Naga Thrust of Assam-Arakan basin, Northeast India. The physical parameters such as pH, TDS, EC and temperature and water table were measured in the field. Ions and heavy metals like Ca, Mg, Na, K, Fe, Mn, Pb, Zn, As, Cu, were analyzed using ICP-AES and Cl^- and HCO_3 by titration method. The pH value of surface water ranges from 6.1 to 8.1 and that of groundwater ranges from 4.1 to 7.2. Out of 25 groundwater samples 14 are acidic in nature. TDS varied from 40 mg/l to 100 mg/l for surface water and that of groundwater varied from 20 mg/l to 320 mg/l indicating fresh water type. Heavy metals such as Pb and As were not detected and Cu and Zn were below the Bureau of Indian Standard limit for drinking water. The water samples shows high anomalous concentration of Fe and Mn. Fe concentration up to 2 to 3 mg/l in drinking water might pose a problem for individuals who suffer Fe

storage disease called hemochromatosis. Ingestion of Mn may adversely affect human health with the young and unborn being most at risk. Water containing dissolved Fe and Mn are colourless whereas Fe form reddish brown and Mn form a black or deep brown residue when exposed to air. The Fe and Mn exceed 28 and 136 times more, respectively, than the US Environmental Protection Agency limits for drinking water. The study reveals that the elevation of Fe and Mn is controlled by the groundwater flow in the area. The water table contour map study shows regional groundwater flow direction from South to North, the depth to water table and water table elevation varies from 1.52 mbgl to 10.75 mbgl, and 123.64 mbgl to 179.27 mbgl, respectively. Based on the groundwater flow the recharge zone has been identified as around the upstream of Chathe River, the Chathe and Dhansiri rivers confluence and around the upstream of Dhansiri River. Fe and Mn contaminations in water from the Dhansiri and Chathe rivers discharge as influent rivers into shallow aquifers around the flood plains. Groundwater with elevated Fe and Mn in recharge zones supply water to the low lying discharge areas like back swamp, oxbow lake, pond and shallow groundwater leading to high elevation of Fe and Mn concentration. It is recommended to adopt appropriate methods to reduce the Fe and Mn concentration from these water sources for maximum utilization.

Mapping of fluoride vulnerable zones in the hard rock aquifers of south India

Ankita Chatterjee, Shakeel Ahmed
CSIR- National Geophysical Research Institute, Hyderabad 500007

Delineation of safe and unsafe zone with respect to groundwater fluoride contamination is not reliable on the basis of one time concentration data. Because fluoride concentration varies with time therefore the position of safe and unsafe zone will also change. It is necessary first to identify the pattern of variation of groundwater fluoride concentration and associated factors involve for the variation. This study is carried out to investigate the pattern of spatial variability of groundwater fluoride (F^-) concentration and assess the causes behind thechangeability in its spatial variability using long term records of fluoride data (2000-2009) in the agricultural, hard rock watershed of South India (Maheshwaram, Telangana). The dataset is divided into two time periods(2000-2003 and 2005-2009) and the three groups are assigned such as safe, transition and unsafe using the permissible limit given by WHO and BIS for F^- consumption through drinking water. The Theissen polygon maps (for two time periods) are prepared to determine the zone of influence of each borewells or fluoride sampling points. The probability of occurrence method is used to characterize each sampling points by their highest occurring group. *The study identified that most of the zones are transformed from safe to transition or unsafe and vice-versa in the second time period (2005-2009)* while others zones are remained constant. The correlations between the factors (water-rock interactions, irrigation return flow from paddy field, variation in hydraulic conductivity) responsible for F^- accumulation and enhancement in groundwater and the spatial variability of fluoride content in the study area are determined. Vulnerability assessment mapping of fluoride contamination was developed and vulnerable, least vulnerable, least safe and safe classes are assigned for the watershed on the basis of the changing pattern and parameters associated with the variability of fluoride content. This approach of vulnerability assessment by using probability of occurrence of contaminant is independent of assumptions and can be applicable where long time data are available. The area has been changing quite fast from agricultural land to settlements and such predictive results will guide to safe planning for settlements and also planning for a possible treatment plant.

Recent scenario of Rajghat dam reservoir of district Sagar, Madhya Pradesh, India and their health impact

Abhilasha Chourasia*, R.K. Rawat
Department of Applied Geology, Dr. Harisingh Gour University, Sagar
**abhi9080@gmail.com*

Water quality assessment and management of groundwater sources that have biggest problem facing in rural and surrounding areas. Some important parameters are Turbidity, Total Alkalinity, Chloride, Total hardness, Calcium, Magnesium and Fluoride of the study area shown the present scenario of the Rajghat dam reservoir which is mainly used for drinking water supply by the municipal co-operation. Eleven samples have been collected from Rajghat dam catchment in pre and post monsoon seasons during year 2014. Different parameters of water have been analyzed and evaluated to find out its suitability of drinking water for human consumption, public hygiene scenario and health impacts. These parameters are observed within the prescribed limits of ISO: 10500 (2012) for drinking water. The present study is aimed at assessing the water quality aspects of Rajghat dam reservoir situated in Sagar District of Madhya Pradesh, India.

The study area falls in Survey of India (1:50,000) topo-sheets No. 55I/9, 55I/10, 55I/11, 55I/12, 55I/13 and 55I/14. The Rajghat dam is rock and earth-fill type of dam. This dam is 1680.0 m long with 400.0 m masonry spillway. The catchment gets water from Bewas River, Parkul River, and Jamunia River junction at Hinota village. Bewas River is 53.03 kms, Parkul River is 33.93 kms, and Jamunia River is 18.05 kms long at the dam site. The catchment area of Bewas river at the dam site is 472 sq. kms is located between 23° 23' 36" N to 23° 46' 22" N latitude and 78° 30' 32" E to 78° 46' 42" E longitude. The total water capacity of dam is 96.0 million cubic meter with 80.0 live storage, and 16.0 dead storage. Bed level of river is 495.0, minimum sill level is 509.0 m, maximum water level is 518.0 m, and maximum bed level is 520.0 m at dam site. The Bewas River originates from the northeast part of Raisen district located at about 720 meter near the Pipalia Katan. The normal annual rainfall of the study area is 1234.8 mm about 90% of the annual rainfall takes place during the southwest monsoon period i.e. June to September only 5.5% of annual rainfall takes place during winter and about 4.5% of rainfall occurs during the summer months. Last ofDecember to January end is the coldest months with the temperature falling as low as 4.6^0 C and max. up to 24.5^0 C, and in the month of May, the temperature goes up to 48.7^0 C.

The present scenario of Rajghat catchment is mainly shown by the physico-chemical condition to find out the suitability of the groundwater through the water quality assessment.

Hydrogeochemical study for the assessment of groundwater quality in trans-varuna region of Varanasi city, Uttar Pradesh

Sughosh Madhav*, Arif Ahamad, N. Janardhana Raju
School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067
**sughosh.madhav@gmail.com*

Water is the most common yet the most precious resource on the earth without which there would be no life. Trans -Varuna region is a part of lower Varuna basin of Varanasi district. Groundwater quality of the study area is highly influenced by the agricultural and urbanization

activities. The hydrogeochemical study was undertaken by randomly collected 31 samples from hand pumps to assess the hydrogeological processes and geochemical quality of groundwater through analysis of major ions and heavy metals. Groundwater of the study area is neutral to slightly alkaline in nature, because of the influx of HCO_3^- ion in the groundwater aquifer. On the basis of TDS all the samples in both seasons are within the range of desirable to permissible for drinking and agriculture purpose. As per Wilcox's diagram and US Salinity laboratory classification, most of the groundwater samples are suitable for irrigation except one sample in post monsoon season. On the basis of residual sodium carbonate all the samples of both seasons fall in the safe category except one sample (13) which lies in marginally suitable category. Permeability index indicates that the groundwater samples are suitable for irrigation purpose. Iron contamination is found in the major part of study area. The concentration of Fe in water samples ranges from 58.7 µg/l to1376.5 µg/l with a mean value of 445.4 µg/l. In pre monsoon season 74% groundwater samples are having iron content is above the permissible limit prescribed by WHO (1993).

Although the general quality of groundwater in Trans - Varuna region of Varanasi city is suitable for irrigation purpose, 36% samples in premonsoon and 52% samples in post monsoon are having nitrate content more than permissible limit (>45 mg/l) which is not good for human consumption. Poor drainage, domestic waste and application of Nitrogen fertilizers on agricultural land may be the major sources of nitrate in groundwater in the study area.

Groundwater occurrence in the Tarai region of district Udham Singh Nagar, Uttarakhand, India

Ashok Kumar
Department of Geology, Kumaun University, Nainital

Bhabhar region is delimited in the north by Lower Siwaliks and Tarai region in South. The Bhabar region is mainly constituted of unconsolidated sediments like clay, sand, gravel and boulders and Tarai region is mainly composed of well sorted clay, sandy clay and fine to medium sand and occasionally gravel. The Bhabhar zone forms a perennial source of water to the Tarai region. The groundwater aquifers of the Tarai region have been delineated and studied for groundwater flow regime. The aquifer formations of the groundwater have been demarcated by groundwater level of pre- and post- monsoon records and two dimensional subsurface cross sections. The study is significance in ascertaining groundwater potential of the region. The depth to groundwater level has been recorded from 2.7 mbgl to 5.7 mbgl in post monsoon season of 2015. In addition to it shallow water aquifers also occurs frequently in the Tarai region. The groundwater abstraction in pre-monsoon is approximately 0.84 million m^3 per day and in monsoon season is approximately 0.36 million m^3 per day with an average of about 1.2 million m^3 per day per year. The precipitation record as compared to previous years shows decreasing trend. The average rainfall to the extent of about 138.8 mm was recorded in 2011 which was reduced to 110.6 mm in 2013. The groundwater recharge was recorded to 19709 ha-m in 2011 and 14736 ha-m in 2013. The groundwater recharge is decreasing and overland discharge has been increased due to reduced recharge areas with the rapid growth of urbanization and industrialization.

Chemical quality of ground water around Tosham area, district Bhiwani, Haryana

Savita Kumari[1]*, Naresh Kumar[1], Vinod Kumar Garg[2], Naresh Kochhar[3]
[1]Department of Geology, Kurukshetra University, Kurukshetra 139119
[2]Department of Environmetal studies, C.U.P Bhatinda
[3]Department of Geology, Punjab University, Chandigarh
** savi_geokuk@yahoo.com*

Tosham Ring Complex (TRC; Survey of India topography sheet no. 44P/13; Scale 1:50,000); (28° 46'-28° 55' N; 75° 50'-75° 58 E) is located 160 KM WNW of Delhi which is a part of Malani Igneous Suite (MIS) and composed of acid volcanic and the associated granites. Water is vital for life, well-being, food security and socio-economic development of mankind. In many developing countries, availability of water has become a critical and urgent problem and it is a matter of great concern to families. The chemical quality of groundwater has been studied in and around Tosham area to assess its impact on human health. Quality parameters including temperature, pH, salinity, conductivity, TDS and concentration of trace elements were measured in water samples around Tosham area. The pH and EC of different samples varies from 7 to 8.6 and 1 to 24.4 respectively. The concentration of As in surrounding area of Tosham is found to be 4.1 mg/l in village Khanak and 2.5 mg/l in village Nigana followed by 1.9mg/l in village Dulheri, 1.3mg/l in village Dadam, 1.2 mg/l in village Riwasa which is higher than the limit (0.05mg/l) described by BIS (Bureau of Indian Standards) (IS-10500, 2012). Similarly the concentration of Pb is 0.9 mg/l in village Khanak, 0.69 mg/l in Nigana, 0.59 mg/l in PWD guest house, Tosham which is higher than limit (0.01mg/l) described by BIS. The concentration of other trace elements like B and Fe also found higher than the prescribed limit. Excess trace metal accumulation in water is toxic to humans. The higher concentration of trace elements in water may cause many harmful impact on human health. The excess of Arsenic may create skin poisoning, affects kidneys and central nervous system. The higher concentration of Pb may cause burning of mouth, severe inflammation of the gastro-intestinal tract with vomiting and diarrhoea, abdominal pain, paralysis, anaemia and mental confusion. Moreover, the concentration of Flouride is also more than the prescribed limit in water samples of Khanak (1.6 mg/l), Panjokhera (1.9 mg/l) and Riwasa (1.8 mg/l) villages. The excess of Flouride may be harmful to human health and may cause reduction in dental carries and may also cause crippling skeletal fluorosis.

The chemical quality of ground water may be affected due to the contacts and reactions between the rocks of buried Aravali -Delhi ridge, high heat producing Tosham granites (Malani), and quartzites with the water horizons of the studied area (Kochhar et al. 2012). Moreover the rain water quality may be alter by major minerals constituents of host TRC during its percolation through the rock fracture, joints before becoming the integral part of ground water aquifer. The weathering process like hydration, hydrolysis and solution may be the cause of change in water chemistry of particular area.

Kochhar et al. (2012) IGWC, 611-626.

Geochemical processes controlling groundwater salinization in a coastal aquifer of southern Tamil Nadu: identification of natural and anthropogenic influences

S. Selvakumar*, N. Chandrasekar
Centre for Geotechnology, Manonamniam Sundaranar University, Tirunelveli, Tamil Nadu
**geoselvas@gmail.com*

Fresh groundwater stored in Indian coastal aquifers is an important resource for the natural environment, as well as for urban, agricultural, rural residential and industrial activities. Salinization is a common groundwater natural contamination process in arid and semi-arid coastal region of India, but often it is also the result of human activities mainly urban development, industrial effluents, agricultural practices with over exploitation and beach placer mining activities. The present study has analyzed the pre and post-monsoon physicochemical data of groundwater samples from 202 production and monitoring dug wells and bore wells. To assess the impact of natural and anthropogenic activities, the coast was divided into four zones namely Tuticorin, Tiruchendur, Uvari and Kanyakumari. Various graphical, ionic-ratio plots, statistical analyses and saturation indices calculations have been carried out using physicochemical data to deduce a hydro chemical evaluation of the study area. Spatial distribution maps were prepared for various physico-chemical parameters using geographical information system. Multivariate statistical analysis combined with conventional hydro chemical methodologies, were applied, with the aim to interpret the spatial variations in the groundwater quality and to identify the main hydro geochemical factors and human activities responsible for the high ionic concentrations in the groundwater analyzed. The application of GIS and multivariate statistical analyses in the study area is a promising tool to understand the spatial pattern of groundwater quality and its management.

Salinization in groundwater quality from natural activities (deficient rain due to climate change, tidal level fluctuation and sea level rise) and anthropogenic activities has resulted from seawater intrusion along the coastal areas due to groundwater over pumping (particularly in the Uvari zone, the most important influence is the high volume of extraction during dry season) extensive use of fertilizers, infiltration of sewage water and beach placer mining activities.

Factors controlling the export of geochemical solutes in meltwater stream of Sutri Dhaka Glacier, Chandra basin, Western Himalaya

Ajit Singh*, Parmanand Sharma, Lavkush Patel, Thamban Meloth, C.M. Laluraj, Vinay Kumar
Earth System Science Organisation - National Centre for Antarctic and Ocean Research, Goa
**ajit.t.singh@gmail.com*

Himalayan glaciers make an extremely important source of fresh water to the mountain people as well as those live downstream. These glacierised areas are the ideal environment to study the water-rock interaction, since chemical weathering rates are high and anthropogenic impacts are often minimal. Since, the melt-water qualities of these areas are the important tool for investigating the configuration and dynamic nature of the subglacial hydrological system, it is essential to monitor the glacier melt water characteristic. The present study aims to understand the hydrochemical composition and their provenance at Sutri Dhaka glacier stream, Chandra basin, Western Himalaya

during summer season. The observed discharge of Sutri Dhaka glacier stream ranges from 8.8 m^3s^{-1} to 17 m^3s^{-1} with a mean discharge of 12.3 m^3s^{-1}. Systematic meltwater samples were collected from the discharge site of Sutri Dhaka glacier during peak ablation season on daily basis (from 5th July 2015 to 4th August 2015) and analysed for major ion and trace element determination using Ion Chromatography (IC) and Inductively Coupled Plasma mass Spectrometry (ICP - MS). The study showed that HCO_3^- (74.5%) was the dominant anion followed by SO_4^{2-} (24%), NO_3^- (1%) and Cl^- (0.12%) while Ca^{2+} was the dominant cation contributing 78.5 % followed by Mg^{2+} (14.3%), K^+ (4.78%) and Na^+ (1.6%). The Piper diagram indicates that the Sutri Dhaka meltwater stream is Ca^{2+} - HCO_3^- type. Gibbs plotting [$(Na^+ + K^+)/Na^+ + K^+ + Ca^{2+}$)] indicates that rock - water interaction is a dominant factor in controlling the concentration of major ion in meltwater stream. In our study C-ratio ($HCO_3^-/HCO_3^- + SO_4^{2-}$) was ~0.75 indicating the dominance of carbonate weathering in the enrichment of major ions. Trace element analysis reveals that the Fe and Al was the most dominant trace element present in Sutri Dhaka meltwater stream followed by Mn, Sr, Ti, Rb, Co, As, Cr and U. Electrical conductivity, major ions, Sr and U concentration showed a significant inverse relationship with the discharge suggesting enrichment of these solutes caused by higher residence time during low discharge conditions. Principal Component Analysis (PCA) results shows three dominant factor loadings constituting 79.9% of variability. Factor one shows positive loadings (>0.50) for EC, K^+, Mg^{2+}, Ca^{2+}, SO_4^{2-}, HCO_3^-, Mn, Co, Rb and Sr, suggesting solute enrichment caused by rock water interaction. Factor two reflects higher loading for Na^+, NH_4^+, Cl^- and NO_3^- indicating dominant contribution of these ion from snow and ice melt. Factor three reflects the influence of processes like physiochemical changes (adsorption - desorption; precipitation and co- precipitation) with high loadings for Al, Fe, Ti and Cr. The present study on major ions and trace elements provides new insights in to the possible control mechanism on the characteristic melt- water of Sutri Dhaka glacier.

Hydrogeological studies with reference to groundwater and surface water quality in parts of Mulugu and Venkatapur Mandal, Warangal district, Telangana State, India

Satyanarayana. E*, M. Muralidhar
Department of Geology, Osmania University, Hyderabad
**sathishv36@gmail.com*

Fifty water samples including Surface water, Dug well, Hand pump and Bore well during the pre-monsoon (May-June) and post-monsoon season (November) in parts of Mulugu-Venkatapur mandals, Warangal District to an extent of 453 sq. km and falls under Toposheet No. 56 N/15 & 56 N/16 of Survey of India were collected. The samples were analysed for major ion chemistry using to study the groundwater characteristics and its suitability for drinking as well as irrigation purposes. Various indices like Salinity index, Sodium Absorption Ratio (SAR), Kelly's Ratio (KR), Residual Sodium Carbonate (RSC), Soluble Sodium Percentage (SSP), Permeability Index PI) and Water Quality Index (WQI) are used to classify groundwater and surface water for drinking as well as irrigation purposes. Besides this, Piper trilinear diagram, Wilcox diagram, Doneen's classification and Gibb's plot were studied for geochemical controls, and hydrogeochemistry of groundwater and surface water.

Groundwater quality: focus on fluoride and nitrate concentration in Kodangal and Doulatabad Mandals, Mahabubnagar district, Telangana, India

G. Hari Krishna, E. Satyanaryana, M. Muralidhar
Department of Geology, Osmania University, Hyderabad

Groundwater is the most vital resource which is available in varying quantities due to lateral and vertical variation in the geological formations. The study area is one of the drought affected areas in Mahabubnagar district, mostly covered by hard rocks and it comprises sandstone, green stone, purple shale, granite, gneisses, migmatites (with minor xenoliths of tonalite, trondhjemite, granodiorite, amphibolites and biotite schist) and Deccan traps. The Deccan trap formations are represented by vesicular-amygdoloidal and massive basalt. The district annual normal rainfall is 604 mm. There are no major, medium or minor surface water irrigation sources in the study area and is totally dependent on groundwater.

There is a severe problem in obtaining adequate water supplies for both the drinking and irrigation purposes. Two villages are without any water including surface as well as groundwater for drinking and agriculture. Keeping this in view, Kodangal and Doulatabad Mandals were selected to carry out hydrogeological studies and groundwater quality conditions. As part of this, the field work has been carried out during pre-monsoon and groundwater samples have been collected covering all the major hydrogeological environs. These samples were analyzed for major ions and various physico-chemical attributes, and compared with world health organization (WHO) standards. Overall view of the samples reveals that out of 45 water samples 6 samples of fluoride, 9 samples of Chloride and 29 samples of Nitrate concentrations are exceeding the permissible limits and remaining samples are within the permissible limits. Suitability of water in the area for drinking is determined.

Assessment of groundwater and surface water quality in the covering Katedan watershed, Rangareddy district, Telangana, India

M. Lingaswamy[1]*, Atulya K. Mohanty[2], S. Sankaran[2], V. V. S. Gurunadha Rao[2]
[1]Department of Geology, Osmania University 500007
[2]CSIR- National Geophysical Research Institute, Hyderabad 500007
**maheshwaramlm@gmail.com*

In view of developmental activities, there is significant indiscriminate disposal of treated/untreated liquid waste industrial effluents/(sewerage) as well as solid wastes may likely to pollute the groundwater regime of the region. Apart from effluents, during the rainy season industrial wastes (solid wastes and solid sludge from the effluent treatment plants) also end up in the groundwater as non-point source pollution, as they are openly dumped within the premises of the industries. As a result during the post-monsoon period groundwater pollution is expected to be as high or even higher when compared to the pre-monsoon period. As groundwater and its flow through the surface and subsurface is a dynamic process, periodical updates and monitoring is essential for understanding the various processes responsible for the groundwater contamination.

Assessment of groundwater contamination in industrial development areas (IDAs) in Katedan area has been carried out to prognostic and its environmental impact on water resources. The

untreated industrial waste and toxic chemicals from underground storage tanks contaminate groundwater and also all of these activities can generate pollutants and slowly begin to move through the subsurface environment. The effects of pollution may remain in the aquifers for years because of the residence time of ground water is very slow, and may even result in aquifers or parts of aquifer being damaged beyond repair. A total of 14 samples from groundwater 13 and surface water 1 were collected in December 2012 and analyzed for chemical constituents, The depth to groundwater table from the surface varied from 2.1 m to 10.6 m (bgl) with a mean value of 6.3 m.The pH value of water samples has been varying from 6.2 - 7.5, with an average of 6.7, and the Total dissolved solids (TDS) of groundwater samples ranges from 433 - 3875 mg/l with an average of 1646 mg/l. Major ions such as Na, K, Ca, Mg, SO_4, NO_3, Cl, F, HCO_3 and Heavy metals such as Al, Fe, Mn, Cr, Cd, Co, Ni, Se, Pb, concentrations are found to be above permissible limits Hazardous and industrial wastes with heavy and toxic metals released from industries which is a great cause of concern and polluting the entire hydrological system and aquifer regime of the area.

Impact of urbanization and industrialization on the quality of groundwater in and around Chincholi industrial area, Solapur, Maharashtra

Mukate Shrikant, Panaskar Dipak, Wagh Vasant
School of Earth Sciences, Swami Ramanand Teerth Marathwada University, Nanded, Maharashtra

The suitability of groundwater for drinking purpose was evaluated in Chincholi industrial area, located in Solapur district of Maharashtra. Solapur is fast growing city, which is known as textile hub of Maharashtra. It comprises arid and semi-arid climate, hence, it faces the water scarcity problems. Population is mainly depending on groundwater for domestic and agriculture need due to less surface water availability. A total of 49 representative groundwater samples were collected and analyzed in pre and post monsoon seasons of 2015. Groundwater quality was assessed for major cations, anions and other ions (EC and TDS). The results compared with the WHO standards, which confirms that TDS 55.1 % and 53 % samples exceed the permissible limit in pre and post monsoon season. The hardness value comprises with 40.8 % and 42.8 % samples exceed the permissible limit in pre and post monsoon season, however; Calcium over the magnesium in both seasons. The Sodium, 24.4 % and 30.6 % samples are beyond the permissible limit in pre and post monsoon season. In both season 6.1 % samples of Potassium are above the permissible limit. The groundwater quality index concluded that, 20.4 % and 26.5% samples fall in unsuitable for drinking in pre and post monsoon season which indicates that industrial activities are altering the water quality. It is clearly observed that, 20.4% and 6.1% samples having poor water quality and hence; unfit for drinking in pre and post monsoon season. The spatiotemporal variation map of water quality index visualized that, the water quality is significantly affected in and around the industrial area and few places where extensive agricultural activities occurred. The study reveals that groundwater quality is heavily deteriorated in both seasons.

Hydrogeochemistry of groundwater quality along the coastal region around north Chennai, Thiruvallur district, Chennai, Tamil Nadu, India

Balasubramanian M*, Sridhar S.G.D.
Department of Applied Geology, School of Earth and Atmospheric Sciences, University of Madras, Guindy Campus, Chennai 600025
**geobalasubramanian@gmail.com*

Seawater intrusion is a major problem in urbanized coastal regions of India which is due to over exploitation of groundwater for various purposes. Fifty five groundwater samples were collected during post monsoon (January 2015) and pre monsoon (June 2015).The groundwater parameters such as pH, EC, TDS, Ca^{+}, Mg^{+}, Na^{+}, K^{+}, Cl^{-}, HCO^{3-}, SO_4 and NO_3 were determined for both seasons. Comparing BIS (2012), Na, Ca, Mg, and K, Cl, HCO_3, SO_4 and NO_3 concentrations were above permissible limit in most of the samples, indicating contamination in groundwater for drinking and other domestic purposes in the study area. Total dissolved solids (TDS) and Electrical Conductivity (EC) are being observed to be above permissible limit in locations like, Parry's corner, Fishery office, Thiruchinakuppam, Palagaithottikuppam, Central Chennai, Attipattuputhunagar, Nungampakkam, Padikuppam, Vadaperumpakkam, and Tiyempakkam, and they are unfit for drinking purpose and moderately useful for other domestic purposes, due to the fact that they are being contaminated by pollution and seawater intrusion that are attributed to over-abstraction of groundwater. At several locations the groundwater is not suitable for drinking and domestic use due to industrial activities and urbanization. Classification of water based on hardness (Sawyer and McCarthy 1967) is described and the hardness (TH) is mainly due to the dissolution of carbonate minerals such as calcium and magnesium. The results of the analyses were interpreted by various geochemical diagrams, like Gibb's plot, Wilcox diagram, USSL diagrams, comparative Box and Whisker plot and (Ca+Mg) vs. (HCO_3+SO_4) diagrams reveal the characterization of groundwater chemistry of the study area.

Assessment of heavy metals concentration in groundwater of Karaipottanar sub basin, Tamil Nadu

Sangunathan U*, Sridhar S.G.D
Department of Applied Geology, School of Earth and Atmospheric Sciences,University of Madras, Guindy Campus, Chennai 600025
**usangu@gmail.com*

Heavy metals are introduced to the environment through natural processes and also due to human activities, such as agricultural practices, transport, industrial activities and waste disposal. The study aims to assess the heavy metals in groundwater through integrated approach like geochemical and statistical processes. A total of 44 samples were collected in Karaipottanar sub basin which covers the Namakkal and part of Tiruchirappalli district of Tamilnadu. The samples were analysed for pH, Redox potential (ORP), Electrical conductivity (EC), Fe, Cr, Zn, Cu, Ni, Co, Mn for post monsoon (POM- Month of January, 2015). The order of dominance of higher concentration of Heavy metals are as follows Fe > Zn > Mn > Co > Cu > Ni > Cr. 82, 73 and 2 % of Fe, Ni and Mn exceeds the permissible limit of BIS and other metals are within the permissible limit, respectively. Fe, Co, Cr increases and decreases with certain pH. The pH is between 6.8 and 7.2 and above this pH, they get decreased. Higher concentration of metal is noted in the acidic to near neutral pH. Two

processes have been observed between metals and EC which exhibits that lower EC with higher concentration of metals and higher EC with higher concentration of metals. The spatial distribution of Co, Cr, Cu, and Ni is observed as patches in all parts of the regions which lies in Fissile hornblende biotite gneiss, Fe in north east which lies in charnockite, Mn and Zn in south west part which is observed in alluvium of the study area. From the statistical methods five factors have been extracted whereas the factor 1 - 5 is dominated by Zn and Mn, Cu and EC, Fe and Co, Cr and Ni, pH and ORP, respectively. The poor positive correlation exists between the metals and pH shows negative correlation with metals. Lithology, lineament and anthropogenic processes control the process of heavy metals in groundwater of these regions.

Seasonal and spatial behavior of uranium in groundwater of hard rock aquifers of Madurai district, Tamilnadu

Thivya C*, Chidambaram S., Thilagavathi R., Nepolian M.
Department of Geology, University of Madras, Guindy campus, Chennai
Department of Earth Sciences, Annamalai University, Annamalai Nagar
**thivyac1988@gmail.com*

Uranium is a radioactive element normally presents in hexavalent form as U (VI) in solution and its elevated levels in drinking water cause health hazards. A total of 216 representative groundwater samples were collected for four seasons viz. Pre-monsoon (PRM), South west monsoon (SWM), North east monsoon (NEM) and Post-monsoon (POM) from different litho-units of Madurai district of Tamilnadu and were analyzed for total uranium, major and minor ions. pH, Eh, temperature, total dissolved solids (TDS) and electrical conductivity (EC) parameters of the water samples were measured in the field. Sampling and analysis were carried out using standard procedures (APHA 1992). The average concentration shows that the uranium increases with monsoon and highest concentration observed during SWM. The order of dominance of uranium in different seasons is SWM > PRM > POM > NEM. The higher content of uranium in PRM, SWM and NEM lies in granitic terrain whereas in POM it lies in Charnockite due to the leaching of elements present in fractures. The spatial distribution of uranium shows that the higher concentration is observed in north eastern part of the study area where it is covered by granitic terrains. To identify the hidden sources, uranium has been compared with lineaments, land use, water level and lithology maps. The study concluded that the interplay of different factors (higher lineaments density, distribution of surface water bodies, agricultural runoff, deeper groundwater level and granitic intrusions) results in dissolution and spatial variations of uranium in groundwater.

Groundwater quality: focus on fluoride concentration in Sarabhanga sub basin in Salem district, Tamilnadu

A. Shanmugasundharam*, S. R. Mahapatra, M. Jayaprakash
Department of Applied Geology, University of Madras, Chennai
**geoshan36@gmail.com*

The present study has been made to evaluate the fluoride concentration of groundwater from Sarabhanga sub basin in Salem district of Tamilnadu. For this, 46ground water samples were collected and analyzed for fluoride and other water quality parameters (EC, TDS, pH, Na, K, Ca, Mg,

Cl, NO_3, HCO_3 and SO_4). Due to depletion of surface waters, groundwater is the only source of drinking water in this area. Hence people are using groundwater for drinking purpose and they are exposed to health vulnerability. This study reveals that fluoride concentration varies between 0.25 ppm and 7.98 ppm with an average of 5.56 ppm. The dominance of cations and anions in the area are as follows: $Na+ > Ca^{2+} > Mg^{2+} > K^+$ and $Cl^- > HCO_3 - > SO_4^{2-} > NO_3$. The concentration of fluoride in the area is found to be high, which is due to leaching of ions from the country rocks around the study area. The results indicate that the groundwater quality in the vicinity of this area needs to be studied in detail.

Slope stability evaluation: a geo-engineering approach on NH-22, Rampur to Powari Region, H.P.

Satish Kumar[1]*, Kishor Kumar[2], N.N. Dogra[1]
[1]Department of Geology, Kurukshetra University, Kurukshetra
[2]CSIR-Central Road Research Institute, New Delhi
**satishgeologist@gmail.com*

Under the present study some of the critical slopes in Satluj valley on NH-22 between Rampur to Powari, Himachal Pradesh have been investigated. These slopes have recurrently been failing since many decades and disrupted the highway communication leading to impact on socio-economic conditions of the area including damage of property, loss of revenue on direct or indirect losses and hardship to the inhabitants. Though over 25 number of difficult slopes have been studied, in this paper detailed analysis on evaluation of the stability of 5 critical slopes is given. The stability evaluation was done using geo-engineering approach which includes collection of primary data on geology, rock mass, structure, slope etc. The data collected from the field and their analysis, have been done for slope stability evaluation on the basis of Rock Mass Rating (RMR), Slope Mass Rating (SMR), Geological Strength Index (GSI) etc. The study indicates towards the need of detailed investigation of various slope parameters, before cutting the slopes for construction and maintenance thereafter.

Surface ablation modeling (2011-2015) over the debris-covered ablation zone and sensitivity of Chorabari Glacier, central Himalaya, India

Kapil Kesarwani[1,2]*, D. P. Dobhal[1], Alok Durgapal[2]
[1]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Department of Physics, D.S.B. Campus, Kumaun University, Nainital
**kapilcfg@gmail.com*

In present study, an attempt has been made to model the surface ablation over the debris-covered ablation zone and to assess the sensitivity of the Chorabari Glacier (a benchmark glacier of Indian part of Central Himalaya located in the Mandakini basin, Alaknanda catchment). We analyzed the meteorological (collected using automatic weather station) and surface mass-balance observations (in-situ glaciological method) at point scale (4270 masl) in the course of four consecutive glaciological years (2011-12, 2012-13, 2013-14 and 2014-15). Surface ablation was estimated using the physically based Surface Energy Balance (SEB) model during the ablation seasons (June-October) of study period. The model was forced with meteorological parameters and

specified heat conduction through supraglacial debris layer in order to estimate melt rates at the debris/ice interface with consideration of debris-covered (non-climatic factor) concentration as one of the input. The cumulative flux of four radiation components (both incoming and outgoing for shortwave and longwave radiation) was directly measured and the turbulent heat fluxes (sensible and latent heat fluxes) were calculated using the bulk aerodynamic approach. Results indicate that net radiation was the largest contributor to total energy flux used for melting followed by the turbulent latent heat flux. However, turbulent sensible heat flux, heat flux supplied by precipitation and subsurface heat flux were negative throughout the ablation season. The modelled mass loss show a close correlation ($r^2 = 0.98$) with the observed values. The sensitivity of the glacier was assessed using altered the possible contrasting climatic (meteorological conditions) and non-climatic (surface characteristics) parameters. The model was run using altered near-surface air temperature by ± 1°C, surface temperature by ± 1°C, relative humidity by ± 20%, precipitation by ± 20% and debris thickness by ± 20 cm. Based on the perturbation of each variable and its respective influence to the other parameters, the relative change in specific mass-balance for each variation was determined. Results of sensitivity check suggested that if T_a or T_s is increased by 1ºC, glacier surface mass loss will be increased by 5% which is higher than other meteorological parameters. However, if h_d is reduced by 20 cm, an increase of 25% in surface mass loss would be occurred which was observed more higher than meteorological conditions. This reveals that besides the meteorological conditions, the debris-covered glaciers are also highly sensitive to changes in debris thickness. This model can be useful to calibrate the spatially distributed energy and mass balance models at glacier as well as regional scale. Using the different climate change projections, this model can also be used to predict the future of water supplies from the glacierized catchments.

Evolution of hydro-geochemical processes and solute sources study of Dokriani (Bamak) Glacier meltwater, Garhwal Himalaya, India

Sipika Sundriyal*, Sameer K. Tiwari
Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001
**sipika@wihg.res.in*

The distribution of glaciers in the Himalaya is uneven with higher number in the northwest as compared to northeast region (Vohra, 1981; Kaul et al., 1999). Total number of glaciers in the Ganga basin are 6237 and covering the total glaciated area of 18392.90 km^2 (SAC, 2011). The Dokriani (Bamak) is well developed valley type small glacier, situated in the Uttarkashi district of Uttarakhand state, India. The glacier lies about to 25 km east of Bukki village and extends from (30º 50'to 30º 52' N and 78º, 47'to 78º 50'E) in Bhagirathi basin, of Garhwal Himalaya. The total catchment area of Dokriani glacier is 15.7 km^2 up to discharge site, out of this 7.0 km^2 is covered by glacier and which is 45% of overall glacierised area of the basin (Dobhal & Mehta, 2008). The total length of glacier is 5.5 km, extends between 3880m and 6000m above sea level. The Din Gad stream tributary of Bhagirathi River originates from the snout of the Dokriani glacier (3965 m a.s.l).

Meltwater hydrochemistry of glaciers is significant to understand the complex weathering dynamics operating in the glacier system (Sharma et al., 2013). Chemistry of meltwater near the snout basically reveals the enrichment in concentration of dissolved ions. Mineral dust species due to weathering of rocks, small contribution from atmospheric inputs (anthropogenic) and atmospheric sea salts are the main sources of ions in the glacial meltwaters. The amount of dissolved ion concentration in the meltwaters shows intensity of effective hydrochemical reaction within the

glacier system in different sessions and particularly at the interface with bedrock of the catchments. Silicate minerals below zero and sub-zero temperatures react with water speedily because of high dissolution of atmospheric carbon di oxide in this meltwater supplies H^+ ions essential for acid hydrolysis of the rock minerals, during this reaction, carbonate and cations are released in to the melts (Raiswell, 1984).

Meltwaters draining from Dokriani (Bamak) Glacier were sampled during the pre and post monsoon sessions for the period of two years from (2013-2015) to understand the chemical characterization and seasonal variation in the dissolved major ions chemistry. Samples were collected followed by international protocols and analysed in the state of art lab facilities at Wadia Institute of Himalayan Geology. The pH of meltwater of Dokriani Glacier was varied from acidic to alkaline in the pre-monsoon and slightly acidic to neutral in the post-monsoon. The anions for all sampling seasons in decreasing order would be SO_4^{-2}>HCO_3^-> NO_3^->Cl^->F^- whereas cations in decreasing order for all season order would be Ca^{+2}>Mg^{+2}>Na^+>K^+. Calcium and sulphate are the two major constituents of melt water, constituting approximately 80% and 64% of the total anions and cations respectively in all the sessions. The elevated values of (Calcium + magnesium)/ (sodium+ potassium), calcium/sodium, magnesium/ sodium, alkalinity/ sodium and low content of sodium+ potassium show that dissolved ion chemistry of Dokriani Glacier is generally controlled by carbonate weathering with little contribution of silicate weathering. Lower side C-Ratio of meltwaters of all sessions shows that pyrite oxidation is major proton producing reaction and sulphide oxidation and carbonation coupled reactions control the solute acquisition process in the Dokrinai Glacier. (Na + K vs Cl) plot suggests relatively small contribution from atmospheric input to the chemical characterisation of meltwater. Results of factor analysis for pre-monsoon and post-monsoon season show that meltwater chemistry of the Dokriani Glacier is controlled by carbonate followed by silicate weathering, sulphide oxidation, sulphate mineral dissolution, atmospheric precipitation and lastly anthropogenic activities. Extensive seasonal variations in the dissolved major ion concentration are found in this area.

Vohra, K., 1991. Technical Report, Department of Science and Technology, 4.
GSI (Geological Survey of India), 1999. In: Kaul, M.K. (Eds.), Special Publication Number 34, 165.
Dobhal, D. P., & Mehta, M., 2008. Himalayan Geology, 29(3), 23-25.
Sharma, P., Ramanathan, A. L., and Pottakkal, J., 2013. Hydrological Sciences Journal, 58(5), 1128-1143.
Raiswell, R., 1984. Journal of Glaciology 30 (104), 49-57.

Hazard evaluation of progressive Pawari Landslide Zone, Kinnaur, Satluj Valley, Higher Himalaya, India

Vipin Kumar[1, 2]*, Vikram Gupta[1], Y.P. Sundriyal[2]
[1] *Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*HNB Garhwal University, Srinagar 246174*
**vipin@wihg.res.in*

The Pawari landslide zone, located in the Satluj valley in Higher Himalaya is a progressive complex landslide and has been active since long. It is observed that the frequency of the slope failure and dimension of the landslide area has increased considerably in last decade which poses threat to a population of 4000 people residing in and around landslide zone. In order to evaluate the hazard, associated with the landslide zone, analyses is performed in spatial as well as in temporal domain. The spatial component involves stability analyses of the landslide zone by using Finite Element

Method (FEM) and kinematic analysis while the temporal framework comprises landslide activity analyses using historical satellite imagery and decadal slope failure analyses. The rainfall data of point station and Tropical Rainfall Monitoring Mission (TRMM) are also correlated to evaluate the rainfall effect on landslide activity. The FEM analysis involved numerical simulation of two slope models i.e. S-1 (rockmass only) and S-2 (rockmass overlain by debris) which were chosen along the width of landslide zone. The Shear Strength Reduction (SSR) method was incorporated in FEM to quantify the existing slope strength and determine pattern of strain and accumulation development. The stereographic projection method was applied to perform kinematic analyses on the rockmass exposure in the landslide zone.

The analyses results show that the main scarp of the landslide zone has increased ~7.27 % in last decade and presently major as well as minor scarps accommodate maximum shear strain (0.001-0.006) and displacement (0.08-0.20 m). The annual rainfall pattern correlates well with the slope failure activities of last decade and bimodal monthly rainfall regime brings out influence of non-monsoon rainfall (western disturbance) on landslide zone. The present work intends to evaluate the hazard of landslide zone by analyzing pattern of landslide activity and determining internal deformation characteristics of the slope.

Seasonal groundwater variability in few selected sectors of North Eastern Region of India using GRACE

Swakangkha Ghosh[1,2]*, ShyamSundar Kundu[2], Kuntala Bhusan[2]
[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*North Eastern Space Applications Centre, Dept. of Space, Meghalaya 793103*
**swakangkhaghosh23@gmail.com*

Groundwater is a dynamic and replenishable natural resource whose occurrence and distribution is not uniform; rather it varies significantly based on the geology, geomorphology and rainfall of a particular region. With respect to North Eastern Region (NER) of India, the state of Assam is one of the largest and the most potential groundwater reservoirs of the country having three distinct physiographic units namely, Hills and Plateau, Piedmont zones and Plains. The prevalent rock formations in Assam range in age from Archaean to Recent and vary widely in composition and structure. The variation in landforms as well as rock formations, induced local variation in groundwater prospects in the State of Assam, where estimated Annual Replenishable Groundwater Resource is 27.23 BCM (CGWB, 2006). The high relief areas of NER with steep topographic slopes and characteristic geological setup (devoid of primary porosity) offer high runoff and little scope for rainwater infiltration like any other hilly terrain. In those areas, the availability of groundwater is of limited extent. However, with the advancement in space technology, traditional ground based in-situ measurements or observations are augmented with satellite data and derived products, to study the terrestrial water resources and groundwater condition.

The Gravity Recovery and Climate Experiment (GRACE) satellite was launched jointly in March 2002 as a collaboration between the U.S and German Space agencies, NASA and DLR, which provides an opportunity to detect the variability of groundwater on a large spatial scale. The time variable gravity observation from GRACE can be recovered as terrestrial water storage (TWS), which consists of surface water, ice (and snow), the biosphere, soil moisture, and groundwater.

Many researchers have used GRACE data across the world to estimate and monitor inter annual groundwater variation in a large river basin/ at and order 200,000 km^2. While the capability for GRACE to monitor continental scale anomalies and changes in monthly water storage is now well documented, little, if any, work has addressed fundamental issues such as the characterization of its space-time variability and its role in terrestrial hydroclimatology. For example, how observed TWS is distributed among the subsurface and surface stores and how the fluxes of precipitation, evapotranspiration and runoff act to enhance or dissipate the storages.

This research work intends to characterize precipitation-groundwater exchange in four different study areas of NER region that includes Dibrugarh, Golaghat, Cachar and Meghalaya, each with varying aquifer conditions, using GRACE and TRMM satellite data for the years 2002 to 2013 at monthly time scales. With statistically significant correlation between the GRACE and TRMM (Tropical Rainfall Measuring Mission) data, this study aims at exploring this potential to quantify seasonal variability of TWS with respect to changes in precipitation and geological setup. This study intends to provide a first order understanding of the interaction between groundwater storage and precipitation using publicly available data. Further, in-situ groundwater well data, which were collected during the years 2008-2009 for Assam and 2011-2012 for Meghalaya, will be used for validation.

Hydrochemistry of waters in the peidmont zone of Udham Singh Nagar, Uttarakhand, India

Divya Thakur, S. K. Bartarya
Wadia Institute of Himalayan Geology, Dehra Dun 248001

Groundwater is the most prominent source for drinking and agricultural purposes. Rapid increase in urbanization, industrialization and agricultural activities have had an adverse impact on the availability of fresh and uncontaminated water. Further, the excess extraction of groundwater leads to the lowering of water table. The movement of water through aquifers of different compositions also contributes towards modifying the composition of water. Therefore, it is important to understand the effects of natural and anthropogenic activities on groundwater level and its quality in the region.

The Udhamsingh Nagar in piedmont region of Uttarakhand has witnessed rapid industrialization and urbanization after the formation of Uttarakhand. The present study investigates the chemical behaviour and quality status of water in different parts of district Udhamsingh Nagar, Uttarakhand. Geologically, the study area consist of Quaternary deposts which are further divided in to the *Bhabar* and *Tarai*. The Bhabhar consists of boulder, sand and clay and Tarai or alluvial plains consists of sand, clay and silt. The aquifers are mostly of unconfined nature in Bhabar, however, artesian condition prevails at few places in Tarai region. Total 28 water samples were collected from tubewell, handpump and local streams representing different landuse patterns, which were then analysed for different physical and chemical parameters i.e., pH, temperature, conductivity, total hardness, dissolved major ions and trace elements.

HCO_3^-, SO_4^{2-} and Ca^{2+}, Mg^{2+} are the most dominant ions among the anions and cations respectively. The Piper plot shows the dominance of alkaline earths in the groundwater. Most of the samples fall close to the Ca-Mg-HCO_3^- axis. Ca^{2+} and SO_4^{2+} are relatively enriched in deep aquifers

(tubewell) in comparison to shallow aquifers (handpump) indicating increased contact time of water with aquifer mass at depth. Results from various scatter and trilinear plots indicate the weathering of dolomites of Krol sequence, present in the recharge areas of the aquifers in the Lesser Himalaya, is the primary source of these ions in the water of the area. Trace elements are present in minor concentrations, some of which remain absent at many locations. All the water quality parameters are within the permissible limit of BIS (2012) and WHO (2006), although fluctuations are shown in some samples.

BIS, 2012, IS: 10500:2012, Bureau of Indian Standards. New Delhi.
WHO, 2006. Guideline for drinking water quality, 3rd Ed. World health organization.

Environmental impact assessment of water resources and urbanization in Varanasi district, U.P., India

Antara Gupta, Ajai Miahra*, Daya Shankar Singh
Department of Geology, University of Lucknow, Lucknow 226007
**ajaimishra2007@yahoo.co.in*

The District Varanasi is occupying a unique location on the left crescent- shaped bank of the Ganges between the confluences with two rivers: the Varuna and the Assi streams, from which it derives its name Varanasi. While the ancient city of Varanasi was located on the northern part of present day Varanasi, in the area known as Rajghat, where remnants of city wall, pottery and artifacts were unearthed, suggesting to the evidence of ancient settlements in the area. Being located in south-eastern part of Ganga Plain of the Indo-Gangetic Plains of North India, represented by the fertile alluvium of quaternary time deposited and rejuvenated by Ganges river system.

Varanasi lies between Latitude N 25°18'00" to N 25°18'34"and Longitude E 82°59'00" to E 82°59'18". The district bounded by Gazipur in the north, Mirzapur in the south, Jaunpur and Sant Ravidas Nagar in the west and Chandauli in the east.

The district, Varanasi is occupying an area of 1535 km^2 with a population density of 2395 having a population of 3676841 (according to 2011 Census) and is sited on confined and unconfined aquifers made by Ganga river system. The exponential growth of the population has been recorded 17.15% in the population of 2011 as compare to census 2001. There was 25.14% increase in population recorded in 2001 as compare to census 1991, where the large scale emigration from rural areas to urban areas degrading the water quality and depleting the Water Resources in the district.

The surface drainage and underground aquifer system has been disturbed by the large scale urban infrastructural development activities. Due to heavy population pressure and over exploitation of water resources the data of year 2013-14 were analysed to know the change in water quality due to rapid increase in population. The various parameters like pH , conductivity, chloride, alkalinity, calcium (Ca^{++}) magnesium(Mg^{++}), sulphate (SO_4) , phosphate (P), Nitrate (N), Coli-form and metals like iron, lead, chromium, cadmium and nickel shows that water quality is deteriorated due to over exploitation and unscientific management.

However the parameters at some places under the permissible limits with WHO and BIS standards but some places they are crossing the permissible limits .The concentration of calcium , Magnesium , Iron, Manganese were found higher in limit while lead, cadmium, nickel sodium and

potassium were at border line. However the water received at the user end contaminated and causes potential health risk to the users. The higher ph shows the degradation of water quality at various places.

Therefore there is need to an integrated approach for the sustainable development of water resource management, awareness and education for conservation and mitigation of pollution cause by urbanization.

Recent developments in Quaternary stratigraphy climatic and oceanographic considerations

Devesh K Sinha*, Ashutosh K Singh
Department of Geology, University of Delhi, Delhi 110007
**deveshksinha@yahoo.com*

KEY NOTE

In the recent Geological Times Scale (GTS-2012) the base of the Quaternary has been made coincident with the base of Pleistocene and is now been placed at the base of Gelasian Stage. The base of the Gelasian Stage is defined as the base of the marly layer overlying sapropel MPRS 250, located at 62m in Monte San Nicola section, Italy (GTS-2012). The astronomical age of Mediterranean Precession Related Sapropels (MPRS)-250 (mid-point), corresponding to precessional cycle 250 from the present, is 2.588 Ma, which can be assumed as the age of the boundary (Rio et al, 1998). This definition of the base of Quaternary is within Marine Isotope Stage 103 and has been accepted by the International Commission on Stratigraphy (ICS) (Sinha et al, 2013). Holocene is the youngest subdivision of Quaternary having the rank of Epoch/ Series in the Geological Time Scale (GTS-2009-Walker, Geissman and compilers, 2009). It is placed above the Calabrian Stage based on chronostratigraphic considerations. In the Geological Time Scale (GTS-2009) the Holocene Series / Epoch was placed as the Later /Upper part of the Quaternary System / Period, though much debate occurred on the status of Quaternary itself (eg. Van Couvering *et al*, 2009). Though, two more formal Stages namely Ionian Stage and Tarantian Stage in ascending stratigraphic order have been proposed above Calabrian and below Holocene, they are still to be ratified by the IUGS.

Our studies from several DSDP and ODP cores from various parts of the world ocean show that the base of the Quaternary and Pleistocene as per the new definition can be approximated biostratigraphically by the planktic foraminiferal events which have been recorded close to the Matuyama Gauss boundary like *Globorotalia inflata* FAD; *Globorotalia tosaensis* FAD; *Dentoglobigerina altispira* LAD; *Globorotalia plesiotumida* LAD; *Globorotalia merotumida* LAD (Sinha & Singh, 2008, Sinha *et al*, 2013).The last occurrence of *Discoaster pentaradiatus* which occurs in most low and mid-latitude areas close to isotopic stage 99, some 80 kyrs above the boundary (Rio et al ,1998) is also a way to approximate this boundary. This new definition of Quaternary and Pleistocene has stretched the lower limit of both which was earlier 1.88 Ma. The upper limit of Quaternary and Pleistocene is defined by the top of Holocene. Sinha and Singh (2008) recorded a remarkable faunal turnover close to Matuyama/ Gauss boundary and attributed it to northern hemisphere glaciations. Also a large number of climatic events resulting from polar ice sheet expansion have been demonstrated during Quaternary (Sinha et al., 2007). Thus the new definition of Quaternary is a logical consequence of global climatic shifts synchronous over wide latitudinal range and can be approximated with the help of microfaunal events.

Sinha, D.K., Singh, A.K. and Tiwari, M. 2007, Current Science, 90 (10).
Geological Time Scale, 2004. Gradstein, F. Ogg, J. & Smith, A. (eds) A Geologic Time Scale, Cambridge University Press. pp. 589.
Rio, D., Sprovieri, R., Castradori, D. and Distefano, E., 1998. Episodes, 21, 82-87.
Sinha, D. K, and Singh, A.K., 2008. Journal of Foraminiferal Research, 38, 3, 251-270.
Sinha, D.K. Singh, A.K., Mallick K, and Singh, V.P. 2013. Holocene (Editor, B.S. Kotlia) ISBN-978-1-62257-722-4, Nova Science Publishers Inc., USA, p. 1-8
Walker, J.D., and Geissman, J.W., compilers, 2009. Geologic Time Scale: Geological Society of America, doi: 10.1130/2009.CTS004R2C. © 2009 The Geological Society of America.

Scenario of lower Gondwanan ecosystem through palynology, taphonomy and palynofacies during late Permian in Sattupalli area, Godavari Graben, India

Shreya Mishra*, Neerja Jha
Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226007
** shreyamishra1005@gmail.com*

Palynological, palynofacies and taphonomic studies have been undertaken to present a scenario of late Permian Gondwanan Ecosystem in the rock sequences encountered in the 601 m deep MSP-21 borehole from the Sattupalli area, Godavari Graben. The collected samples are of lacustrine to fluvial deposits and no signatures of marine influence have been encountered. The palynological investigations revealed the presence of two distinct floral assemblages. Both the assemblages are dominated by striate bisaccates. Palynoassemblage-I is marked by the high incidence of stratigraphically significant palynotaxa i.e., *Striasulcites*. While, palynoassemblage-II differs from the later in having high incidence of *Densipollenites* sp., an enveloping monosaccate pollen. The palynocomposition indicates the dominance of glossopterids, peltasperms and conifers representing presence of a thick arborescent vegetation near the depositional site. Pteridophytic spores constitute the rare component of the palaeovegetation and represent the presence of opportunist understorey flora. Palynofacies studies recorded the dominance of opaque phytoclast and sub-dominance of structured organic matter and palynomorphs indicating the presence of luxurious vegetational cover in the hinterland and oxidizing conditions during the deposition of sediments.

The prime focus of our study is to analyse the relationship between sedimentary facies and palynomorph assemblage. Therefore, considering the palynomorphs as a sedimentary particle, studies have been done following the previous classification of Jäger (2004) and Cushing (1967). The classifications have been emended in order to make it suitable for the present study. The sedimentary features of palynomorphs are governed by their buoyancy, distribution and sedimentation. While, the preservational state of palynomorphs depicts its depositional history from its death till its final burial. Presence of five distinct taphofacies have been reported on the basis of studies based on these two classifications. Each taphofacies represents different sedimentary facies and environment of deposition. The palynocomposition of the complete sequence is dominated by striate bisaccate pollen and is para- to allochthonous origin. However, changes in the palynocomposition and their preservational states are strongly influenced by vegetational composition of the source area, sporopollenin content of the exine, depositional condition and associated lithology.

Cushing, E.J., 1967. Review of Palaeobotany and Palynology 4, 87-101.
Jäger, H., 2004. Review of Palaeobotany and Palynology 130, 121-140.

Foraminiferal biofacies of the early Eocene warming in equatorial India

Sonal Khanolkar
Department of Earth Sciences, IIT Bombay, Mumbai
sonal.k.12@gmail.com

The carbon isotope excursions (CIE) attributed to Early Eocene warming events are reported in marginal marine sequences to inner shelf sequences of western India that were placed near the equator. Foraminiferal biofacies of the CIE demarcated sections of Kachchh and Vastan are investigated in this study to examine how foraminifera responded to the warming events. The biostratigraphy of the examined sections refers them to shallow benthic zones (SBZ) 5/6 to 11. A significant change in the foraminiferal assemblage is observed across the section. The SBZ 5/6 to SBZ 10 interval (corresponding to PETM, ETM 2 and ETM 3) consists of (i) low diversity and dwarfed foraminifera, (ii) rectilinear benthic foraminifera, and (iii) biserial and triserial planktic foraminifera indicating high runoff, upwelling and eutrophic conditions. The SBZ 11 is characterized by i) higher diversity of foraminifera, and ii) species reaching to large sizes. The stressed environments of the SBZ 5/6 to SBZ 10 appear to have returned to normalcy in SBZ 11 corresponding to EECO. The statistical analyses of foraminiferal distribution data suggest two major biofacies in the Early Eocene. A) *Bulimina thanetensis* Biofacies: The taxa in this biofacies comprise *Bulimina thanetensis, Chiloguembelina trinitatensis, Jenkinsina columbiana,* and *Rotalia* sp. It is marked by a high percentage of triserial planktic foraminifera and high percentage of RBF. This biofacies consists of early Eocene foraminifera ranging from SBZ 5/6 - SBZ 8. This foraminiferal assemblage is indicative of eutrophic conditions which prevailed during the PETM and ETM 2. B) *Quinqueloculina contorta* Biofacies: The taxa in this biofacies include *Quniqueloculina contorta, Sagrina* sp, *C. succeedens, Asterigerina abertyswythi, Asterigerina bartoniana, Pararotalia curryi* and *Brizalina oligocaenica.* It is marked by higher abundance of rounded smaller benthic foraminifera and larger benthic foraminifera. The zone SBZ 11 is characterized by this biofacies. The foraminiferal assemblage is indicative of oligotrophic conditions during the EECO. It is concluded that the stressed environments typical of the hyperthermal PETM and ETM 2 events ameliorated in later part during the EECO when foraminifera attained normal size and larger benthic genera were more diversified and abundant.

First record of a giant late Triassic Phytosaur (Reptilia: Diapsida) from India

Debajit Datta*, Sanghamitra Ray
Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721302
**debajitdatta9@gmail.com*

Phytosaurs are an extinct group of large, quadrupedal reptiles which were widespread throughout the Late Triassic and are used as index fossils for biostratigraphic correlations (Stocker and Butler, 2013). These reptiles represent a group of long snouted freshwater forms, which were similar to the present-day crocodiles in their overall form and structure. They had world-wide distribution and are reported from nearly all continents except from Antarctica and Australia (Stocker and Butler, 2013). The Gondwana basins of peninsular India are rich storehouses of vertebrate fossils, including the phytosaurs, which are known from the Maleri and Dharmaram formations of the Pranhita-Godavari basin and the Tiki Formation of the Rewa Gondwana basin, a sub-basin of the Son-Mahandi basin (Bandyopadhyay, 2011). The latter is considered coeval with the lower part of

the Maleri Formation and both the formations have yielded medium sized phytosaur *Parasuchus hislopi* (Chatterjee, 1978) with a skull length of about 0.6 m. Based on the fossil flora and fauna, the Tiki and Maleri formations are considered to be Late Triassic (early Carnian) in age (Mukherjee et al., 2012; Ray, 2015). Here we report the discovery of a giant phytosaur from a new monotaxic bone bed from the Tiki Formation. The bone bed covers an area of about 48 m^2. Systematic excavation has resulted in the recovery of about 1500 in situ skeletal specimens belonging to seven individuals of different sizes. These specimens include partial skulls, lower jaws, numerous vertebrae, limb and girdle bones, which are mostly disarticulated but found in close spatial proximity. Based on their morphology and degree of ossification, the phytosaurs were either juveniles or sub-adults, except for an adult individual with 1.1 m long lower jaw and estimated body-length (from head to tail) of about 7 m. The skull is cone shaped, with a long slender snout which expands posteriorly into the broader cranial portion. The cranial elements are thick and robust with the dorsal surfaces bearing ornamentation. The mandible is Y-shaped, with a robust, cylindrical ramus, which diverges posteriorly into two extensive prongs. The anterior extremity of the mandible expands into a large hemispherical cordiform structure and bears three large tooth sockets on either side, protruding outwards. Extending posteriorly, the jaw ramus narrows from the anterior expansion into a cylindrical rod-like structure bounded on either side by a tooth row. The posterior region of the mandible is formed by several bones such as the surangular dorsally, angular and prearticular ventrally, and articular posteriorly. The Tiki phytosaur is one of the largest forms known from the Carnian stratigraphic horizons globally. Preliminary examination suggests that this phytosaur is more advanced than the basal *Parasuchus* and pertains to a new mystriosuchine genus. The discovery of this new phytosaur shows that the Tiki fauna belongs to a new Land Vertebrate Faunachron and provides a scope to reassign the age to the Tiki Formation.

Bandyopadhyay, S., 2011. 33-46 in J. O. Calvo, J. Porfiri, B. Gonzalez, and D. D. Santos (eds.).Paleontología y Dinosarios desde América Latina. EDIUNCE, Editorial de la Universidad Nacional de Cuyo, Mendoza, Argentina.

Chatterjee, S., 1978. Palaeontology 21, 83-127.

Mukherjee, D., S. Ray., S. Chandra., S. Pal., S. Bandyopadhyay., 2012. Journal of the Geological Society of India 79, 563-575.

Ray, S. 2015. Journal of Vertebrate Paleontology 35, DOI: 10.1080/02724634.2014. 930472.

Stocker, M. R., and R. J. Butler., 2013. Special Publications of the Geological Society of London 379.

Effect of taphonomic overprinting on drilling predation in molluscs

Debattam Sarkar[1]*, Shubhabrata Paul[1], Subhronil Mondal[2], Subhendu Bardhan[3]

[1]Department of Applied Geology, Indian School of Mines, Dhanbad 826004

[2]Department of Geology, University of Calcutta, Kolkata 700019

[3]Department of Geological Sciences, Jadavpur University, Kolkata 700032

**debattam.15@gmail.com*

In the fossil record, predator-prey interaction is best documented by predatory drillholes made by gastropods on their molluscan prey. A number of studies have used frequency of drilled shells as a measure of predation intensities of past (Bardhan et al., 2012). One of the major assumptions behind equating drilling frequency with predation intensity is equal preservation potential of both drilled and undrilled shells. Some studies suggest that these predatory drillholes may act as a weak spot resulting in preferential destruction of drilled shells due to taphonomic processes (Roy et al., 1994). Following this line of argument, it can be hypothesized that drilling frequency will

be lower in a taphonomically highly altered assemblage, because drilled shells may undergo greater degree of taphonomic alteration than undrilled shells. In the present study, we test this hypothesis with a new dataset of drilling frequencies of one bivalve and one gastropod species, *Donax scortum* and *Diplomeriza spectabilis* respectively, collected from Chandipur, Orissa. Shells were initially categorized into three size classes and then each size class was further divided into three taphonomic groups ranging from unaltered to extensively altered shell (Flessa et al., 1993). Each shell was assigned to taphonomic group based on articulation of valves and its morphological features, such as presence of periostracum layer, shell color, complete aperture, and well defined ornamentation, portion of surface area covered by microborings and well preserved muscle scars and pallial sinus. Drilling frequency was measured for each taphonomic grade within all the size classes for both species.

In case of *Diplomeriza spectabilis*, contrary to our expectations, drilling frequency does not decline significantly among three different taphonomic grades (Chi-square test, $p>0.05$). This lack of any relation between drilling intensity and taphonomy also holds true for three different size classes. Large size class of *Donax scortum* also shows similar pattern. However, drilling frequency of the intermediate size class of *D scortum* displays a different scenario. Drilling frequency decreases significantly from nearly unaltered shells to highly altered shells. Statistical analysis could not be performed for small size class due to lack of specimen within it. These results speak for the heterogeneity of taphonomic processes operating on marine shells. Statistically significant difference of intermediate size class of *D scortum* might reflect that drilled valves of a particular size class could be prone to destruction due to its size and also the shell shape and ornamental pattern. Hence effect of taphonomy must be analyzed with significant effort in each species as it can skew the perception of biotic interaction.

Bardhan et al., 2012. Palaeogeography, Palaeoclimatology, Palaeoecology, 317, 153-161.
Flessa et al., 1993. Paleobiology, 266-286.
Roy et al., 1994. Palaios, 413-421.

The genus *Indosphinctes* Spath 1930 (Ammonoidea) from the Callovian of Kutch, Gujarat: A systematic and stratigraphic view point

Rakhi Dutta*, Subhendu Bardhan
Department of Geological Sciences, Jadavpur University, Kolkata 700032
**rakhi.geol@gmail.com*

Spath (1930) first introduced the genus *Indosphinctes* from Kutch and described twelve species under it. Later this genus was described from many areas in Europe (Mangold, 1971; Cox, 1988) and North America (Hall and Poulton, 2012). Spath (1931) described the genus as a large form with evolute and compressed shell and as such he considered it as a macroconch. The majority of his species, however, are based on young septate specimens while complete mature shells may exceed 250 mm in diameter. The genus may be characterised by strong primary and secondary ribs in the inner whorls and the furcation point of ribs takes place near middle of the flank. Ribs disappear completely or weaken with the start of the adult body chamber and finally disappear at the peristome. Suture is complex and highly frilled. Mangold (1971) later found its sexual antidimorph in *Elatmites* which is small, thoroughly ribbed and has lappets.

We revisited *Indosphinctes* in Kutch based on type material as well as additional specimens systematically collected by us from different sections of mainland of Kutch. The holotypes of a majority of species of *Indosphinctes* have ambiguous stratigraphic information. For example, the holotype of *I. indicus* was said to have come from the Golden Oolite of Keera (Lower Callovian). Spath (1931) doubted its stratigraphic position and mentioned that the holotype does not include the characteristic oolitic grains and this has been confirmed by our recent inspection of the holotype in the repository section of Geological Survey of India, Kolkata. We, however, collected similar specimens from the Middle Callovian horizons in different sections and they show strong morphological resemblance with the holotype. Both Waagen (1975) and Spath (1931) did not visit Kutch and described specimens collected by others including amateurs. We reiterated Spath's view in retaining *I. indicus* as a distinct species. Spath's other species based on immature specimens are, however, doubtful and have uncertain stratigraphic information.

We conclude that *Indosphinctes* appeared in the Early Callovian in Europe but it only reached Kutch during the Middle Callovian where *I. indicus* is abundant and regionally widespread thus enabling to erect a new biostratigraphic horizon within the Anceps Zone (Jana et al., 2005).

Cox, B.M., 1988. Part 1. Monograph of the Palaeontographical Society, London, 54 pp.
Jana, S., Bardhan, S., Halder, K., 2005. Palaeonotology, 48(4), 883-924.
Mangold, C., 1971. Documents des Laboratories de Géologie de la Faculté des Sciences de Lyon, 41(2), 246.
Hall, R. L. and Poulton, T. P. 2012. Revue de Paleobiologie, 11, 379-397.
Spath, L.F., 1933. Geological Survey of India, New Series, 9 (2), 1-945.
Waagen, W., 1873-1875. Palaeontologia Indica (Series 9, Memoir), 1, 1-247.

Predator-prey interaction on the molluscan assemblage from Chandipur-on-Sea, Odisha

Sandip Saha[1]*, Subhronil Mondal[2], Subhendu Bardhan[1], Sumanta Mallick[3], Arijit Pahari[4], Debattam Sarkar[5], Dipankar Buragohain[1], Anirban Das[6], Pritha Goswami[7], Rakhi Dutta[1]

[1]Department of Geological Sciences, Jadavpur University, Kolkata 700032
[2]Department of Geology, University of Calcutta, Kolkata700019
[3]Department of Geology, Triveni Devi Bhalotia College, Raniganj 713347
[4]Department of Geology, Banaras Hindu University, Varanasi 221005
[5]Department of Applied Geology, Indian School of Mines, Dhanbad 826004
[6]Exploration Zawar Mines, Hindusthan Zinc Ltd, Udaipur, Rajasthan313004
[7]Department of Geology, Durgapur Government College, Durgapur 713214
**sandipsaha.ju@gmail.com*

20 square km stretch of coastal region of Chandipur is characterized by a diverse set of ecosystems which include intertidal-subtidal-beach-barrier and bar-estuarine environment. This complex ecosystems host great diversity of molluscan fauna including about 52 bivalve and gastropod species. This biodiversity hotspot is characterised by extensive interactions between different kinds of predator and their molluscan prey. Among many molluscan predators, drilling gastropod predators are very diverse and are represented by 13 species of 7 genera within three families. Some of them are very abundant. As a consequence, circular or semi-circular perforations indicative of drilling predation are ubiquitous in the collected shells from Chandipur. We here systematically collected and studied 18,803 molluscan specimens to document the intensity of gastropod drilling predation

(drilling intensity, DI) on the molluscan assemblage in Chandipur. Our preliminary analyses reveals that in Chandipur molluscan assemblage, 3802 out of 18803 specimens (DI=20.22%) are drilled. Among these, gastropods were more frequently drilled (2838 out of 13235 specimens; DI=21.44%) than bivalves (964 out of 5568 specimens; DI=17.31%). Among gastropods, the most dominant three prey families are Terebridae (DI=50.31%; n= 644), Epitonidae (DI=41.25%; n=80) and Turridae (DI=37.82%; n=698) .Similarly, among 12 families of bivalves, Tellinidae (DI= 23.26%; n=418.5), Mactridae (DI=20.59%; n=1496) and Veneridae (DI=18.52%; n=2154.5) are the most dominant prey families. Analyses of relationship between prey abundance (i.e., number of individuals) and DI revealed that predation intensity is weakly correlated with prey abundance, suggesting that the most common prey is not always the most preferred prey. Very high value of this assemblage-level predation intensity in Chandipur can be a result of intense predation, competition pressure mainly due to presence of multiple groups of drilling predators and availability of abundant prey types.

Role of microbial mat in intrastratal clast generation in Carbonate formations

Adrita Choudhri*, Subir Sarkar
Department of Geological Sciences, Jadavpur University, Kolkata 700032
**adritachoudhuri@gmail.com*

Besides having the same carbonate composition and Mesoproterozoic age, the ~40m-thick Chikkshelikere Limestone of the Bagalkot Group, Kaladgi Supergroup and the ~15m-thick lower part of the Rohtas Limestone of the Vindhyan Supergroup, have a few more commonalities. They are typically constituted by alternations between light and dark ribbon-like bands in variable frequencies. The light bands are fine grained, generally planar laminated and only occasionally ripple laminated, while the dark bands look again fine-grained and massive. Erosional features are minor in nature and highly localized. Frequent disruption of bands has engendered clusters of intrastratal clasts that pass laterally into undisturbed sediments. The clasts are invariably derived from the dark layers and on many instances they are crumpled. The dark bands and clasts derived there from are distinctly richer in carbon than the light bands or light matrix in the interstices between the dark clasts. Raman Spectroscopy records peak characteristic of Kerogen within the dark constituents. The range of $\delta^{13}C_{org}$ obtained from the dark constituents varies from -17 to -24‰ PDB in the Chikshelikere Limestone and -28.8 to -32.3‰ PDB in the Rohtas Limestone. The former range matches with that of cynanobacterial mat, while the latter is attributable to microbiota-related degradation of cyanobacterial mat. Preferred concentration of pyrite along the dark bands indicates proliferation of sulphate-reducing heterotrophs in the mat association. Intermittent microbial mat growth presumably turned the aforementioned limestone formations into two-layer systems, intrinsically unstable and prone to pore-fluid overpressuring. Many bed surfaces within the studied part of the Rohtas Limestone bear numerous minute mud volcanoes having radiating cracks around their craters. This feature is not noticed in the Chikshelikere Limestone possibly because of extreme scarcity bedding plane exposures. Microbial mat growth was apparently facilitated in the relatively calm and quiet carbonate depositional environments of these formations and at a time when it reached its acme worldwide. Even minor stress accumulation readily generated significant amount of hydrostatic pressure within the two-layer systems. The mat layers apparently responded to stress in semiductile to brittle deformation, while the light non-mat layers underwent ductile deformation. Crumpled clasts evince mat fragmentation at shallow depth, not long after deposition. Intrastratal clasts were, thus, generated often and in abundance from the comparatively more consistent mat

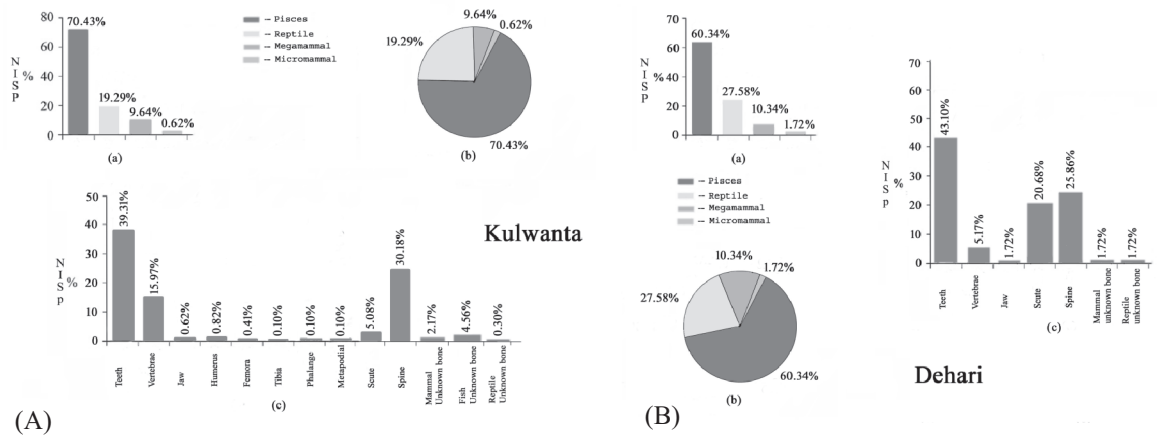
layers. The study highlights the necessity for adequate comprehension of the role of microbial mat in generation of intrastratal clasts in carbonate formations.

Taphonomy and palaeoecology of faunal and floral assemblages from lower siwalik sequence exposed around Ramnagar, Udhampur district, Jammu and Kashmir

Ningthoujam Premjit Singh
Centre of Advanced Study, Panjab University, Chandigarh 160014
ningthoujampremjit11@gmail.com

The highly fossilliferous Lower Siwalik deposits exposed in the Ramnagar area, Udhampur District, Jammu and Kashmir is famous for Miocene Apes since between last and 150 years. However, till date the taphonomy of fossil megavertebrate, microvertebrate and floral accumulation around Ramnagar is little known. From this perspective the present study is focused on megavertebrates, microvertebrates and floral assemblages to interpret their taphonomical and palaeoecological conditions. The Ramnagar Member is the upper lithostratigraphic unit of the Mansar Formation which is equivalent to Chinji Formation and has been dated between ~11 and 14 Ma based on rodent biostratigraphy. The taphonomic analysis of Ramnagar area involved field and laboratory data collection from Kulwanta, Sunetar, Thaplal, Bassi, Mata, Nambela and Dehari sites. The present study analysed skeletal elements for taxonomy, bone articulation/disarticulation, abrasion, weathering and scavenger/carnivore tooth marks.

The preservation of most resistant parts specially teeth and many undetermined bone fragments suggest that there is a high degree of breakage and fragmentation before burial. Disarticulated and fragmented bones also indicate their sub-aerial exposure prior to burial. The breakage pattern like smooth breaks perpendicular to the length of the bone represent post fossilisation damage generally produced by the load of sedimentation, whereas irregular breakage may indicate pre fossilisation damage. In terms of abrasion, wear marks are present in some bones. Overall these taphonomic features indicate that the Ramnagar materials were of fluvial origin and witnessed short distance transportation. There is no evidence of any scavenging mark on the fossil material of Ramnagar. Based on a comparison with their modern counterparts the fossil vertebrates



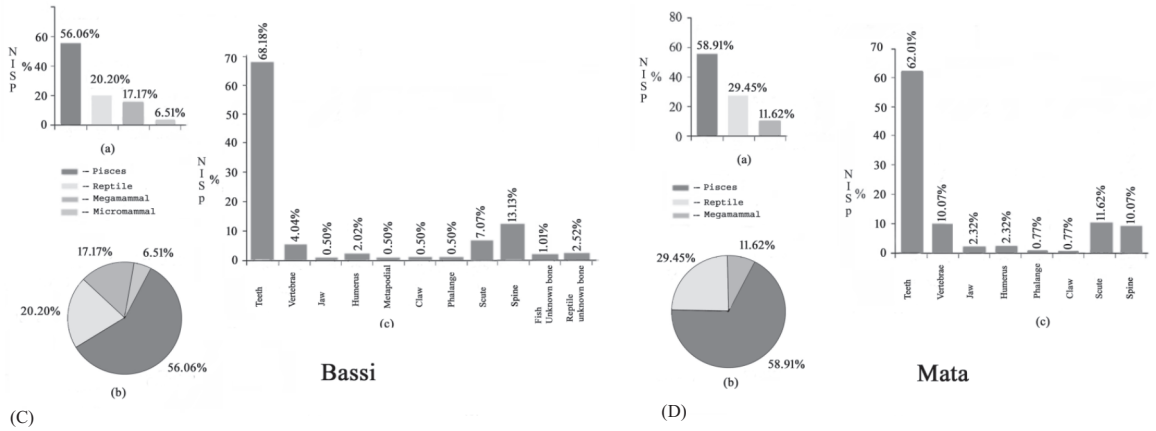


Fig.1. A. (a and b) Percentage of biotic composition of Kulwanta site of Ramnagar area, (c) Percentage of elemental representation of Kulwanta site of Ramnagar area; B. (a and b) Percentage of biotic composition of Dehari site, (c) Percentage of elemental representation of Dehari site; C. (a and b) Percentage of biotic composition of Bassi site, (c) Percentage of elemental representation of Bassi site; D. (a and b) Percentage of biotic composition of Mata site, (c) Percentage of elemental representation of Mata site.

have been divided into aquatic and terrestrial communities. The terrestrial vertebrate fauna combined with fossil leaves suggest presence of a dense and thick woodland growing under humid and abundant rainfall condition.

Ichnofacies analysis of the Tal Group (Cambrian) of the Nigalidhar syncline, Lesser Himalaya, India

C.A. Sharma[1]*, Birendra P. Singh[1], O.N. Bhargava[2], Naval Kishore[1]
[1]Center of Advanced Study in Geology (CAS), Panjab University, Chandigarh
[2] INSA Honorary Scientist, 103, Sector-7, Panchkula 134109, Haryana
**anuprcsharma@gmail.com*

We recovered nineteen (19) ichnogenera i.e. *Bergaueria*, *Catenichnus*, *Cochlichnus*, *Cruziana*, *Diplichnites*, *Dimorphichnus*, *Diplocraterion*, *Gordia*, *Guanshanichnus*, *Lockeia*, *Merostomichnites*, *Monomorphichnus*, *Palaeophycus*, *Phycodes*, *Planolites*, *Psammichnites*, *Rusophycus*, *Skolithos* and *Treptichnus* from the Tal Group (Cambrian) of the Nigali Dhar Syncline, Lesser Himalaya, India. The stratigraphic occurrences of these ichnogenera represent alternating proximal *Cruziana* and *Skolithos* ichnofacies along the contact of Sankholi and Koti-Dhaman formations. Five ichnogenera namely *Catenichnus*, *Guanshanichnus*, *Lockeia*, *Merostomichnites* and *Psammichnites* are recorded for the first time from the Nigali Dhar Syncline. The preservational characters of the *Cruziana* ichnofacies in the upper part of the Sankholi Formation to lower part of the Koti Dhaman Formation in the NigaliDhar Syncline indicate the subtidal environmental condition and poorly sorted, unconsolidated substrate with depositional conditions ranging from moderate to -high energy levels below the fair weather base but above the storm wave base under nearshore to the foreshore setting in a wave dominated shallow water condition. The proximal *Cruziana*-ichnofacies is interrupted by the *Skolithos* ichnofacies in the Tal Group of the Nigali Dhar Syncline which indicate fluctuating high energy condition which is unfavorable for the opportunistic organism which were

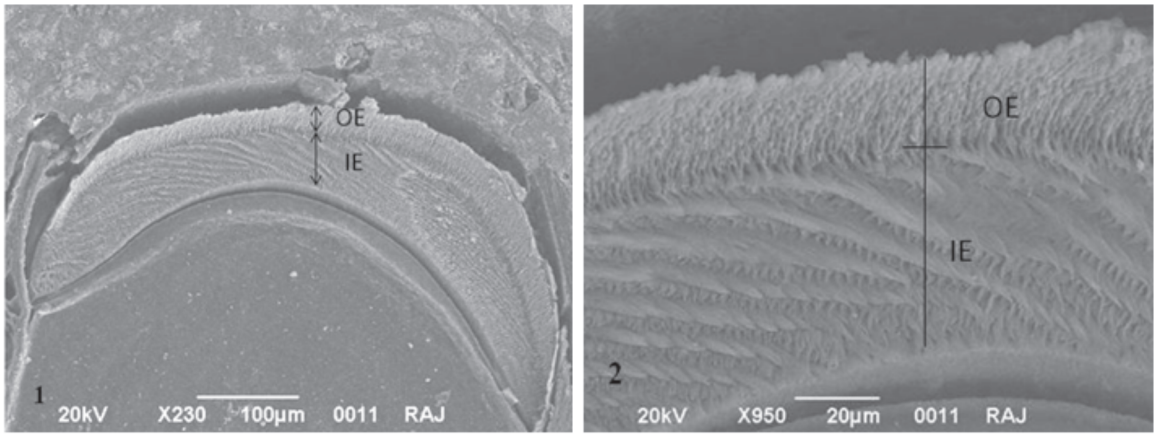
dominant during the proximal *Cruziana* ichnofacies. The excursion of *Skolithos* ichnofacies (as a pipe rock in the upper part of Sankholi Formation) into the proximal *Cruziana* ichnofacies in the Tal Group indicate the increased energy and allied parameters attributed to the high rate of sedimentation near the proximal part of the basin. The level bearing the *Skolithos* ichnofacies in the Nigali Dhar syncline at the juncture of Sankholi and Koti-Dhaman formations (= a level equivalent to the transition between the Deo-Ka-Tibba and the Dhaulagiri formations in the Mussoorie Syncline) can be correlated to the level marked as unconformity in between the Deo-Ka-Tibba and the Dhaulagiri formations by the conglomeratic horizon. Thus, the Tal Group of the Nigali Dhar syncline at this stratigraphic level represent slightly deeper water condition than the Mussoorie syncline, where in the later the aerial exposure dominated which leads to the deposition of conglomeratic horizon and subsequent formation of unconformity. The overall ichnological and sedimentological dataset allow us to infer that the Cambrian successions of Nigali Dhar syncline were deposited in a wave-dominated proximal part of the basin under the foreshore to close to upper shoreface regimes of the shallow marine setting.

Identifying rodent assemblages in the Siwalik fossil record using incisor enamel microstructure

Ankita Singla
Department of Geology, Panjab University, Chandigarh
singlaankita06@gmail.com

Rodents like other microvertebrates (ex. foraminifers) have very high evolutionary rates (vary from 0.1 to 1 Ma) and speciate very rapidly. Further, they are very sensitive to climatic changes, which lead to change in community structure, migration and reduction in number of species or even extinction of certain groups. Siwaliks offer a continuous record of murid rodent occurrences from Middle Miocene to Middle Pleistocene. The taxonomy of Siwalik murid rodents is primarily based on molar morphology but in the fossil record molars are less abundant as compared to the ever-growing incisors, because the latter occur as isolated fragments. Ever growing incisor of rodent exhibit all stages of tooth formation at anytime and this ideal characteristic makes them ideal model for the study of enamel formation.

Incisor based taxonomy of Siwalik rodents have never been attempted. The present work for



Figs. 1&2: Transverse section of mouse (M.M.musculus) incisor showing outer enamel (OE) and inner enamel (IE).

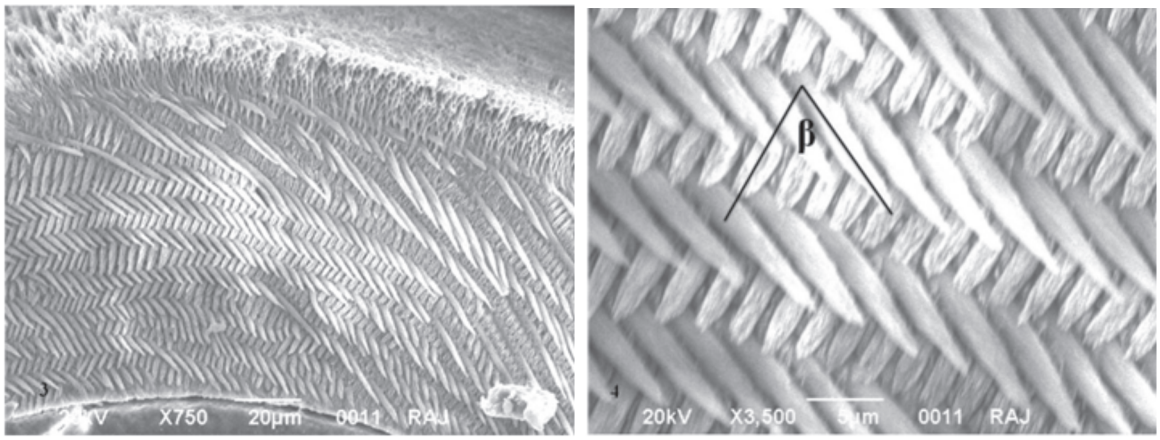


Fig. 3 & 4: Inner enamel showing decussation angle (β).

the first time takes up this objective to carry out a comprehensive enamel microstructure analyses of fossil murine rodents collected from various Plio-Pleistocene sections exposed between Ghaggar and Markanda river valleys. The data generated is being compared with the modern murine rodents from India for taxonomic identification, biostratigraphic correlation and to understand the biomechanical properties. The methodology involves sectioning along transverse and longitudinal planes, etching with 5% HNO_3 acid, ultrasonic cleaning, gold coating and then study under the Scanning Electron Microscope (SEM).

House mouse (*Mus musculus*) incisor has been taken as a model for this study (Fig.1-4). The incisor enamel parameters used in this study includes shape of enamel, centrolabial thickness, thickness of outer vs. inner enamel, shape of prism, decussation angle, angle between the prisms and outer enamel, angle between prism rows and enamel dentine junction.

Thecamoebians and associated microflora from late Cretaceous Lameta sediments and dinosaur coprolites of Nand-Dongargaon basin, central India

Hemant Sonkusare[1]*, Bandana Samant[1], D. M. Mohabey[2]
[1]Post Graduate Department of Geology, RTM Nagpur University, Nagpur 440001
[2]Ex-Geological Survey of India, C3, 24 HIG, Amravati Road, Giripeth, Nagpur 440001
**hemantsonkusare19@gmail.com*

The Late Cretaceous Lameta Formation covers an area of approximately 5000 km^2 in the states of Maharashtra, Madhya Pradesh and Gujarat. The sediments of this formation were deposited in six inland basins namely (i) Nand-Dongargaon (N-D) (ii) Jabalpur (iii) Sagar (iv) Ambikapur-Amarkanta (v) Balasinor-Jhabua, and (vi) Salbardi-Belkher (Mohabey, 1996; Mankar and Srivastava, 2015). Out of these basins, detail palynological work has been carried out only in N-D and Jabalpur basins only.

The Lameta Formation in Nand-Dongargaon Basin covers an area of about 700 km^2 in Maharashtra (Mohabey, 1990a,b). Lithologically, it comprises red clays, green silty clays, sandstones, limestones and marlites. Biofacies and lithofacies analysis of sediments indicate that the

formation was deposited in alluvial-limnic and palustrine environments under semi-arid to arid climatic conditions (Mohabey et al., 1993, Mohabey and Samant, 2005). Rich mega and microbiota including fossil remains of sauropods (represented by bones, coprolites, and nests) have been recorded from the sediments of Nand-Dongargaon Basin (Mohabey and Udhoji 1996). Matley (1939) for the first time reported sauropod coprolites from the basin and divided them into four types viz. Type-A, Type-B, Type-Ba, and Type-C based on their size and morphology.

To know the microfloral remains of the study area maceration of coprolites as well as associated sediments was carried out. The study revealed presence of good concentration of microfossils represented by three genera of thecamoebians, viz., *Centropyxis*, *Difflugia* and *Pontigulasia,* grass phytoliths of Poaceae, starch cells, peltate hairs, fungi and other plant remains like leaf cuticles and tracheal material. Thecamoebians occur commonly in freshwater and slightly brackish environments and are common in recent freshwater lakes. Their fossil record is known from Neoproterozoic, Early Permian, Albian and Cenomanian. The study shows that the palynomorph recovery from the coprolites is better than that of the associated sediments probably due to their concentration in the gut of the animal. The palynoflora from the Lameta sediments and sauropod coprolites is represented by gymnosperms (*Araucariacites* sp., *Cycadopites* sp., *Podocarpidites* sp., etc), angiosperms (*Palmaepollenites* sp., *Longapertites* sp., *Graminidites* sp., etc.) and pteridophytes. Palynological evidences suggest that the preferred diet of sauropods was soft tissues of angiosperms, gymnosperms and pteridophytes. Presence of phytoliths and mycorrhizal fungi in coprolites suggests grazing habit of the sauropods. The intake of thecamoebians, algal remains and mycorrhizal fungi might be through water intake by the animal.

Mankar, R S. and Srivastava, A.K., 2015. Current Science, 109(7), 1337-1343.
Matley, C.A., 1939. Rec. Geol. Surv. India, 74, 535-547.
Mohabey, D.M., 1990a. Gondwana Geol. Mag., 3, 32-34.
Mohabey, D.M., 1990b. Symp. Workshop IGCP 216 and 245, Chandigarh, 18-21.
Mohabey, D.M., Udhoji, S.G. and Verma, K.K., 1993. Palaeogeo. Palaeoclim. Palaeoecol., 105, 83-94.
Mohabey, D.M. and Udhoji S.G., 1996. Gond. Geol. Mag., Spl. v. 2, 349-364.
Mohabey, D.M., 1996. Memoir Geological Society of India, 37, 363-386.
Mohabey, D.M. and Samant, B., 2005. Gondwana Geological Magazine, 8, 37-52.

Response of Benguela upwelling during late Quaternary glacial Interglacial cycles

Ankush Shrivastava[1]*, Devesh K. Sinha[1], Ashutosh K. Singh[1], Rengaswamy Ramesh[2]
[1]Department of Geology, University of Delhi, Delhi
[2]Physical Research Laboratory, Ahmadabad
**ankushocean@yahoo.in*

In the present study, Benguela upwelling response during late quaternary glacial-interglacial cycles have been analyzed by using planktic foraminiferal assemblage and stable carbon and oxygen isotopic records. This analysis was carried on ODP site 1085A which lies in the southeast Atlantic and under the influence of one of the major upwelling region of the world ocean i.e. Benguela upwelling. Planktic foraminiferal census and stable carbon and oxygen isotope datafrom ODP site 1085A (SE Atlantic Ocean) have been used to reconstruct the inter-oceanicexchange, surface water productivity and upwelling during the Late Quaternary. Planktic foraminiferal record reveals enhanced interoceanic exchange during interglacials. Howeverduring 1.6-1.5 Ma and 0.85-0.62 Ma which are

also interglacial periods, named IOE-1 and IOE-2 respectively, such events are not observed. Low $\delta^{13}C$ values coincide with the enhancedinteroceanic exchange and points towards the role of Agulhas leakage in lowering theproductivity of the surface waters. $\delta^{18}O$ record of thermocline dweller planktic foraminiferal shows a gradual depletion of 1‰ after IOE-2 onwards which is indicative of gradual warming of the thermocline. During IOE-1 and IOE-2 values of $\delta^{18}O$ increase indicating cooling. $\delta^{18}O$ (*Gr.inflata- O. universa*) were used as a proxy to reconstruct the vertical mixing of the thermoclineand mixed layer water and associated productivity. A long-term vertical stratification of thethermocline and mixed layer water associated with low productivity were observed from 1.8-0.9Ma excluding HP-1 (1.6-1.5 Ma), HP-2 (1.3-1.2 Ma) and HP-3 (1.1-0.90 Ma). The presentstudy reveals "warm" upwelling in the Southeastern Atlantic Ocean 0.6 Ma onwards due toprobable thermocline warming (?) along with enhanced vertical mixing and increasedproductivity after IOE-2.

Petrographic characterstics of host rocks of Banswara Manganese Ores Belt, Banswara district, Rajasthan (India)

Mohd Shaif*, F.N. Siddiquie, Juned Alam
Department of Geology, Aligarh Muslim University, Aligarh
** msaif125@gmail.com*

The petrographical characters of manganiferrous phyllite, phyllite, biotite-phyllite, siliceous-phyllite, garnetiferous-mica schist, quartz-mica schist, quartzite, limestone and dolomite rock types encountered in the present study area. In different samples of phyllite rocks mineral composition showed that the rocks formed at low temperature and pressure under green schist facies. The Petrographic studies of phyllite reveals porphyroblasts of biotite are sat in a fine grained schistose mossaic, open folding on foliation plane is also noted**.** Later mineral composition of schist like Garnetiferous-Mica Schist, Quartz-Mica Schist, define intermediate grade amphibolite facies, Dolomite and Limestone beds express deposition of calcareous materials possibly formed due to low grade metamorphism equivalent to albite-epidote-amphibolite facies.

Banswara district is situated in the southern most part of Rajasthan. Topographically most of the part of the district is having rugged topography (Mukherjee & Kapoor 1961). Stratigraphyically, these are belongs to Kalinjara formation of Lunavada group falls under Aravalli Supergroup of paleoproterozoic age. The Lunavada Group has been subdivided by into the Kalinjara, Wagidora, Bhawanpura, Chandanwara, Bhukia and Kadana Formations.

Gupta, et al., 1997. Mem. Geol. Surv. Ind. 123, pp. 1-262.
Henrich, E. Wm., 1956. Microscopic Petrography, Mcgraw Hill Series, 1956, pp 200-01.
Mukherjee, K. K. and Kapoor, S.C., 1960. G.S.I. Progress Report for the Field Season 1959-60 (Unpublished).
Roy, P. K., 1984. G.S.I Progress Report for the Field Season 1983-84 (Unpublished).

Fluid chemistry and microthermometry of Pb-Zn deposits of Rajpura Dariba Bethumni Belt, Udaipur district (Rajasthan), India

Juned Alam*, F.N. Siddiquie
Department of Geology, Aligarh Muslim University, Aligarh 202002
** juned.iit87@gmail.com*

Fluid inclusion studies have been carried out on major Pb-Zn deposits and prospects in the Rajpura-Dariba region to determine the compositions of the associated fluids and the processes responsible for Pb-Zn mineralization. Importance to the ore minerals like galena and sphalerite which have been reported in association with the buffer minerals like pyrite and pyrrhotite occurred in the host rocks of the study area. An attempt has been made to study Geothermometry viz. heating and freezing study of entrapped paleo-fluids, (such as sedimentary and /or hydrothermal in origin) in the different types of fluid inclusions, hosted predominately in quartz host grain and a few in sphalerites. Fluid inclusions in quartz associated with the ores show that fluids forming vein-type ore are low-salinity (4.3-14.7 wt % NaCl equiv) H_2O-NaCl fluids. The trapping temperature of vein-type ore fluid was estimated to be in the range of 395 degrees to 290 degrees C at a pressure of about 1,450 bars. Fluids associated with sphalerite ore are H_2O-CO_2-NaCl fluids of lower salinity (about 3-4 wt % NaCl equiv).The quartz hosts were identified with four types of fluid inclusions, such as i) monophase (gas/vapour) ii) gas-rich biphase, iii) liquid-rich biphase and, iv) polyphase types. Limited data made available in gas/vapour rich fluid inclusions from the boiling condition of the set of five fluid inclusions showed complete homogenization of gas/vapour phase around +380^{0}C. Data from the fluid inclusions and salinity calculation (low salinity) reveal that rate of cooling was the important mechanism of ore deposition in the study area.

Deb, M., 1982b. J. Geol. Soc. India, 23, 253-260.
Roedder E., 1972. U.S. Geol. Survey paper 440-JJ, 164.
Roedder, E., 1984. Review in Mineralogy, 12, 644.
Talluri, J.K., Pandalai, H.S., Jadhav, G.N., 2000. Econ. Geol., 95, 1505-1525.

High-K granitoid of Banded Gneissic Complex (BGC), Aravalli craton: result of thermally reactivated older basement entity

Md Sayad Rahaman*, M.E.A. Mondal
Department of Geology, Aligarh Muslim University, Aligarh 202002
** rahamanamu@gmail.com*

Archaean basement lithology of Aravalli craton collectively known as Banded Gneissic Complex (BGC) is represented by mainly three magmatic episodes i.e., 3.3-3.2 Ga, 2.9-2.8 Ga and 2.6-2.5 Ga with varied compositionally different lithologies (Heron, A.M., 1953; Gopalan et al., 1990; Wiedenbeck et al., 1996). The 3.3-3.2 Ga magmatic activity is dominated by grey gneisses, whereas the 2.9-2.8 Ga activity is characterized by gneissic as well as volcano-sedimentary sequence formation (Gopalan et al., 1990). The 2.6-2.5 Ga event is represented by the granitoid magmatism (Wiedenbeck et al., 1996). So the older grey gneisses and the younger granitoids occupied a major portion of the Archaean basement. Structurally these two lithological units show very complex and contrasting features throughout the basement. Commonly younger granitoid shows intrusive relationship with older gneisses and at some places it shows gradational contact with gneiss. Older

grey gneisses are also found as enclaves within the younger granitoid. Basement granitoid also show inlier relationship with the younger Aravalli supracrutsal rocks. To resolve the genesis, we have used whole rock geochemical and Sm-Nd isotopic data of Neoarchaean granitoids to decipher the Neoarchaean crustal evolution mechanism of the Aravalli craton.

Neoarchaean continental crust of BGC was represented by younger basement granitoid showing high- K calc-alkaline characteristics, high silica (70.9-78.34 wt%; avg. 74.62 wt%), K_2O (4.25-8.24 wt%; avg.5.48 wt%), Al_2O_3 (13.16-15.15 wt%; avg. 14.57 wt%) K_2O/Na_2O (>1.8) content and very low MgO, Cr, Ni content, highly fractionated REE pattern (LaN/YbN >27) with a strong negative Eu anomaly (≤ 0.57) and pronounced negative anomalies of HFSE (Nb, Ta and Ti). All these distinctive geochemical characteristics indicate a subduction related arc tectonic setting where the granitoid was formed in a low pressure depth leaving plagioclase in the residue. The highly negative Sr anomaly further strengthens the crustal source of this granitoid. Analyzed Sm-Nd isotopic data of this granitoid suite shows TDM model ages varying from 2.88-3.43 Ga which is much greater than its crystallization age. The negative ε_{Nd} (-4 to -8) values indicate that this high-K granitoid suite was formed by remelting of the older crust which is also strengthened by the field evidence of gradational contact with older gneiss and by the petrographic studies which indicate very low concentration of mafic minerals. Overall whole rock geochemical and Nd isotopic characteristics of this high-K suite indicate its origin related to a subduction related arc tectonic setting in a low pressure zone where partial melting of pre-existing older crust occurred, leaving plagioclase in a residual phase.

Heron, A.M., 1953. Memoir Geological Survey of India, 79, 1-389.
Gopalan, K., Mc Dougall, J.D., Roy, A.B., Murali, A.V., 1990. Precambrian Research, 48, 287-297.
Wiedenbeck, M., Goswami, J.N., Roy, A.B., 1996. Chemical Geology, 129, 325-340.

Geochemistry and petrographic investigations of Triassic sandstones from the Spiti valley, Tethys Himalaya: preliminary studies

Abdul Samad Siddiqui, Shaik A. Rashid*
Department of Geology, Aligarh Muslim University, Aligarh 202002
** rashidamu@hotmail.com*

Preliminary studies have been carried out on the Triassic sandstones (belonging to Lilang Group) exposed in the Spiti Valley, Himachal Pradesh, Tethys Himalaya. An integrated approach consisting of petrography and geochemistry was employed to infer their provenance, paleoclimate and tectonic setting. The Spiti Valley forms a part of the Spiti-Zanskar Basin of NE Himachal Pradesh that belongs to the geotectonic zone of the Tethyan Himalaya. In contrast to Permo-Carboniferous, the Triassic succession is the thickest in the Spiti Basin and exists in almost all parts of the basin.

The petrographic investigations (framework composition) and major element geochemistry suggest that the sandstones of LilangGroupare Quartzarenite, sublithareniteand subarkose types. Heavy minerals such aszircon, rutile, ironoxides and muscovite are noticed in the thin sections. In the QFL (quartz-feldspar-lithic fragments) plot, the sandstone samples fall in recycled orogen block field implying recycling of sediments before deposition. When the major elemental data was plotted on provenance discrimination diagrams, it is observed that the sediments fall in Quartzose-Sedimentary provenance field. Few samples indicate felsic igneous provenance and also shows the passive continental margin tectonic setting. Chemical maturity of sandstones of Spiti area expressed as a

function of SiO_2 and total Al_2O_3, K_2O and Na_2O. Most of the samples show humid climatic conditions with increase in maturity with some samples falling into Arid to Semi-Arid climatic conditions. The A-CN-K (Al_2O_3-CaO*+Na_2O-K_2O) triangular plot for the sandstone samples suggest moderate to intense chemical weathering in the region during this period.

Grey gneisses of the Mangalwar Complex, Aravalli craton: Insight from geochemistry

Iftikhar Ahmad*, M.E.A. Mondal
Department of Geology, Aligarh Muslim University, Aligarh 202002
**ifahmad@msn.com*

Archean cratons of the world are dominantly comprised of "grey gneisses". Geochemically, a major proportion of these grey gneisses are granitoids of tonalite, trondhjemite and granodiorite (collectively termed as "TTG") composition. Grey gneisses from several parts of the Indian craton, e.g. central Aravalli craton, have been, interchangeably, mentioned as TTG without any geochemical connotation (Gupta et al., 1997, Buick et al., 2006, Bhowmik and Dasgupta, 2012). This leads to a serious confusion in correlation of the Aravalli craton with other cratons of India and the world. Till date, the Aravalli craton remains unrepresented in any computed models of crustal evolution and/or supercontinent cycle.

Chemically, TTG are defined as a group of sodic rocks with high SiO_2 (avg. 64 wt %), Sr/Y and Sr, contents with highly fractionated rare earth element (REE) patterns [$(La/Yb)_N$ up to 150 sometimes] (Drummond and Defant, 1990). It is imperative to understand that all grey gneisses from Archean craton are not TTG in composition (Moyen, 2011). Previously it was considered that TTG are ubiquitous in Archean cratons. Nevertheless, recent studies have shown that grey gneisses can have any of the following compositions: (i) TTG, (ii) sanukitoids, or (iii) high-K granitoids. In this backdrop, geochemical study of basement gneisses from Mangalwar Complex of the Aravalli craton has been taken up to understand the nature of the basement. The grey gneisses of the Mangalwar Complex have been classified as low SiO_2 gneisses (LSG) and high SiO_2 gneisses (HSG) based on their chemistry. The LSG is characterized by low SiO_2 (avg. 60.2 wt.%; hereinafter all data reported as average) and high MgO (4.3 wt.%) contents. They are enriched in compatible (Cr=190 ppm; Ni=81 ppm) and incompatible (Sr=502 ppm; Ba=586 ppm) elements with high Sr/Y ratio (28.1). They also have low Y (19 ppm) and Yb (2 ppm) contents. Chondrite normalized REE patterns of the LSG are fractionated [(La/Yb)N=12.1] with small europium anomaly (ΔEu; 0.9). Geochemically, the LSG show characteristics of Archean sanukitoids (s.l.) and striking similarities with Berach sanukitoids of the southern Aravalli craton (Mondal & Raza, 2013). On the other hand, the HSG are characterized by high SiO_2 (68.7 wt.%) and low MgO (1.1 wt.%) contents. They are depleted in compatible elements (Cr=8 ppm; Ni=6 ppm) and show moderate enrichment in incompatible elements (Sr=286 ppm; Ba=469 ppm), and Y (40 ppm) and Yb (5.1 ppm). REE patterns are moderately fractionated [(La/Yb)N= 15.1] with moderate ΔEu (0.6). The HSG are comparable with high-K granitoids reported elsewhere from several cratons.

Tectonometamorphic implications of olivine dolerites dykes of Almora nappe, Kumaun Lesser Himalaya

Mallickarjun Joshi[1]*, Ashutosh Kumar[1], Kanchan Pande[2]
[1]Department of Geology, Banaras Hindu University, Varanasi 221005
[2]Department of Earth Sciences, IIT Bombay, Powai, Mumbai 400076
** joshimallickarjun@gmail.com*

Almora Nappe is one of the largest nappes in the Himalaya. The area studied is located west of Almora town and comprises alternating bands of schists, gneisses and quartzites of the Saryu Formation of the Almora Group (Valdiya, 1980). The prograde metamorphic sequence spanning from green schist facies to the upper amphibolite facies K-feldspar- sillimanite gneisses was metamorphosed at temperatures exceeding 700°C and pressures around 7.9kbar (Joshi & Tiwari, 2009). This metamorphic sequence has undergone tight to isoclinal F_2 folding reflected in several repetitions of schistose and gneissic bands across the strike of the nappe and is intruded by olivine bearing dolerites in the Ranikhet area (Sharma, 1962). The two unaltered dolerite dykes roughly trend ~ N70W (Joshi, 2006) and the major constituents are plagioclase, clinopyroxene and olivine with grain size exceeding 2mm at places. Plagioclase and clinopyroxene show ophitic to subophitic texture. The core of the dykes is coarse while the margins are fine grained eventually ending up as chilled margins in contact with the country rocks. Almora Nappe is largely accepted as a southern equivalent of the Higher Himalayan metamorphics (Gansser, 1964, and others) that are believed to have been extensively metamorphosed during the Tertiary Orogeny (Frank et al., 1973 and many others). These unmetamorphosed dykes intruding the Tertiary (?) metamorphics is puzzling and open hitherto unasked questions on the tectonics and metamorphism of the Almora Nappe particularly because the development of extensional fractures tapping mantle is not favoured during the Himalayan collisional tectonics.

Ar-Ar dating of the dykes at IIT Bombay yielded a date of ~640Ma with the plateau ages, the isochron ages and the inverse isochron ages tightly constrained around 639Ma (error ranges between ±2.3 and ±5.6 Ma). The whole rock chemical analyses carried out at W.I.H.G, Dehradun and IIT Bombay are consistent. The analyzed samples plot in the WPB, OIB and IAB fields in the various tectonic discrimination diagrams. There is no major rift event known in the Cryogenian period of Neoproterozoic Era for the Himalayan metamorphics. The plots that fall even in the IAB region are very close to the OIB field in the Ti-Zr-Y discrimination diagrams while in the Nb-Zr-Y and Ti-V-Sc diagrams the analyses plot in the OIB field. The field setting as isolated dykes within the metamorphic ensemble and the chemical affinities with the OIB and WPB suggests a likely mantle thermal plume source (Rodinian?) for these dykes.

As the Ar-Ar closure temperatures of minerals hosting argon in the dolerite, viz. plagioclase, hornblende and biotite range between 300-500°C, it is clear that the temperatures never exceeded 500°C after the emplacement of these dykes, viz. after ~640Ma. It is obvious that the metamorphic ensemble comprising the Almora Nappe hosting the dykes is older than Cryogenian.

Ultra-high temperature and decompressive textures in Sapphirine granulites from Usilampatti, Madurai Block, India

R. Yadav*, D. Prakash
Centre of Advanced Study in Geology, Institute of Science Banaras Hindu University, Varanasi
** yadavroopali05@gmail.com*

The Usilampatti area constitutes part of the granulite- facies rocks of the Madurai block in Southern Granulite Terrain (SGT), India. Usilampatti area is situated 35 km away from Madurai District. Rock types exposed in the area include quartzite, charnockite, khondalite, sapphirine-bearing granulite, calc-silicate rocks, leptynite, mafic granulite and ultramafic rocks. Near about 10 km NE of Usilampatti, sapphirine bearing granulite is exposed in an abandoned pit. Here we found association of Sapphirine+quartz presenting evidence for UHT metamorphism (Prakash et al., 2016). The sapphirine-quartz is regarded as a robust diagnostic UHT mineral assemblage. The highest P-T conditions of 9 kbar and 940°C were obtained from the core compositions of sapphirine-bearing granulite and they are regarded as the near-peak thermal conditions of granulite-facies metamorphism in the area. Common mineral assemblages of metapelites include garnet, cordierite, sapphirine, orthopyroxene, spinel and sillimanite. Nearly isothermal decompression is also evident from symplectites of orthopyroxene-cordierite, orthopyroxene-spinel-cordierite, orthopyroxene-plagioclase and orthopyroxene- sapphirine-cordierite. The P-T evolution of the sapphirine granulites has been constrained through the use of TWQ and PERPLE_X programs.

Prakash, D., Yadav, R., Tewari, S., Frimmel, H.E., Koglin, N., Sachan, H.K., Yadav, M.K., 2016. Geological Journal, (under review).

P-T evolution of the UHT granulites from Rajapalayam, Madurai Block, southern India

Manoj Kumar Yadav*, D. Prakash
Department of Geology, Banaras Hindu University, Varanasi 221005
** mkyadav.geo@gmail.com*

The Rajapalayam, the study area, forms a part of the eastern domain of the Madurai Block of the Southern Granulite Terrain of India. Madurai Block is tectonically, located between two high strain shear zones viz. W-E trending Palghat Cauvery Shear Zone (PCSZ) in the north and WNW-ESE trending Achankovil Shear Zone (ASZ) in the south. The major rock types that constitute the Madurai Block consist dominantly of massive charnockite, hornblende-biotite orthogneiss, mafic to ultramafic rocks, pink granites, metasedimentary rocks including quartzites, metamorphosed carbonates, iron formations, calc-silicate rocks and Mg-Al-rich rocks (Prakash and Lal, 2008). The present study area, Rajapalayam is located about 85 km southwest of Madurai city in the state of Tamil Nadu and represents a somewhat newly discovered UHT locality in Madurai Block. The occurrence of UHT metamorphism is indicated by the presence of sapphirine + quartz association in Mg-Al granulites in an abandoned quarry in Mottamala village near Rajapalayam town. The Mg-Al granulite occur within granite as dismembered layers in the western part of the quarry. The high Mg-Al granulite occurring within the granite is composed of cordierite-quartz-orthopyroxene-garnet with inclusions of sapphirine + quartz. The P-T evolution of these Mg-Al granulites has been constrained through the use of THERMOCALC and PERPLE_X programs.

Prakash and Lal, 2008. GSI Spl. Pub. No. 91, 28-44.

Petrogenesis and geodynamic significance of a mid-Cretaceous, ultramafic lamprophyre dyke from the Kutchch rift, NW-India

Rohit Pandey[1]*, Prashant Dhote[2], Dinesh Pandit[1], N.V. Chalapathi Rao[1], A.K. Choudhary[3], B. Lehmann[4], Samarendra Sahoo[1]

[1]EPMA Laboratory, Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi, India
[2]Bhumi Geoservices, 1 & 2 MaaBamleshwari Nagar, Godhani Rly., Nagpur 441111, India
[3]Institute Instrumentation Centre, Indian Institute of Technology, Roorkee 247667, India
[4]Mineral Resources, Technical University of Clausthal, 38678 Clausthal-Zellerfeld, Germany
***** *rhtgeo@gmail.com*

Petrological and isotopic (Sr and Nd) studies on a mid-Cretaceous (125 Ma), ultrabasic and peralkaline dyke from Palanpur, NW India, are presenting in this study. The dyke intrudes Jurassic sandstones on the western flank of Jura dome, Kutchh rift zone, NW India. Microscopic studies reveal that moderate to weak inequigranular texture dominated by phenocrysts of olivine, clinopyroxene and phlogopite. The matrix phase comprises micro-phenocrysts of olivine, clinopyroxene, feldspar, perovskite, spinel, apatite and very minor calcite. Field and microscopic studies reveals that the dyke is undeformed and un-metamorphosed. Mineral composition studies carried out by EPMA reveals that olivines (phenocrysts as well as micro-phenocrysts) are forsteritic (Fo: 85-87) and show little variation. The Clinopyroxene is a diopside having a compositional range of Wo: 45.8-51.2, En: 37.3-44.4, Fs: 5.2- 9.5 and Ac: 1.4-4.2. Feldspar has predominant albite component (Ab: 71.6 -91.8) and is mostly altered. Perovskite is wide spread in the groundmass and is occasionally seen to occur as garlands around some of the olivines. Most of the pervoskite grains are euhedral and at times cubic in shape and display a narrow range of compositional variation (CaO: 37-39 wt%, TiO_2: 54-59 wt %). Incompatible trace element contents of analyzed perovskite reveal their enrichment in Nb (Nb_2O_5: 0.33-0.94 wt%), La (La_2O_3: 0.01-0.55 wt%), Ce (Ce_2O_3: 0.17-1.12 wt%) and Nd (Nd_2O_3: 0.04-0.54 wt%). The apatite (CaO: 49-54 wt%, P_2O_5: 39-42 wt%) occurs mainly as prismatic crystals with a relatively lower incompatible trace element content (La_2O_3: 0.03-0.11 wt%, Ce_2O_3- 0.01-0.19 wt%, Nd_2O_3: up to 0.05 wt%, and Sm_2O_3: up to 0.02 wt%). From the REE concentration in these two accessory phases which host REE, it is evident that the latter are sequestered substantially into the early crystallized perovskite than into the later crystallized apatite.

This ultra-basic dyke was earlier reported as a lamproite. However, presence of groundmass Na-rich feldspar, high sodium content, lack of ultrapotassic, nature, and bulk rock incompatible and trace element ratios demonstrate it as an ultramafic lamprophyre (UML). $^{87}Sr/^{86}Sr_i$ (0.704604 to 0.704607) and $^{143}Nd/^{144}Nd_i$ (0.512449 to 0.512604) isotopic ratios point out involvement of a mantle source that shows long term depletion in light rare earth elements similar to that of global ultramafic lamprophyres, Group I kimberlites and Ocean Island basalts. Geochemical modeling reveals generation of the Palanpur UML from small-degree melting of enriched garnet-lherzolite source region. It is well known that UML are globally confined to the regions of continental rifting and location of this studied dyke within the Kutch rift is, thus, no exception. Nd isotopic modal ages (T_{DM} Ma) of upto 900 m.y. suggest an ancient (Neoproterozoic) source enrichment age. The geodynamic significance of this UML in the context of the break-up of the Gondwanaland and the Greater India would be discussed.

Petrogenesis of Madawara Igneous Complex, Bundelkhand Craton, central India

N. Mohanty[1]*, M. Satyanarayanan[1], S. P. Singh[2], V. Balaram[1]
[1]CSIR-National Geophysical Research Institute, Hyderabad 500007
[2]Department of Geology, Bundelkhand University, Jhansi 284001
** niranjanmohanty9090@gmail.com*

The unique Madawara ultramafic intrusion in Lalitpur district, UP, is a well-differentiated complex comprising concentrically zoned ultramafic-mafic intrusion confined in between the two major shear zones, namely, Madawara-Karitoran and Sonrai-Girar trending E-W located along the southern fringes of Bundelkhand Craton, Central India. It intrudes into the Bundelkhand gneissic complex (BnGC)) with an age > 3300 ma. The ultramafic rocks namely peridotite and olivine pyroxenite are mostly seen in the central part of intrusion enveloped by mafic gabbro and in some places diorite, while the contacts between these rocks are gradational in nature. The petrographic study of the ultramafic rocks shows the presence of serpentine, talc and tremolite along with minor phases of chlorite, and displays both mesh and cumulate textures. Mafic rocks show ophitic to sub-ophitic texture. The observed crystallisation sequence is olivine (cotectic spinel)-orthopyroxene (Opx)-clinopyroxene (Cpx)-Hornblende (Hbl)- Plagioclase (Pg). The SEM-EDS and BSE images show the presence of disseminated crystals of sulfides, mainly sphalerite, pentlandite, (Pd, Fe) S along the margin of the pyroxene. Ultramafic rocks have high MgO, Ni, Cr, PGE and low Al_2O_3, CaO, K_2O, TiO_2, V contents and displays peridotitic komatiite affinity. The ultramafic intrusive rocks are characterised by slight enrichment in LILE elements and depleted in HFSE elements relative to mafic gabbro. Trace elements particularly HFSE and REE along with different elemental ratios of most of the studied samples, indicate higher $(Gd/Yb)_N > (1.0)$, $CaO/Al_2O_3 > (1.0)$, $Al_2O_3/TiO_2 < (18)$ together with lower HREE, Y, Zr and Hf signifying their derivation from deeper upper mantle with minor garnet involvement in residues. At several places, the rocks are relatively enriched in total platinum group elements (PGE ~ 300 ng/g). The discrimination diagrams suggest that PGE's are enriched in source magma at moderate to deeper depths at low sulphur fugacity by the high degree of partial melting of the mantle.

Occurrence and origin of pyroclasts in the central Indian Ocean Basin: Are intraplate environments congenial for explosive volcanic eruptions?

Ankeeta Amonkar*, S.D. Iyer
CSIR- National Institute of Oceanography, Dona Paula, Goa 403002
** aamonkar@nio.org*

The seafloor is known to be a volcanically active site with the mid oceanic ridges (MOR) accounting for most of the eruptive output in the form of basaltic lava. These result in the formation of pyroclastic material of different shapes, sizes and composition that is common not only at the MOR but also at sites of intraplate volcanoes and seamounts. These unconsolidated materials formed during explosive volcanic activities occur as fluidal clasts, bubble-wall and highly vesicular fragments. In contrast, hydromagmatic (phreatomagmatic) eruptions would form hydroclastics such as lithic fragments coated with lava, coarse-grained basalt fragment and altered glass. Such material may be formed *in situ* or transported by various agents. Deep-sea pyroclasts occur in the sediment cores recovered from the Pacific and Atlantic ridges and a few seamounts. For example, Sohn et al.

(2008) found unconsolidated pyroclastics covering >10 km^2 at a water depth of 4000 m on the ultra-slow-spreading Gakkel Ridge. Clague et al. (2009) reported several pyroclastic deposits on the Juan de Fuca and Gorda Ridges, EPR, Fiji back-arc basin and various seamounts. Many of these are located at more than 3,000 m water depth. They suggested that high effusion rate of eruptions produced sheet flows with abundant pyroclastic, while low effusion rates produced pillows with few pyroclastics, This perhaps indicates the role of magmatic gases that influence the high effusion rates of the lava. And of these, elevated CO_2 content in the upper mantle be the driver for explosive volcanism at the MOR.

Most of the above cited studies concern basaltic pyroclasts but there are no reports of silicic equivalents in the deep sea. This could be because the understanding and monitoring of such phenomena is still meager and technically challenging. Extensive volcanological work of the Central Indian Ocean Basin (CIOB) has been carried out especially of the basalts and pumices, but there is a paucity concerning the deep sea pyroclasts and volcanogenic-hydrothermal material (vhm). There are reports of presence of vhm at the base of seamounts and near fracture zones. The vhm is comprised of fragile bread-crust particles, glass shards (silicic and basaltic), dominant presence of magnetite spherules, spherules of Fe-Ti composition and rare occurrence of native metal such as aluminium. It has been suggested that the vhm represents sporadic phreatomagmatic and hydrothermal events in the CIOB since 625 ka to as recent as 100 yr. Rhyolitic glass shards are common in the basin and have been suggested to have been transported from the Indonesian Volcanic Arc and are products of the Youngest Toba Tuff (~74 ka) eruption (Pattan. et al 2014). In contrast, the recent finding of four volcanic horizons of rhyolitic glass shards in a sediment core recovered near a fracture zone in the CIOB have been attributed to submarine Strombolian volcanic eruptions.

The investigation of the volcanic material from the CIOB raises several questions regarding their morphology, composition, enigmatic source and mechanism of formation (volatile and/or water driven explosions). A detailed study of deep sea volcanism would help to better understand the magmatic input in the intraplate regions and to unravel the history of volcanism in the CIOB.

Variation in oxygen fugacity with depth in the upper mantle beneath the Dharwar Craton, southern India

Sourav Misra*, Sujoy Ghosh
Department of Geology and Geophysics, IIT Kharagpur, Kharagpur
** souravmisra.gg@iitkgp.ac.in*

The oxidation state of the Earth's mantle can be described using a term called "oxygen fugacity or fO_2", which being a significant parameter in various geochemical processes in the Earth's mantle, such as speciation and mobility of volatile elements, generation of magmas, metasomatism and also evolution of the atmosphere of the earth (Kasting, 1993). Redox profiles (shortened equivalent of 'reduction-oxidation' reactions due to movement of material through rocks) of the upper mantle have been modeled by calculating $Fe^{3+}/\Sigma Fe$ ratios in spinel, garnet, pyroxenes (both ortho and clino) from mantle xenoliths using Mössbauer spectroscopy. Mössbauer spectroscopy is widely used method to calculate the fO_2 in the samples with its ability to distinguish between ferrous (Fe^{2+}) and ferric (Fe^{3+}) oxidation states of iron. We can also determine $Fe^{3+}/\Sigma Fe$ ratios in silicates using Flank method in EPMA that is semi quantitative method (Hofer & Brey, 2007).

Mafic and Ultramafic xenoliths have been reported in kimberlite pipes from Wajrakarur Kimberlite Field (WKF), Eastern Dharwar Craton (EDC) (Ganguly and Bhattacharya, 1987), confined within the Precambrian shield of central and southern India. The dominant rock types of these xenoliths are garnet lherzolite, while some of these garnet bearing nodules are also having spinel. These samples shed important light on the source depths of these ultramafic xenoliths i.e. 70-220 km. The measurements of fO_2 on ultramafic mantle rocks from cratonic lithosphere reveal a decreasing trend in fO_2 with depth (Woodland and Koch, 2003), which results from the effect of pressure on the controlling Fe^{3+}/Fe^{2+} equilibria (Frost and McCammon, 2008). This observation suggests that mantle is more reduced below 300-km depth. On a large scale, the measurements of oxygen fugacity in silicates would contribute to our understanding of oxidation state of the upper mantle beneath the EDC that has important implications on direct links to the deep volatile cycle in the Earth.

Foley, S.F., 2011. J. Pet. 52, 1363-1391.
Frost D.J., McCammon, C.A., 2008. Annu. Rev. Earth Planet Sci. 36, 389-420.
Ganguly, J., Bhattacharya, P.K., 1987. In: Nixon, P.H. (Ed.), Mantle Xenoliths. John Wiley & Sons. 249-265.
Hofer and Brey, 2007. American Mineralogist, 92, 873-885.
Kasting, J., 1993. Science, 259(5097), 920-926.
Woodland, A.B., Koch, M., 2003. Earth and Planetary Science Letters, 214, 295-310.

Water in mafic-ultramafic xenoliths from eastern Dharwar craton, southern India

Lipsa Chakra*, Sujoy K. Ghosh
Department of Geology and Geophysics, IIT Kharagpur, West Bengal
** lipsa@iitkgp.ac.in*

Water has played an important role in Earth's evolution due to its strong influence on the chemical and physical properties of crust and mantle constituents. Nominally anhydrous minerals (NAM) e.g., olivine, orthopyroxene, clinopyroxene and garnet constitute a significant reservoir for mantle hydrogen (Bell and Rossman 1992), possibly incorporating H_2O in the form of hydrogen associated with point defects in the mineral structures (Kohlstedt et al., 1996), and therefore, crucial for explaining the internal water cycle of the Earth. The highest hydrogen concentrations is found in peridotitic olivines from cratonic mantle, and are likely due to the depth of origin (Demouchy and Bolfan-Casanova 2016). Xenoliths (peridotitic or eclogitic) from kimberlites have shown that it may contain small amounts of water, on the order of 100s to 1000s ppm H_2O. NAMs in peridotite xenoliths are collected from kimberlites in Eastern Dharwar craton (EDC), Southern India and currently we are doing detail petrography and textural study of the mantle xenoliths from Wajrakarur Kimberlite Field (WKF). After finishing the petrography and textural studies, we will measure water content in NAMs present in the xenoliths from the same area. It is highly possible that NAMs from the upper mantle in WKF may lose most of their water (mainly olivines) during ascent (Ingrin and Skogby 2000). Therefore, analyses of natural samples provide a lower limit of the actual water content in the mantle, whereas measurements of water solubility in high pressure experimental samples give the maximum solubility of water in NAMs. We have prepared slides from each sample to identify the NAMs in the ultramafic xenoliths using optical microscope. Using Electron Probe Micro Analyzer (EPMA) mineral compositions will be analyzed. Water contents in natural minerals will be measured with Fourier Transform Infrared Spectroscopy (FTIR), which is the most widely used method to detect and analyze structurally-incorporated hydrogen, water solubility and mechanisms for hydrogen

incorporation in the minerals. The measurements of water contents in NAMs present in mantle xenoliths from WKF will likely yield information about how those melts are formed as well as understanding of the deep water cycle in the Earth and how much water is stored beneath EDC.

Bell, D.R., Rossman, G.R., 1992. Science 255, 1391-1397.
Bolfan-Casanova, N., Keppler, H., Rubie, D.C., 2000. Earth Planet. Science Letters 182, 209-221
Ingrin, J., Skogby, H., 2000. European Journal of Mineralogy 12, 543-570.
Kohlstedt, D.L., Keppler, H., Rubie, D.C., 1996. Cont. to Mineralogy and Petrology 123, 345-357.

Raman spectroscopic study of carbonaceous matter: assessment of temperature of hydrothermal activity and low-T metamorphism

Debidarsani Sahoo[1]*, Kamal Lochan Pruseth[1], Dipak C. Pal[2], Rahul Banerjee[3]
[1]Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721302
[2]Department of Geological Sciences, Jadavpur University, Kolkata 700032
[3]Atomic Mineral Directorate for Exploration and Research, DAE, Hyderabad 500016
** debidarsani@gg.iitkgp.ernet.in*

There is a paucity of suitable geothermometers for low temperature geological processes. Water-rock interactions at lower temperatures relevant to diagenesis, low-T hydrothermal process and low-T metamorphism can be studied if chlorite is present as a stable phase. However, this requires meticulous analytical data acquisition and complicated formula calculation protocols. For a quick assessment of low-T events in sedimentary and metasedimentary rocks, Raman spectroscopic study of associated carbonaceous matter provides a convenient alternative. Here we show the efficacy of this method (Kouketsu et al., 2014) and provide chlorite thermometric estimates (Bourdelle et al., 2013) for comparison from the Proterozoic Banganapalle Quartzite. While Raman spectroscopic study of carbonaceous matter, probably of organic nature, yielded the temperatures of 327, 357, 370, 400 and 413 °C, the corresponding temperatures obtained from chlorite thermometry were 228, 322, 339 and 347 °C. Although the temperatures of 327 to 357 °C overlap with the chlorite temperatures from 322 to 347 °C, the carbonaceous matter record still higher temperatures while the chlorites record still lower temperatures indicating the irreversible change that occurs in the carbonaceous matter and the capability of the chlorites to re-equilibrate to lower temperatures, at least partially.

Kouketsu, Y., Mizukami, T., Mori, H., Endo, S., Aoya, M., Hara, H., Nakamura, D., Wallis, S., 2014. Island Arc, 23, 33-50.
Bourdelle, F., Parra, T., Chopin, C., Beyssac, O., 2013. Contribution to Mineralogy and Petrology, 165, 723-735.

Modelling using trace elemental behaviour for generation and emplacement of low melt fractions of Dalhousie granite, Himachal Himalaya

Rimpi Dhiman*, Sandeep Singh
Department of Earth Sciences, IIT Roorkee, Roorkee 247667
** rrimpidhiman@gmail.com*

Dalhousie granite of Himachal Himalaya has been considered as a part of the Lesser Himalayan Granite Belt (LHGB) and has been divided into Western granites: outer band of Dhauladhar Range and Eastern granites: Dalhousie Granite with sharp and intrusive contact (Kumar

and Bhatia, 1977, 1978, 1980; Bedi & Parsad 1981), Mukherjee et al. (1998) considered them as a single moderately paraluminous Palaeozoic granitic body with S type nature.

Variability in geochemical behaviour of the Dalhousie Granites are being considered for different stages of magmatic differentiation or different anatectic conditions (P, T, XH_2O, fO_2) having same source rock. Trace element modelling shows this remarkable enrichment in LILE (Cs, Rb, Th, U) relative to HFSE, Nb as well as the enrichment of Rb, Th as compare to Nb. Negative Ba anomaly to adjacent element provides the estimation that out of two feasible theories. Dalhousie Granites are derived from granitization theory with the involvement of upper continental crust (Metasedimentary) along with low concentrations of Ce, Zr, Hf and Sm pattern shows the characteristics features of Syn-Collision granites (Pearce et al 1984). Dalhausie Granites have a wide range in total amount of REE (Σ REE =5.59-142.63ppm) with the maximum range approximately close to quartz-intermediate greywackes (REE130-176 ppm) (Taylor and Mclennan, 1985). This indicates two distinct groups i.e.: 1. REE poor group (Σ REE<10 ppm) 2, REE rich group (Σ up to 143). REE shows significant variations (min of 5.59 to max of 142.63ppm) indicates LREE are relatively enriched. LREE/HREE fractionation ratios (1.33) shows HREE fractionation relative to the LREE but moderate negative Ce anomaly (Ce/Ce*493.51) and Eu anomaly (Eu/Eu*0.81) which corporate plagioclase fractionation along deficiency of plagioclase in the melt. Ratios Rb/Sr, Rb/Ba and Sr/Ba are used constrains source granitic magma (Miller, 1985; Harris and Inger, 1992) with low Rb/Sr (4.95), Rb/Ba (5.06) clearly indicate the partial melting of bodies from pelitic source. Presence of H_2O rich fluids by Rb-Sr relationship shows granites was emplaced as liquidus at shallow depth. Rise of liquidus magma cause metasomatism indicated by large K-Feldspar crystals and presence of magmatites near by area of these granites. The dehydration melting of source rock metapelites causing presence of fluid mostaly at the temperature higher than 850^{o}C and pressure up to 1Gpa (Burnham, 1967, Brown & Fyfe, 1970). Emplacement and ascent of Dalhousie body of voluminous and mobile magma is basically depend upon actual shape of the diaper or fracture induced magma propagation instead of intrinsic properties, reduced viscosity or the density constant which later got modification due to Himalayan collision tectonics. Their migration also causes the dehydration of protolith in restite condition and enrichment of heat producing elements and LIL in upper crust (Clemens, 1996).

Carbonatite petrogenesis in the framework of the northeast Indian Kerguelen Plume Volcanism

Arundhuti Ghatak*, Anirban Chowdhury
Indian Institute of Science Education and Research, Bhopal
** arundhutighatak@iiserb.ac.in*

The geochemistry and petrogenesis of carbonatites is an area of intense research. Although their importance in mantle studies is unequivocal, the depth at which carbonatite or carbonate-silicate magmas are generated remains uncertain. Geological evidences such as their overwhelming presence in the continental crust and repeated activity in some complexes, with episodes separated by millions of years, indicate that the continental lithospheric mantle plays a critical role in their generation. Therefore, study of carbonatites becomes important for our understanding of secular evolution of the mantle sources involved in carbonatite generation. Carbonatites and associated alkali-rich melts are believed to sample large volumes of the mantle due to their low viscosity.

Therefore carbonatitic-alkalic-ultramafic suites of rocks are important in that they characterize the mantle composition as well as the processes of assimilation of the continental crust and lithosphere. Many researchers have described carbonatites and associated alkalic-ultramafics in terms of their petrology (Wyllie et al., 1989), major and trace element geochemistry (Nelson et al., 1988), radiogenic isotopes (Bell, 2001) and stable isotopes (Srivastava and Taylor., 1996). These studies strongly indicate a mantle origin for these carbonatites and associated alkalics which are have been correlated with mantle plume activity.

Experimental phase-equilibria studies of peridotite-CO_2 system demonstrate that primary carbonatite magmas can be generated at depths greater than ~70 km (Wallace and Green, 1998). These experiments imply that primary carbonated magmas generated at such depths will release CO_2 vapor on rising to shallower depths of ~70 km, increasing the solubility of pyroxenes in the magma from the ambient lithosphere or plume, and also assist in the thinning of the lithosphere due to high pore pressure of CO_2 rich fluids. This decarbonation reaction can convert lherzolite into wehrlite, which can coexist with carbonated magmas and dissolve an adequate amount of olivine and pyroxene to provide Al, Fe, and Si necessary for the crystallization of ultrabasic alkaline silicate magmas of nephelinitic composition. It has also been suggested that pyroxenites in alkalic environments may result from the reaction between silicate rock and carbonatite magma. In another scenario, it has been experimentally shown that carbonated eclogites can be the potential source of continental carbonatites.

This study aims to understand the relationship of silicate rocks and spatially associated carbonatities. Here we attempt to review the existing geochemical data and attempt to find a possible petrogenetic relationship between carbonatites and associated silicic rocks in the framework of the northeast Indian Kerguelen plume volcanism.

Bell, K., 2001. Carbonatites: Geological Society of America Special Paper.
Nelson, D.R., Chivas, A.R., Chappell, B.V. and McCulloch, M.T., 1988. Geochim. Cosmochim. Acta, 52, 1-17.
Srivastava, R., K., Taylor, L.A., 1996. International Geology Review, 38, 419-429.
*Wallace, M. E., and Green, D.H., 1988. Nature, **335**(6188), 343-346.*
Wyllie, P.J., 1989. Unwin Hyman, London, 500-545.

Petrology and geochemistry of Gokanakonda ferrosyenites from Settupalle alkaline complex of Cuddapah intrusive province, Andhra Pradesh, India

Kandukuri Sai Krishna*, R. Mallikarjuna Reddy
Department of Geology, Kakatiya University Warangal, Telangana 506009
***** *saikrishnageo@gmail.com*

The Ferrosyenites hosted by Settupalle alkaline complex is sub oval - shaped with an extent of 40 km^2. The silica over saturated and silica under saturated Settupalle alkaline pluton from cuddapah intrusive province is confined to an extremely narrow linear belt which is close to the known basement fracture zone (Leelanandam, 1989). The Gokanakonda sub-alkaline Ferrosyenites falls between (15°56'57"N: 79°52'31"E to 15°57'15"N: 79°51'30"E) and occupies an area of 5 km^2, towards the southern marginal portion of the Settupalle alkaline complex. Based on mineralogy the Ferrosyenites can be differentiated into two types i) fayalite ± clinopyroxene syenite, ii) fayalite ± quartz syenite. Both the Ferrosyenitic rock types express mesocratic nature with medium to coarse

grained hypidiomorphic texture which are more prominently exposed in Gokanakonda village but less prominent at puvvada village. The fayalite ± clinopyroxene syenite is found on the east and fayalite ± quartz syenite on west of Gokanakonda village, the Gundlakamma River forms the contact between these two rock types. The fayalite ± clinopyroxene syenite is composed of alkali feldspars, clinopyroxene, and fayalite as essential minerals and plagioclase, ferrohastingsite, biotite as accessory minerals whereas the fayalite ± quartz syenite is composed of alkali feldspar and Quartz as essential minerals and fayalite, amphibole as accessory minerals. The contact between fayalite ± clinopyroxene syenite and gabbro on the eastern side and the contact between fayalite ± quartz syenite and the Gabbro on the western side is sharp.

The detailed geochemical investigations were carried out on XRF and HR-ICPMS which revealed fractional crystallization as the petrogenetic process in the formation of these two litho units namely fayalite ± clinopyroxene syenite and fayalite ± quartz syenite.

Leelanandam, C., 1989. Journal of the Geological Society of India v.34, pp. 25-45.

2540 Ma anorogenic magmatism in Bundelkhand craton: Evidence from SHRIMP U-Pb zircon chronology and biotite composition

Gajender Kumar*[1], Santosh Kumar[1], Keewook Yi[2]
[1]*Department of Geology, Centre of Advanced Study, Kumaun University Nainital, India*
[2]*SHRIMP Centre, Korea Basic Science Institute, Ochang Campus, Chungbuk, Korea*
***** *gajendraarya99@gmail.com*

Bundelkhand massif is the northernmost craton of Precambrian Indian shield, which is mainly comprised of 3.5-2.7 Ga tonalite-trondhjemite-granodiorite (TTG), migmatites and predominant 2.5 Ga granitoids (diorite, granodiorite, granite), rhyolite and greenstone complex (Mondal et al., 2002; Kumar et al., 2011; Singh et al., 2015; Saha et al., 2016). Granitoids and associated volcanic rocks have been characterised largely as calc-alkaline, metaluminous (I-type) granite formed in subduction setting. Biotite composition (FeO^t/MgO=3.36-3.6) from leucosome of migmatite exhibit crystallization in peraluminous (S-type) felsic melt formed in syncollision tectonic setting. We report herewith a syenogranitoid body in the eastern part of craton, north of Bundelkhand Tectonic Zone, which bears typical alkaline character as exhibited by biotite composition (FeO^t/MgO=7.15-7.63) crystallized in anorogenic (A-type) granite melt formed in post-collisional rift environment. SHRIMP U-Pb zircon chronology yielded 2539.6±6.8 Ma (MSWD=1.5) crystallization age of zircon in the syenite melt. Inherited zircons from migmatite yielded upper intercept crystallization age of 3478±48 Ma (MSWD=8.2), over which 2700±16 Ma (MSWD=2.3) old growths can be recorded, which were most likely formed in a syn-collisional tectonic environment. Based on available evidences we conclude that 3.5 Ga old and even still older mafic to dioritic crust were recycled extensively forming 2.7-2.55 Ga subduction-collision related vast magmatism, which probably ended with 2.54 Ga old anorogenic (A-type) magmatism in post-collisional rift setting. Chemistry of zircon is being targeted for having some additional evidences in this regard.

Association of porphyritic volcanics and quartz pegmatite in Laguar region of Kumaun Lesser Himalaya: field evidence of granite assimilation and generation of hydrothermal system

Saurabh Gupta, Rajnish K. Singh, Santosh Kumar
Department of Geology, Centre of Advanced Study, Kumaun University, Nainital

Outer Kumaun Lesser Himalaya in Nainital District is mainly comprised of Bhowali volcanics and Nagthat quartzite together forming Bhowali Formation, which are resting over Amritpur granite and granite gneisses (*ca* 1890 Ma). These lithounits are extensively exposed in the north of Main Boundary Thrust (MBT), and tectonically juxtaposed with the Siwalik Group of rocks. New field observations in and around Laguar area located in the north of MBT have been documented which demonstrate features of partial assimilation of granite basement by profuse volcanic activities leading to generation of hydrothermal fluids probably in post-collision marginal rift environment. A body of porphyritic volcanics are exposed, in close association with pegmatite, which frequently bears mm sized tiny xenocrysts of K- feldspar, quartz and cm sized felsic xenolithic materials forming variety of disequilibrium textures at outcrop and microscopic levels. This is likely that the assimilation of basement Amritpur granite-granite gneiss by volcanic materials has generated the hydrothermal system profusely forming barren pegmatite which emplaced within the surrounding lithounits. The inferred sequences of events are I: Amritpur granite and granite gneisses forming the basement; II: development of marginal rift system synchronous with volcanism, assimilation and subsequently generation of hydrothermal fluids; and III: emplacement of barren pegmatite in the country rocks. These hypotheses have to be further tested using modern methods of mineralogy and petrology.

Kinematics and deformation temeprature of Almora and Ramgarh klippes south-eastern Kumaun Lesser Himalaya: emphasis on microstructure and quartz LPO study

Mohit Kumar[1]*, P.D. Pant[1], R.C. Patel[2]
[1]*Department of Geology (CAS), Kumaun University, Nainital*
[2]*Department of Geology, Kurukshetra University, Kurukshetra 136119*
* *puniyamohit@gmail.com*

Microstructures and quartz LPO data are analyzed to constrain the kinematics and deformation temperature of the Almora and Ramgarh klippe. Our study area encompasses three transects: North Almora Thrust (NAT) zone, South Almora Thrust (SAT) zone and Ramgarh Thrust (RT) zone, along a 30 km long a cross-strike north-south profile in Almora and Ramgarh klippe.

A detailed shear sense study in microscopic scale across the mylonite zone has yielded two senses of shears i.e. top-to-SW and top-to-NE. It suggests that the entire zone probably developed during the southward emplacement of the Almora klippe along the Almora Thrust while top-to-NE shearing was superimposed later along which NAT was reactivated as back thrusting. The presence of myrmekite, perthite newly recrystallized quartz texture, chess board extinction in quartz and mica fish texture indicates that NAT has undergone deformation at medium to high temperature (400-600°C). At SAT, microscopic study of quartz grains show sweeping undulose extinction. Myrmrkite

and perthite development in K-feldspars are commen features of this granodiorite. A few large original mica crystals still exist and form mica-fish structures. All these features in the granodiorite indicate the high deformation temperature in the range of 500 to 600°C. RT zone shows intense dynamic deformation resulting in recrystallized porphyroclast, myrmekite growth, tapering twining in plagioclase, grain boundary migration, perthite, antiperthite, fractured porphyroclast filled with newly recrystallized grains and ductile flow. All these microstructures in RT zone show 400-600°C deformation temperature and top to SW shear sense.

Quartz c-axis patterns of all samples resemble broken single girdles with maxima either at the Y or close to the Y axis or between X and Z directions. NAT have deformed by active prism <a>-slip and basal <a>-slip. Co-existance of prism slip with basal slip implies early medium-temperature deformation superimposed by late low-temperature deformation with opening angle 32 to 62° and show top to SW movement. The c-axes of samples close to the SAT (in footwall) cluster into girdle of two maxima along the XZ plane close to the Z-axis (near the primitive circle at an angle to the foliation) with 57° but close to the RT show broken single girdle with maxima between X and Z directions and another girdle of maxima at the Y or close to the Y axis. The quartz grains having c-axis maxima close to Z-axis have basal <a>-slip while c-axis maxima at or close to Y-axis have prism <a>-slip. If interpreted in terms of co-existing basal and prism slip directions, both fabric components give a consistent sense of shear that confirms with top-to-south shearing in all samples.

Petrology and geochemistry of acid volcano-plutonic rocks from Riwasa and Nigana areas, Bhiwani district, western Haryana, India

Naveen Kumar*, Naresh Kumar
Department of Geology, Kurukshetra University, Kurukshetra 136119
*** naveen.nain48@gmail.com***

The rocks exposed in Riwasa and Nigana area are part of Neoproterozoic Malani Igneous Suite (MIS) which is largest A-type, anorogenic and high heat producing (HHP) magmatism in Indian subcontinent and represents Pan-African thermotectonic episode (Kochhar, 1984; Vallinayagam, 2003; Baskar and Sharma, 1994; Bhushan and Chittora, 1999; Kochhar, 1983). The rocks of MIS are granite, rhyolite, dacite, trachyte, andesite, pyroclasts, basalt, gabbro and dolerite. The rocks of Riwasa and Nigana are classified as volcanic phase (rhyolites), plutonic phase (granites) and dyke phase. Generally, both rhyolite and granite show various shades of grey and pink colour. Xenoliths, sharp contacts between rock types, vertical columns, joints, fractures, small sized veins with copper enrichment (upto 1578 ppm), spheroidal weathering are the distinctive features of these lithounits. Rhyolite shows flow bands, porphyritic, aphyritic, spherulitic and perlitic textures when viewed under a microscope and consists of phenocrysts of orthoclase, quartz, and arfvedsonite as essential minerals in the quartzo-feldspathic groundmass. Gray granites porphyry are coarse to medium grained with mainly quartz, plagioclase feldspar (albite), biotite, muscovite and accessory minerals are hematite, riebeckite, illmenite, zircon, anite, apatite, monazite and rutile. Pink granite porphyry consists of fine grained and mainly quartz, k-feldspar (perthite, orthoclase), arfvedosonite, aegirine, aenigmatite, riebeckite and accessory minerals are hematite, apatite, zircon, monazite and rutile. Quartz porphyry, biotite granite and pegmatitic knots are also present in this area in minor form. The Riwasa rhyolites show high SiO_2 (71.05-75.73), high Al_2O_3 (12.15-14.08), high total alkalis (8.46-10.03), low Fe_2O_3 (2.56-6.20), low TiO_2 (0.13-0.22), low CaO (0.81-1.23) compositionally. The chemical concentration values of Sc, Ni, Cu, Rb, Zr, Ba, Pb, Th, and U of the Riwasa rhyolites

varies from 5.0-7.4, 1-18, 1-26, 316-357, 194-221, 365-714, 42-61, 94-145 and 7.4-15.1 respectively. The Riwasa rhyolites have DI, ASI, and AI average values: 88.49, 1.08, and 0.70 respectively. Nigana granites show high SiO_2 (68.31-74.59), high Al_2O_3 (12.72-14.03), high total alkalis (8.84-10.03), low Fe_2O_3 (2.55-4.97) compositionally. The chemical concentration values of Sc, Cu, Rb, Zr, Pb, Th and U of Nigana granite varies from 4.9-8.7, 2-1578, 289-372, 153-335, 21-97, 76-121 and 4.6-14.6 respectively. The Nigana granites have DI, ASI, and AI average values: 87.0, 1.06 and 0.76 respectively. The high A/CNK ratio values suggest these rocks as peraluminous nature. Grey and pink rhyolites of Riwasa area show high concentrations of Heat production (HP) 13.0 & 10.16 μWm^{-3} and total Heat Generation Unit (HGU) i.e. 30.96 & 24.19 respectively. On the other hand, Grey and pink granites of Nigana area display enrichment of HP (9.48 & 10.97 μWm^{-3}) and HGU (22.58 & 26.12) respectively in comparison with rhyolites of Riwasa area. Overall, they have much higher values of HP and HGU than the average value of continental crust (3.8 HGU), which imply a possible linear relationship among the surface heat flow and crustal heat generation in the rocks of MIS. In plutons of Nigana, the absence of flow structures which generally formed during the emplacement of magma are indicating towards the long time heat retained aspect in the studied area (Kochhar, 1983). The geochemistry of acid volcano-plutonic rocks, high concentration of trace elements indicated that they have formed by intraplate magmatism with co-magmatic origin and have mineralization potential probability which can be studied in future.

Kochhar, 1984. JGSI, 25, 155-161.
Vallinayagam, 2003. IJG, 18, 1-18.
Baskar and Sharma, 1994. CS, 66(1), 67-69.
Bhushan and Chittora, 1999. JGSI, 66, 741-763.
Kochhar, 1983. PINSA, 49 A, 459-490.

A-type granites from Khanak and Devsar areas of Bhiwani district, southwestern Haryana, India: A geochemical characteristics

Radhika Sharma*, Naresh Kumar
Department of Geology, Kurukshetra University, Kurukshetra 136119
** radhika8822@gmail.com*

In this paper, petrological and geochemical characteristics of the granitic rocks from the Khanak and Devsar areas have been discussed. Acidic rocks from Devsar and Khanak areas in Southwestern Haryana are part of Neoproterozoic Malani Igneous Suite (MIS) which covers an area of 55,000 sq. km in Northwestern Indian Shield. The MIS represents the largest acidic magmatism in India and owes its origin to hot spot tectonism (Kochhar, 1984; Bhushan, 1985; Vallinayagam, 2001). Neoproterozoic MIS (750±10 Ma) comprised peralkaline, metaluminous to mildly peralkaline and peraluminous granites in Siwana, Jalor, Tusham and Jhunjhunu respectively. The MIS predominantly consists of acidic volcanics with acidic plutonics (granite of various types), mafic volcanics, mafic intrusives and minor amount of pyroclasts (kochhar 1984, Singh and Vallinayagam, 2003). Khanak and Devsar area are located in Survey of India topographic sheet no H43V13 and H43W1; Scale 1:50,000; 75˚50′45″-75˚52′45″E, 28˚53′45″-28˚54′36″N and 76˚04′45″ - 76˚05′20″E, 28˚46′15″ - 28˚46′45″N in the Northwestern Peninsular India respectively.

These granites show various shades of colour viz. green, grey, and pink with biotite granites. They are essentially composed of k-feldspar, quartz, amphibole, plagioclase, biotite as essential

minerals and hematite, zircon, annite, monazite & rutile as accessory minerals. Petrographically, they show hypidiomorphic, granophyric and microgranophyric textures. Numerous dykes of fine grained grey microgranites cut the coarse grained green granites which indicate the last phase of igneous activity in Khanak area. Contact zone between two phases of granite porphyry and xenoliths in the host granite porphyries, incrustation of iron oxide are distinguished features in the Khanak and Devsar areas. Geochemically, they show enrichment in SiO_2 , Na_2O+K_2O, Fe/Mg, Rb, Zr, Sr, Y and depletion in MgO, CaO, P, Ti, Ni, Cr and V suggested about A-type affinities in Northwestern Peninsular India. Most of the granite samples lie in the field of peraluminous A-type granites. The high A/CNK ratio values range from 0.10 to 1.18 suggesting a peraluminous nature (corundum and anorthite normative; AI >1). Green and Grey granites of Devsar area show high concentrations of Heat production (HP) 9.68 & 11.70 μWm^{-3} and total Heat Generation Unit (HGU) i.e 23.04 & 27.86 respectively. On the other hand, pink granites of Khanak area display higher enrichment of HP (16.53 μWm^{-3}) and HGU (39.37) than those granites of Devsar area. Overall, they have much higher values of HP and HGU than the average value of continental crust (3.8 HGU), which imply a possible linear relationship among the surface heat flow and crustal heat generation in the rocks of MIS. From the petrography as well as chemistry of Khanak and Devsar granites, it is suggested that they might have formed from the similar source of magma.

Bhushan, S.K., 1985. Journal of Earth Sciences, 12, 58-71.
Kochhar, N., 1984. Journal of Geological Society of India, 25, 155-161.
Vallinayagam, G., 2001. The Indian Mineralogist, 35(1), 121-133.
Singh, A.K., Vallinayagam, G., 2003. Journal of Applied Geochemistry, 5, 16-25.

Petrography of Gokanakonda gabbro pluton, Prakasam alkaline province, Andhra Pradesh, India

T. Pulla Rao*, J. Ratnakar
Department of Geology, Osmania University, Hyderabad 500 007
***** *thodasapr87@gmail.com*

The Prakasam alkaline province (PAP) in Andhra Pradesh, southern India, is a Mesoproterozoic intra-plate igneous province formed in rifting environment east of the Cuddapah (taphrogeosynclinal) basin. PAP has experienced by three tectonothermal events marked by intrusion of (1) early basic igneous rocks (early basic magmatism), (2) Middle alkaline- to calc-alkaline rocks (alkaline- to calc-alkaline magmatism), and late basic rocks (late basic magmatism), implying cyclic magmatism. The *early basic magmatism* resulted in to emplacement of plutons of sub-alkaline gabbroic rocks; *middle alkaline magmatism* into alkali syenites and nepheline syenites, and *calc-alkaline magmatism* into syenites and A-type granites; and *late basic magmatism* resulted into lamprophyres, lamproites and basaltic-doleritic dykes. It is considered that the early basic magmatism has predated and also post-dated alkaline magmatism. The gabbro plutons are located at Gokanakonda, Boggulakonda, Settupalle, Purimetla, Pasupugallu, Chimakurthi and Kanigiri in the PAP. These plutons occur in a narrow structural zone (east of the Cuddapah basin) within the Precambrian amphibolites and granitic gneisses in rift zone and hence their emplacement is tectonically controlled. The PAP has experienced four episodes of folding; the F3 fold axis trending NNE-SSW coincides with the orientation of the gabbro plutons. The present study is on Gokanakonda gabbro pluton (GGP) in the PAP. The GGP is closely associated with younger ferrosyenites in the field.

The *Gokanakonda gabbro pluton* (GGP) is a NNE-SSW extending linear body occupying an area of around 10 sq km. The contacts between the GGP and country rocks are sharp. Absence of chilled margins around the pluton indicates preheated nature of the country rocks. GGP is devoid of xenoliths of country rocks suggesting permissive emplacement in the crust at mesozonal or katazonal region. The chief rock types of the pluton are olivine gabbro, norite, anorthosite, leucogabbro and melagabbro that are mutually gradational in field and form a continuous series. The gabbroic rocks range from leucocratic (colour index, CI < 30) through mesocratic (C. I. = 30-60) to melanocratic (C. I. > 60) and are medium to coarse grained. Under the microscope they exhibit ophitic to subophitic, cumulate to hypidiomorphic textures. Olivine, plagioclase, clinopyroxene and orthopyroxene are essential minerals, and they are present in varying proportions to define the *rock series* mentioned above. Amphibole and biotite occur in minor amounts; opaques, apatite and sphene are the common accessory minerals. *Olivine* (3-69% by vol.) is frequent, subhedral and occasionally coronal with rim-sequence, from olivine to plagioclase, as [olivine-(orthopyroxene-amphibole)-plagioclase] and/or [olivine-orthopyroxene-(amphibole-symplectite)-plagioclase]. *Plagioclase* (10-91%) is mostly unzoned, clouded and turbid in melanocratic and mesocratic gabbroids and infrequently zoned in a few leucocratic varieties. Anorthite content of plagioclase ranges from An_{40-55}: zoned plagioclase crystals have $An_{\sim 70}$ (at the core) to $An_{\sim 50}$ (at rim). *Clinopyroxene* (1-64%) is either colourless or moderately pleochroic in green to yellowish purple. The optically determined composition varies from diopside through augite to titanaugite. Diallage partings and exsolution lamellae are rare in clinopyroxene. *Orthopyroxene* (0-30%), when present, is feebly pleochroic from pink to light green. Secondary green or greenish brown *amphibole* (ferrohastingsite) and reddish brown *biotite* are present. The former occurs as rim around olivine and the latter as anhedral grains closely associated with clinopyroxene. Based on the field relationships between different rock types it is tentatively suggested that the rocks of Gokanakonda pluton are formed in the following sequence: *melagabbro → anorthosite → troctolite → norite → leucogabbro → olivine gabbro.*

Petrographic inferences on eastern Dharwar craton: a case study of granitic rocks of Madugulapalli, Nalgonda district, Telangana, India

J. Nagamma*, J. Ratnakar
Department of Geology, University College of Science, Osmania Univeristy, Hyderabad 500007
**j.nagamma@gmail.com*

Granitoids, gneisses, greenstone belts, schist belts, amphibolites and the Proterozoic sedimentary rocks compose the Precambrian basement complex of Eastern Dharwar Craton (EDC) in southern India. The age of the granitoid group, in particular, ranges between ~2900 and ~2600 Ma. This paper deals with the rock types of EDC around Madugulapalli (Tipparthi Mandal) in the Nalgonda District of Telangana State, southern India. The *EDC around Madugulapalli*, located 100 km SE of Hyderabad, consists of granitic rocks which are frequently massive, occasionally foliated and rarely gneissic. They are leucocratic, grey, and coarse- to medium grained, They frequently carry xenoliths of mafic rocks which are usually foliated. The chief rock-forming minerals of the rocks are orthoclase perthite, quartz, plagioclase (oligoclase-andesine-labradorite), clinopyroxene (augite), green amphibole (hastingsite) and biotite. Accessory minerals include apatite, sphene, zircon and opaques. The rocks of the Madugulapalli area are classified (IUGS systematics) into granite, quartz syenite, alkali-feldspar quartz syenite, quartz monzodiorite, quartz diorite and gabbro. Quartz syenite is the most abundant rock type in the area. Presence of plagioclase in addition to orthoclase in these rocks suggests subsolvus conditions of crystallization. The *mafic enclaves* are melanocratic,

coarse- to medium-grained and occasionally glittery in the field. The enclaves consist of biotite, amphibole, plagioclase and quartz in that order of abundance. They are classified as biotite-hornblende schist which is the oldest rock type in the study area.

Petrographic evidences reveal that the Madugulapalli rocks are formed in the following sequence (*early to late*): biotite hornblende schist (pre-existing?) → gabbro → quartz diorite → quartz monzodiorite → alkali-feldspar quartz syenite → quartz syenite → granite. Mineralogy and phase relations in the rocks of Madugulapalli strongly suggest that *(a)* mafic rocks represent silica-oversaturated part of the '*basalt tetrahedron*', *(b)* granitic rocks represent silica-oversaturated part of the *Petrogeny's residua system* (Or-Ab-Qz) under *subsolvus* conditions, *(c)* liquids parental to the rocks of Madugulapalli are hydrous, and *(d)* phase relations in the Or-Ab-Qz system are under high P_{H2O} and high fO_2 and their compositions approximate to those of the *thermal minimum* of Or-Ab-Qz.

Intergrowth textures and their possible origin in the Koheda pink granite, east of Hyderabad city, India

Ch. Narshimha[1]*, K. Praveen[1], K.S.V. Subramanyam[2]
[1]Department of Applied Geochemistry, Osmania University, Hyderabad 500007
[2]Geochemistry Division, CSIR-NGRI, Hyderabad 500 007
**narsiou@hotmail.com*

A porphyry pink granite has been cropped out to the east of the Hyderabad city, near Koheda village. It occupies 3 sq.km area which surrounded by grey granite. The granite body consists of course grained phenocrysts of feldspars (7cm length X 3cm width) with micro fractures. Quartz veins, small factures are common. The granite hosts for felsic enclaves (aplitic) which are angular in shape and varies up to 150cm X 60cm in dimensions. In the southern side of the body, magmatic lineation and foliation of mafic minerals are profusely seen, especially at the contacts with grey granite. Aplitic (70 cm width), pegmatitic and quartz veins are common. The porphyry granite is holocrystalline, coarse grained essentially consists of quartz, K-feldspar, plagioclase and perthites with accessory phases of biotite, fluorite, amphiboles, sphene, zircon and other opaque minerals. Various types of intergrowth textures are observed. Among these Intergrowth textures, myrmekite, perthite and micrographic are most common. Quartz is anhedral, fine-coarse in grain size whereas fine grains are due to devitrification. Alignment of fine grained recrystallized quartz as an interstitial phase along the boundaries of phenocrysts show granulation characteristics. Quartz is also observed with undulose extinction and quenched into phenocrysts of perthite, orthoclase, and fluorite. Clusters of mafic minerals including amphiboles (alkali?), biotite and opaques are abundantly wide spread. The presence of large sized fluorite is conspicuously seen with quartz inclusions.

Most K-feldspars are euhedral and show characteristic microcline twinning with solid state deformation features. Simultaneous growth of granophyric textures such as myrmekitic and micrographic are observed along phenocrysts of plagioclase and alkali feldspars respectively due to solid state reaction. Perthites occur as strings, vein and microcline perthites. All these types exsolved in solid-state conditions. The process of crystallization does not necessarily cease when the magma becomes solid as long as temperature is high enough, recrystallization and both chemical and textural re-equilibration takes place (Winter, 2010). In the present study feldspars that crystalized in magma are alkaline in nature which show mixtures of exsolved K-rich and Na- rich phases, later perthites formed due to replacement process in autometamorphic condition.

Putnis, A., 2002. Mineralogical Magazine, 66(5), 689-708.
Vernon, R. H., 2004. A Practical Guide to Rock Microstructures. Cambridge University Press, Cambridge. 594.
Winter J.D., 2010. Principles of Igneous and Metamorphic Petrology 2nd edition, Prentice Hall, pp 34-43.

Geochemistry of the lower Vindhyan Black Shales: Implications for source, depositional environment, weathering conditions and atmospheric oxygen evolution

Jivesh Kandpal*, Sunil Kumar Singh
Physical Research Laboratory, Navrangpura, Ahmedabad 380009
** jiveshkandpal@gmail.com*

The Vindhyan sedimentary sequences archive important information pertaining to evolution of life on the Earth and atmospheric oxygen during the Proterozoic. Extracting these valuable information from these sedimentary sequences requires their precise chronology. Providing a precise chronology of sedimentary rocks, however, is a difficult proposition. An effort is being made to provide authentic age of these sequences by dating black shales using Re-Os systematics. In one such study, Re-Os systematic provided an age of ~1200 Ma of Vijaygarh black shales of Upper Vindhyan. In this study, we plan to date the black shales of the Lower Vindhyan. Further, an attempt is being made to characterize them by major and trace element geochemistry to constrain their sources and depositional environment. Towards this, a suit of 18 fresh samples of black shales was collected from Banjari and Dala limestone mines. Major element compositions of these samples were determined using XRF. Al_2O_3 and SiO_2 vary from 8 to 16 wt% and 42 to 77 wt % respectively. Some of them contain significant amount of carbonate in them. Total Fe displays a range of 0.7 to 4.5 wt% in them. Major element composition of these shales indicates granite/granodiorite as their sources, however, isotopic studies are required to confirm the same. Plot of SiO_2% vs K_2O/Na_2O of these shales indicate their deposition in the passive settings. Re-Os chronology of these shales will be determined in near future to provide depositional ages of black shales from Lower Vindhyan and will be further interpreted to track atmospheric oxygen evolution during the Proterozoic era.

Geochemical characterization of Archean mafic volcanics from Amgaon greenstone belt of western Bastar craton, central India: evidence of oceanic crustal remnants

Biswajit Hazarika[1]*, D.B. Malpe[1], A.N. Dongare[2]
[1]P.G. Department of Geology, RTM Nagpur University, Nagpur-440001
[2]Department of Geology, Government Institute of Science
** mail4biswa20@yahoo.com*

The Bastar craton constituted central part of peninsular India. It mostly comprises of supracrustal rocks including greenstone belts, tonalite-trondhjemite-granodiorite (TTG) and intrusive granitic plutons. Amgaon greenstone belt is one of the greenstone belts exposed in the craton. It is situated in the western part of the craton and predominantly composed of orthoamphibolites (metabasalts) occurring as restite blocks and remnants within tonalitic orthogneisses of Amgaon Gneissic Complex (AGC). The study of these rocks is very important to understand the formation and spatial growth history of the craton through geologic time. The study of

mafic volcanics plays a significant role in understanding the nature of mantle sources and tectonic environment of their emplacement.

The mafic rocks of the present study are characterised as low K tholeiites having iron enriched trend. They are metamorphosed to amphibolite facies during the Amgaon orogenic phase under closed system of metamorphism. The smooth crystallization trend in MgO variation diagrams diminishes the possibility of elemental mobilization during metamorphism. The relatively unfractionated nature of these volcanics highlighted by Mg>51 and flat REE pattern (La_N/Sm_N~1) with absence of Eu anomaly (Eu/Eu*=0.89) in chondrite normalized diagram suggest their evolution from depleted mantle source. Low values of Ni and Cr with no Eu anomalies may suggests that the basaltic melts have undergone olivine and plagioclase fractionation prior to emplacement. The absence of P and Ti negative anomaly with La/Ta <22, La/Nb <1.5, Nb/U >40, Th/Nb <1 values suggest insignificant role of continental crustal processes in the petrogenetic evolution of these basaltic melts (Ilnicki, 2012). The less variation in SiO_2 <50 wt% values may be due to their oceanic nature and absence of assimilation or contamination with silicic continental crust. Abundance of large ion lithophile elements (LILE) in primitive mantle normalised spidergrams may also be the effect of sea water alteration. High concentration of TiO_2 >1.5 wt% with Al_2O_3/TiO_2 and CaO/TiO_2 ratios less than chondritic values (20 and 17 respectively) is a common phenomena for mid oceanic ridge basalts (MORB). La/Nd < 1.4 also discriminant these tholeiites from those erupted on arc related setting. Low K tholeiites are dominant counterpart of Archean greenstones whereas enrichment of Fe than modern MORB reflects their source from Archean mantle. The HREE abundance is slightly lower than the modern MORB which may be due to higher degree of partial melting of Archean mantle (Ohta et al., 1996). The other geochemical constituents and trends on different discriminant diagrams also putting constrains on its evolution under oceanic ridge related setting.

Ilnicki, S., 2012. International Journal of Earth Sciences 8, 523-548.
Ohta, H., Maruyama, S., Takahashi, E., Watanabe, Y., and Kato, Y., 1996. Lithos 37, 199-221.

Reaction micro-textures within mantle xenoliths from Kutch area, Gujarat: a possible role of melt-rock interaction

Soumi Chattopadhaya*, Debaditya Bandyopadhyay, Biswajit Ghosh
Department of geology, Ballygunge Science College, University of Calcutta, Kolkata 700019
**geo.soumi@gmail.*com

Mantle xenoliths are considered as window to the mantle. Xenoliths (peridotite fragment) and xenocrysts in Late Mesozoic Deccan Alkali basalts fromKutch area, Gujarat, western India provide us anopportunity to look into the Indian sub continental lithospheric mantle (SCLM). In the present study we report the occurrence of some reaction micro-textures within these mantle xenoliths, which can give us better insight into the processes associated with melt-rock interaction and itsimplication on Indian SCLM. The alkali basalt-hosted xenolithic fragments of this study are mostly unaltered, coarse-grained spinel lherzolites and wehrlitescomposed dominantlyof Cr-bearing diopsides, MgO-rich olivines and orthopyroxenes, and aluminous spinels. These xenoliths are classified as Type-I Group: Cr-Diopside lherzolite Group (Frey and Prinz, 1978; Wilshire and Shervais, 1975). Re-equilibration of the xenoliths is evident from features like diffusion zoning in olivine, reaction rim around orthopyroxene, presence of spongy (sieve textured) clinopyroxene and spinel. We link these features to the process of melt-rock interaction either in-situ or during their

transport up by the host alkali basalt. Detailed petrographic studies indicate bimodal distribution of olivine and clinopyroxene with distinct chemical composition. Within the reaction rim around orthopyroxenes these two mineral phases have different chemical composition than those occurring as primary grains elsewhere. These reaction rims might have formed by incongruent dissolution of orthopyroxenein presence of silica under-saturated host melt (Shaw and Dingwell, 2008). Compositional zoning within olivine grains is also documented at the contact with infiltrated melt. Sieve-textured clinopyroxenes and spinels are also compositionally zoned and mostly occurat the contact of dissolvingorthopyroxeneand melt. They commonly display clear cores retaining the primary chemistry and a spongy altered rim having worm shaped bubbles dominantly filled with very fine material of ambiguous composition. Detailed compositional line scanning across the sieve-textured clinopyroxenes and spinels provide clues to their origin. The boundary between the clear, unaffected cores and the spongy coronas outside them is marked by a distinct compositional discontinuity.The clinopyroxenecores retain their primary chemistry containing high Al_2O_3 and Na_2O value whereas the spongy rims are depleted to these and enriched in TiO_2, similar to spinel grains. The spinel cores have low Ti, Fe and high Al representing the original mantle signature than the spongyrimswith higher Ti, Fe and lower Al. Bivariate CaO vs. Na_2O plotting of clinopyroxeneshows that the composition of the spongy rim is similar to that of the newly formed grains occurring at the margin of orthopyroxenes. Comparison of the compositions of the inclusion-free cores and sieve-textured rims shows that the sieved rims have chemical signatures consistent with melt rock interaction (Shaw and Dingwell, 2008).

Frey, F.A. and Prinz, M., 1978. Earth and Planetary Science Letters, 38, 129-176.
Wilshire, H.G. and Shervais, J.W., 1975. Physics and Chemistry of the Earth, 9, 257-272.
Shaw CSJ, Dingwell DB (2008) Contribution to Mineralogy Petrology, 155, 199-214.

Geochemical investigations of intrabasaltic palaeosols (bole beds) from the Deccan Traps of Koynanagar area (Maharashtra, India): proxy for deducing palaeoclimatic conditions during Deccan Volcanism

S. J. Sayyed*, M. R. G. Sayyed, S. M. Hundekar
Department of Geology, Poona College, Camp, Pune 411001
**sabashirin007@gmail.com*

Geochemical studies for the intrabasaltic palaeosols (bole beds) preserved between the Deccan Trap lava flows, in the Koynanagar area of Maharashtra, India, were carried out in deducing the palaeoclimatic conditions during their formation. The major element oxides data obtained was compared with those of the modern soils and the associated basalts from three weathering profiles containing the bole beds to get the insights into the palaeoweathering and palaeoclimatic conditions that existed during the Deccan Volcanic activity. The red boles in all the three profiles show lower values of Bases/Al_2O_3 and high SiO_2/Al_2O_3 compared to the modern soils indicating selective leaching of bases in the red boles under moderate rainfall conditions as indicated by the Mean Annual Precipitation Values (MAP= 800mm to 1200mm) and well drained conditions as suggested by gleization ratio values which are less than unity. The lower values for Product Index in red boles suggest leaching of silica in slightly alkaline medium as compared to modern soils. The CIA values indicate higher chemical weathering in red boles than in modern soils. However, the higher values of CIA in lower basalt than in red boles indicate that the red boles have escaped further weathering after they were preserved by the overlying basalt while the parent lower basalt continued to weather after

their exposure in Holocene. The lower values of WPI and higher values of PWI in red boles than modern soils indicate appreciable loss of mobile cations in red boles which is also supported by higher hydrolysis resulting in an enrichment of Al_2O_3. It is to be noted that the red boles were formed under higher temperatures and comparatively lower precipitation than the modern soils. Higher calcification and salinization in modern soils indicate somewhat more evaporative and poorly drained conditions which is also supported by higher value of gleization (more than unity) for the modern soils. Higher values of ISR in red boles indicate their formation in oxidizing environment while higher values of clayeyness, gleization and organic matter in modern soils indicate their formation in poorly drained conditions involving slight accumulation of organic matter. Higher ratio of original mafic minerals to original felsic components (M/F ratio) in red boles indicates the removal of felsic component in alkaline conditions. The lower values of M/F in modern soils suggest more retention of original felsic component and selective dissolution of mafic component in acidic fluids. The above observation is in complete agreement to the pH values obtained (for red bole 7.14 to 7.53 and for modern soils 6.78 to 7.05) which indicate prevalence of slightly alkaline medium during formation of red boles and acidic medium during formation of modern soils. The higher values of EC and organic matter in modern soils as compared to red boles indicate higher organic activity in the presence of dissolved nutrients in modern soils but negligible organic activity in red boles due to scanty nutrients. A-CN-K plots indicate the weathering trends towards smectite formation, both in red boles and modern soils, while none of them show any lateritization effect but reaching only kaolinization stage. To summarize the bole beds were formed by intensive weathering under humid, fairly leached and well-drained conditions with moderate rainfall.

Rare earth elements partitioning between carbonatite and silicates at high pressures: Applications to REE in the carbonatites

Jiten Pattnaik*, Sujoy Ghosh
Department of Geology and Geophysics, IIT Kharagpur, Kharagpur 721302
**28jiten@iitkgp.ac.in; 28jiten@gmail.com*

Carbonatites contain the highest concentration of rare earth elements (REEs) of any igneous rock and can be strongly enriched in heat producing elements (U, Th). Carbonatites also contain basic minerals which contain REEs, e.g. bastnäsite, parisite, synchysite, monazite, xenotime (Chakhmouradian & Wall, 2012). Carbonatites are formed by low-degree of partial melting of carbonated perdotite or eclogite by liquid immiscibility which separates from silicate melts and by fractional crystallization from a CO_2-rich silicate melt (Mitchell, 2009). There are several known occurrences of carbonatites in India, e.g. Ambadungar (Gujarat), Chhota Udaipur (Gujarat), Kamthai (Rajasthan), Newania complex (Rajasthan), Sung valley (Meghalaya) (Srivastava 1997; Srivastava & Sinha, 2004). However, partitioning of the REEs between the peridotite and carbonatitic melts is lacking at 50-150 km depths where initial melting takes place. We will perform experiments in the carbonatite-silicate systems in order to understand the partitioning behaviour of REE in Indian carbonatites and peridotite minerals at upper mantle pressures (0.5-3GPa). Starting materials will have different compositions which are close to calcio-carbonatite, magnesio-carbonatite, ferro-carbonatite from India. These compositions will be prepared from reagent grade $CaCO_3$, Na_2CO_3, MgO, SiO_2, FeO, TiO_2, Al_2O_3 and natural magnesite ($MgCO_3$) and siderite ($FeCO_3$). These carbonatites compositions will be mixed in 50:50 ratio with synthetic KLB-1 peridotite which is close to pyrolite composition REE will be added from a mixture of 17 elements (Ce, Dy, Er, Eu, Gd,

Ho, La, Lu, Nd, Pr, Pm, Sc, Sm, Tb, Tm, Y, Yb) prepared from oxides and carbonates. Experiments will be performed in noble metal capsules ($AuAu_{80}Pd_{20}$ Or graphite). Major oxides of the run products in minerals and quenched melt will be analyzed in polished sections by wavelength-dispersive spectrometry (WDS) using the electron microprobe (EPMA) and trace element concentrations in glass/quenched carbonatitic melts and minerals will be determined by LA-ICP-MS in IIT Kharagpur. The experiments will be performed in anhydrous and hydrous phase to get a broad relationship of pressure, miscibility gap width between silicates and carbonatitic melt of the different samples synthesized. REEs define a linear trend in partition coefficient vs ionic potential and the degree of fractionation increases with width of miscibility gap. The high partition coefficient for the REE in water bearing polymerized systems indicate that water rich carbonatites from more evolved alkaline igneous complexes are more prone to form REE deposits than dry ones (Martin et al., 2013). Based on our new results, we will derive better estimates of bulk partition coefficients between peridotite and carbonatitic melt for a range of REEs, U and Th.

Chakhmouradian, A. R., Wall, F., 2012. Elements, 8(5), 333-340.
Mitchell, R.H., 2005. Canadian Mineralogist 43(6):2049-2068.
Srivastava, R.K., Sinha, A.K., 2004. Mineralogy and Petrology, 80, 241-263

Mineral carbonation reaction and thermodynamic modelling for CO_2 sequestration in tholeiitic basalt of the eastern Deccan volcanic province, India

Amit Kumar, Nishi Rani, J. P. Shrivastava*
Department of Geology, University of Delhi, Delhi
**jpshrivastava.du@gmail.com*

The Deccan volcanic province (1.5×10^6 km^2) is one of the largest igneous provinces in the world. It records a vast accumulation of basalt containing primary minerals rich in divalent Ca, Mg, and Fe cations, which are suitable for CO_2 sequestration. However, limited studies have been carried out on this aspect (Rani et al., 2013). In this study, we attempted to perform carbonation reaction experiments and to model primary minerals with CO_2 and water to understand the apposite CO_2 pressure, temperature and time parameters. Basalt specimens and water, when allowed to react at high pCO_2 and temperature conditions in a laboratory time framework, reveal the appearance of neo-formed calcite, aragonite, magnesite and siderite. These specimens also contain significant amounts of smectite, chlorite and smectite/chlorite mixed-layer clays. Such mineral species are produced by the carbonation of basalt under water-saturated, hydrothermal-like conditions, causing significant changes in the pH of the aqueous solutions. We found that the formation of these minerals largely depends upon the pCO_2, temperature and duration of the experiments. The rates of the dissolution of plagioclase, pyroxene and magnetite and the formation of calcite, dolomite, magnesite and siderite indicate that the former chiefly depends on the temperature, while the latter depends on both temperature and pressure. The extent of the carbonation reaction increases with the rise in pCO_2. The present experimental results largely correspond with those obtained from carbonation reaction modelling. In addition, the dissolution mechanisms for primary silicates and the formation of carbonates are explained in terms of the progress, enthalpy, entropy, specific heat capacity and equilibrium constant of the reactions.

Rani Nishi, Pathak Vamdev, Shrivastava J. P., 2013. Procedia, 7, 806-809.

Forearc magmatism near the eastern flank of the Indian plate: evidence from geochemistry of mafic intrusive rocks of the central part of Nagaland-Manipur ophiolite, northeast India

S. Khogenkumar*, A. Krishnakanta Singh
Wadia Institute of Himalayan Geology, Dehra Dun 248001
** Khogen.wihg@gmail.com*

The Nagaland-Manipur ophiolite (NMO) tectonically sandwiched between India-Myanmar continental blocks is geologically one of the least explored regions of the Tethyan ophiolite belt.Such ancient oceanic lithosphere preserved as ophiolite could be generated at diverse tectonic settings; in a mid-oceanic ridge (MOR), supra-subduction zone (SSZ) or within plate environment (Dilek and Furnes, 2011; Saccani, 2015). However, which among these tectonic processes was/were actually responsible to generate the NMO prior to obduction on land is still a debatable question. This paper brings a new insight on the ongoing debate over genesis of NMO based on whole rock and mineral chemistry. Petrological, Geochemical and mineralogical data indicate that mafic intrusive rocks of the central part of NMO can be categorised as hornblende-free (type-I) and hornblende-bearing (type-II) mafic rocks. Type-I is consisted by massive gabbro and dikeshaving moderate TiO_2 (0.72 - 1.93 wt.%) content, show flat REE patterns (La_N/Yb_N = 0.76-1.51) which is purely analogous to tholeiitic N-MORB composition formed at extensional regime. Type-II mafic intrusives are hornblende bearing gabbros of low TiO_2 content (0.54 wt.% to 0.86 wt.%) and depleted LREE pattern (La_N/Yb_N = 0.37-0.49) with respect to HREE which is equivalent to tholeiitic SSZ-type magma composition. They also have high Ba/Zr (1.13-2.82), Ba/Nb (45.56-151.66) and Ba/Th (84.58-744.19) and U/Th ratios (0.37-0.67) relative to the primitive mantle. Such high ratios of large ion

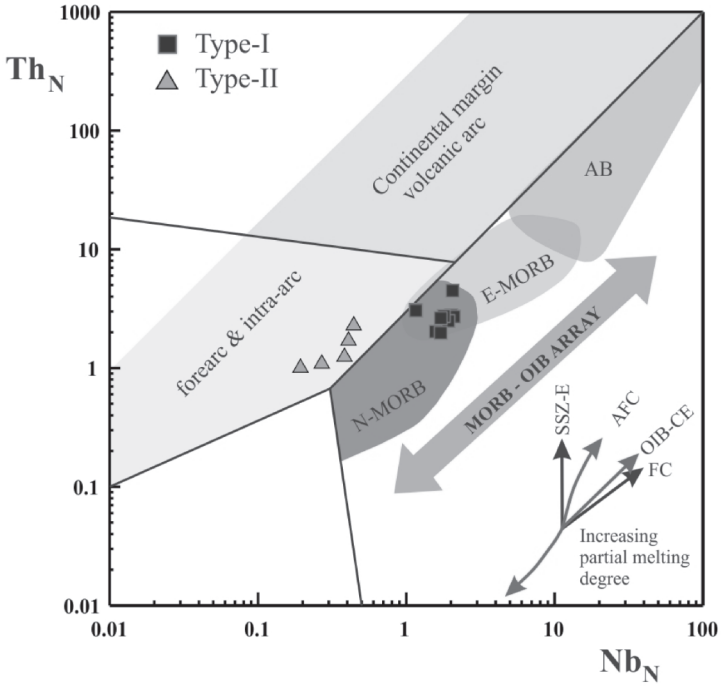


Fig. 1. Tectonic interpretation of the investigated rock samples from the NMO, based on Th_N vs. Nb_N systematic (after Saccani, 2015).

lithophile elements (LILE) are also indicative of SSZ magmatism. Their subduction related origin is further supported by presence of calcium-rich plagioclase ($An_{16.6-32.3}$) andhydrous hornblende mineral. It is likely that hornblende free N-MORB type mafic intrusive rocks (type-I) from the NMO is genetically related to the basalts of the same ophiolite section which were formed at spreading axis developed with the onset of separation of Indian-Australian plates (Khogenkumar et al., 2016). Whereas, the hornblende-bearing mafic intrusive (type-II) rocks of NMO represent the magma composition generated due to partial melting of depleted mantle wedge whose solidus temperature was descended by hydrous fluid released from thesubducting oceanic slab during the initial stage of subduction of Indian plate beneath the Myanmar plate at the forearc region. So, we conclude that the mafic intrusive rocks from the NMO were formed in two separate tectonic environments and different magmatic sources.

Dilek, Y., Furnes, H., 2011. Geol. Soc. Am. Bull., 123, 387-411.
Khogenkumar, et al., 2016. Journal of Asian Earth Sciences, 116, 42-58.
Saccani, E., 2015. Geosci. Front., 6, 481-501.

Geochemistry of Shyok sediments: Implication to weathering and erosion

Nikita Parmar*, S. K. Rai, N. Suresh
Wadia Institute of Himalayan Geology, Dehra Dun 248001
**nikita@wihg.res.in*

Denudation of continental rocks under varying climatic set up is one of the basic process which transforms the geomorphology of earth surface in course of time. Therefore, by studying the nature and intensities of weathering and erosion can be linked with the pattern of climate on basin wide scale. Shyok River in Ladakh region of trans-Himalaya is a major tributary of Indus river system. It is glacial-fed Perennial River and originates from the Rimo glacier which flows between Ladakh and Karakoram region. It has major streams as its tributaries namely Nubra and Tangste. The region of Ladakh and Karakoram is considered to be a rain shadow zone with respect to the Indian summer monsoon. The climate varies from entirely arid to semi-arid and has landscapes evolved accordingly though various time scale. Further, western disturbances provide major precipitation in form of snow during winter months of October-April whereas the remaining is sourced by the invasion of summer monsoon from south. This basin is characterized with cold arid climate, having an annual precipitation of ~250 mm. These studies have been useful to infer about weathering intensity by calculating the modified chemical Index of alteration CIA* (Colin et al., 1999). We found that most of the values are lying between end member litho units through which the river flows. Further sediments are relatively weathered as compared to surrounding rocks and not much transported in the basin. The river flows though Pangong range in the east where lithology laterally varies along the river course as Ladakh batholith, Khardung volcanics and Saltoro range and in the north as Karakoram Range. The average value of CIA* for 55 sediments collected from the basin is 69±2. This indicates that the basin experienced moderate weathering. Three samples collected from the downstream of the confluence of Nubra and Shyok river in the Shyok valley display an average CIA* value 74±2, indicating enhanced weathering intensity. Further studies are in program which will convert CIA* in to CIA by estimating inorganic carbon of the sediments. In addition, isotopic study such as Sr, Nd will also be used to the provenance of the sediments whereas Lithium isotope in the water samples will conclude silicate weathering the Shyok river basin. Thus these studies will resolve questions regarding the paleoclimate, weathering and erosion in the basin and reconstruct the landscape evolution.

Two dimensional geoelctrical structure of central Ganga basin along the Hamirpur - Rupadia profile

L. Adilakshmi*, A. Manglik, M. Suresh, S. Thiagarajan
CSIR- National Geophysical Research Institute, Uppal Road, Hyderabad 500007
**lakshmigeo2008@gmail.com*

The Ganga basin, formed due to the flexure of the Indian plate, contains thick sediments especially in its northern part. Hydrocarbon exploration activities have provided some details of the basin architecture and intrabasinal lithology. However, the nature of the underlying Indian plate is largely unknown despite its important role in influencing the Himalayan tectonics. We have acquired MT data at average station spacing of 6 - 8 km along a 285 km long profile across the central Ganga basin to delineate the crustal structure of the Indian plate in this part of the basin. The profile starts from the northern part of the Bundhelkhand craton (Hamirpur) and ends at the Nepal border (Rupadia). The MT time series were processed to estimate impedance tensors in the period range of 0.001 - 1000 s. These datasets were decomposed into TE and TM modes and jointly inverted along with the Hz data to obtain a geoelectric model of the crustal structure. The results reveal significant contrast in the subsurface structure of the northern and the southern segments of the profile. In the southern segment, the model yields a highly resistive structure which is broken into three blocks. The southernmost block correlates with the Bundelkhand massif and extends down to about 150 km while the remaining two blocks are of smaller dimension and buried under the sediments. Based on these results, we infer that the continental lithosphere of the Bundhelkhand craton is at least 150 km thick, which is contrary to some previous results suggesting thin lithosphere for the Indian shield. In the northern segment of the profile, we obtained a thick electrically conductivity structure around Bahraich. Thus, our results suggest that the crustal architecture of the Indian plate in the central Ganga basin is highly heterogeneous.

Seismic anisotropy beneath NW Himalaya using SKS and SKKS splitting measurements

Shubhasmita Biswal[1]*, Sushil Kumar[2], M. Ravi Kumar[3], William Kumar Mohanty[1], Mahesh Prasad Parija[2]
[1]Indian Institute of Technology Kharagpur, Kharagpur
[2]Wadia Institute of Himalayan Geology, Dehra Dun248001
[3]CSIR-NGRI, Hyderabad
**susmitabiswal123@gmail.com*

Seventy six teleseismic earthquakes comprising of both SKS and SKKS were analysed for the NW Himalaya to infer the characteristics of the shear wave splitting parameters in the region. The anisotropy results obtained from the analysis shows upper mantle anisotropy in the study area with the fast axis aligned along a NNE-SSW direction and the average delay times observed at the station ranges from a minimum of 0.3s to a maximum of 1.7s for SKS and SKKS phases. These splitting results obtained for the this area shows a parallel trend with motion of the India plate as estimated from NUVEL 1A model in contradiction to the orthogonal E-W trend observed for the NE Himalaya observed at the collision front. The seismic anisotropy observed in this region demarcates a shallow source of anisotropy that may be due to the strain flow in the upper mantle which may be the causative source of the anisotropy in the region.

InSAR Technique in post-earthquake surface deformation studies for Bhuj and the expected neotectonic activity

Baral, S.S.[1,*], Das, J.[2], Saraf, A.K.[1], Singh, G.[1], Borgohain, S.[1]
[1]*Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee 247667*
[2]*Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee*
**suman.baral86@gmail.com*

On 26 January 2001 the central Kutch region of Gujarat, India experienced a severe earthquake, which was measured to be of M7.7 on Richer scale. The earthquake lead to huge loss of life, infrastructure and ground deformation as well, in most parts of the earthquake affected region. The rupture of a hidden reverse fault was the cause of this unwanted devastating tectonic activity. As per the activity is concerned, the post-earthquake period is also vital as during this period the crustal layer undergoes relaxation to maintain a stress equilibrium. In this decade considering the efficiency of Sar Interferometry a pair of Envisat dataset have been chosen for the study of post-earthquake ground settlement from the interferogram and deformation maps. A suitable data set with justified perpendicular base line distance of advanced synthetic aperture radar (ASAR) data, acquired through the Environmental Satellite (ENVISAT) satellite is obtained from the European Space Agency (ESA) is used and a positive deformation of 32 cm, 28 cm and 22 cm has been observed in and around Bhuj and Kujisar city.

Estimation of source parameters of the aftershock (M_w=6.7) of the Nepal earthquake

Sohan lal[1]*, Anand Joshi[1], Parveen Kumar[2]
[1]*Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee*
[2]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
**sohangeokuk@gmail.com*

Nepal and its surrounding region were shaking recently by a devastating earthquake on 25th April, 2015. This is the largest earthquake that has occurred in this region during past eight decades. This earthquake has generated some strong shallow focus aftershocks which have also shallow depth. After shocks play a major role in damage and also helpful in characterizing the rupture process of the main earthquake. The aftershock was recorded on strong motion stations located about 500 kms away from their epicenters. Records of accelerographs from these stations have been used to determine the source parameters of these aftershocks using grid search algorithm. Grid Search algorithm used to minimize the misfit error functions between the observed and theoretical spectra. The record is further used to obtain source displacement spectra. The source spectrum obtained from strong motion data is compared with theoretical source spectrum obtained from Brune's (1970) model for the horizontal components using grid search algorithm. The long term flat level and corner frequency from source displacement spectra are used to calculate stress drop, source radius and seismic moment of the earthquake.

Source depth estimation using extreme points of the scaled gravity field

Divyanshu Dwivedi*, Ashutosh Chamoli
Department of Earth Sciences, IIT Roorkee, Roorkee 247667
**dd16march@gmail.com*

Earth has a complex distribution of its physical properties like density, susceptibility, velocity, resistivity, etc. The potential field anomalies are defined using scaling law based on homogeneity law. Scaling behaviour is also grouped under two categories as monoscale and multiscale methods. In monoscale case, techniques are based on solving the Euler differential homogeneity equation and data are measured only at single level of measurement. In multiscale method data are measured at different altitudes by applying upward continuation of data. Depth from EXtreme Points (DEXP) method is a recent method based on the concept of multiscale method. Here scaling function which is a function of altitude is used to characterize the scaling behaviour of homogeneous field. It determines the depth to sources bodies like sphere, cylinder etc. The DEXP method allows estimates of depths of source by determining the extreme points of a 3D scaled field according to specific power law of altitude. The method is fast and stable because it takes advantage of regular behaviour of potential field data versus altitude. The stability of method is also checked by adding Gaussian noise to data. Due to this stability, DEXP method can apply to anomalies with rather low SNRs, and reduces the mutual interference effect. It also determines structural index (shape) of the source independently.

The method is tested on the synthetic gravity anomalies of sphere and horizontal cylinder. For these cases the estimated depths and structural index are close to assumed one. The technique can be used in thickness estimation of sub surface sources. The method is also applied to a gravity data along a profile in Jabera-Damoh region, Vindhyan basin, central India. The results give information about the depths of shallower sources and deeper crystalline basement. The results show that the shallow features represent high density material which is underlain by the combination of high and low density material of crystalline basement along both sides. The results on synthetic and real gravity data will be discussed to show the usefulness and applicability of methodology.

The Mw 6.7, 2016 Imphal earthquake: A case of continuing intra-plate deformation within the subducting slab in the Indo-Burman range

Revathy M. Parameswaran, Kusala Rajendran
Centre for Earth Sciences, Indian Institute of Science, Bangalore

Imphal earthquake, Mw 6.7, 2016, is one of the largest and instrumentally well-recorded seismic events to have occurred on the segment of the Indo-Burman plate boundary, where Indian and Eurasian plates converge in a roughly NE direction (~3-4 cm/yr). This segment of the plate boundary has not generated any great earthquakes in the recent history, but is noted for its complex intra-slab dextral deformation, arc-parallel compression, and slip-partitioning with the continental, strike-slip Sagaing fault. Previous studies have noted a mix of faulting styles and depth-distribution of earthquakes indicating the inherent complexities within this segment. Based on the teleseismic moment inversion of 88 P- and SH-waveforms of the 2016 earthquake from 70 global broadband seismic stations, this paper corroborates the continuing intra-slab dextral slip deformation. It is sourced at a depth of 55 km, where the dip of the slab changes to ~ 50° and shows a P-axis oriented in

the NNE-SSW direction, parallel to the arc. Our analysis of azimuths and plunges of P-axes of 214 earthquakes (M ⩾ 4.5, GCMT) in the Indo-Burman subduction zone is consistent with this trend. Previous studies have noted two distinct types of intra-plate earthquakes along this segment; shallower (25-75 km) events due to arc-parallel bending and the deeper ones (90-150 km) in response to slab pull. Inter-plate seismicity is almost absent and the potential for great earthquakes seems much lower compared to other parts of the eastern India plate boundary.

Evidences of nonlinear site response from earthquake records: A case study based on liquefiable and non-liquefiable sites from Kachchh, India

Thulasiraman Natarajan*, Kusala Rajendran
Centre for Earth sciences, Indian Institute of Science, Bangalore 560012
**thulasiraman@ceas.iisc.ernet.in*

Laboratory-based geotechnical tests have shown that the nonlinear behavior of soil is associated with reduction of shear strength and addition of dampening, which can affect the site response characteristics. During nonlinear behavior, a site violates the Hooke's law beyond a certain amount of input energy due to which permanent strain can occur. This manifests during large earthquakes in the form of soil liquefaction, a major cause for damage in many urban centres, as was observed during the Mw 7.6, 2001 Bhuj earthquake. We used weak and strong ground motions recorded at LIQ, a seismic station that was part of a temporary network, located within the coseismic liquefaction zone to quantify the nonlinear behavior. The station had recorded a large number of aftershocks and in our study we used 120 events with peak ground accelerations (PGA) ranging from 0.001-0.05 g. Using standard 1D site response techniques such as horizontal to vertical spectral ratios using S wave signals, we determined the predominant frequencies and their corresponding amplitudes. A station located on hardrock, considered as the reference station was used for comparison. Significant variations have been observed in the site responses of stations close to sites of liquefaction (PGA > 0.03 g). Notably, the predominant peak tends to shift towards low values (~0.4 Hz) and grow in amplitude. In contrast, for the hard rock sites responses for weak and strong motions remained comparable, showing the absence of nonlinear behavior. While the conventional Spectral analysis do not fully capture the nature of noises and the multiple range of frequencies of the recorded signals, signal enhancement using Hilbert Transformation is found to be more useful. Thus, decomposed intrinsic modal functions (IMFs) are able to highlight anomalous peaks in the S wave coda part and their spectrograms display a range of frequencies that are critical in assessing damage to the built environment. Our study demonstrates that analysis of multiple sets of data using diverse and powerful tools can help improve hazard assessment strategies.

Source mechanism of aftershocks of 2005 Kashmir earthquake

Debarchan Powali[1], Ajay Kumar[1], Camilla Penney[2], Supriyo Mitra[1]
[1]Department of Earth Sciences, IISER Kolkata, India
[2]Bullard Laboratories, Department of Earth Sciences, University of Cambridge, Cambridge, UK

The 8th October, 2005 Kashmir earthquake (Mw. 7.6) is one of the most important modern day earthquakes in the Himalaya to produce well reported surface rupture. This earthquake occurred in a region where it had long been expected. The epicenter of this earthquake lies North-West of

Muzaffarabad, Pakistan. The Global CMT solution reveals that main event occurred on an oblique thrust fault with strike, dip and rake of 334°, 40° and 123°, respectively. We studied the source mechanism of four aftershocks (Mw > 5.2) of this main event. We modelled the source mechanism of these aftershocks using moment tensor inversion of teleseismic P- and SH waveforms. The depths of these events lie between 3 and 6 km. The solution shows that all these aftershocks occurred on northeast-dipping oblique thrust faults with strike, dip and rake ranging between 305° and 330°, 35° and 60° and 80° and 100°, respectively. From their spatial distribution and focal mechanisms, it is evident that these aftershocks occurred on the mainshock fault.

Source parameters of the 25th April 2015 Gorkha (Nepal) earthquake and its aftershocks

Shashwat Kumar Singh[1], Ajay Kumar[1], Supriyo Mitra[1], Keith F. Priestley[2], Shankar Dayal[3]
[1] Department of Earth Sciences, Indian Institute of Science Education and Research, Kolkata, India
[2] Bullard Laboratories, Dept. of Earth Sciences, University of Cambridge, U.K.
[3] Bihar State Disaster Management Authority, Patna

The Gorkha earthquake of 2015 April 25 (Mw 7.8) occurred by thrust faulting on a ~ 150 km long and ~ 70 km wide, locked downdip segment of the MHT, causing the Himalaya to slip SSW over the Indian plate and was followed by major-to-moderate aftershocks. Back projection of teleseismic P-wave and inversion of teleseismic body waves provide constraints on the geometry and kinematics of the mainshock rupture and source mechanism of aftershocks. The mainshock initiated 80 km west of Kathmandu, close to the locking line on the MHT and propagated eastwards, along ~117° azimuth, for a duration of ~70 s, in multi-phase rupture. The mainshock has been modelled using four subevents, propagating from west-to-east. The first subevent occurred from 0-20 s, emanating high frequency, low amplitude energy and ruptured ~6^0 north dipping flat segment of the MHT with thrust motion. The second subevent occurred from 20-35 s and ruptured ~18^0 west dipping lateral ramp on the MHT in oblique thrust motion. The rupture velocity dropped marginally from 3.5 km s^{-1} to 3.2 km s^{-1}, as a result of updip propagation of the rupture. The third subevent occurred from 35-50 s and ruptured ~7^0 north dipping, eastward flat segment of the MHT with thrust motion. This subevent resulted in the largest amplitude arrivals at teleseismic distances and controlled the CMT mechanism. The fourth subevent occurred from 50-70 s and ruptured an oblique strike-slip fault at high angle to the MHT flat. This transfer of slip from the MHT to a transverse structure possibly arrested the eastward propagation of the mainshock. Stress build-up following the mainshock resulted in the largest aftershock (Mw 7.3) on 12 May. This occurred by thrust faulting on a shallow north dipping plane at the eastern edge of the mainshock fault. Source mechanism of aftershocks reveal flexural faulting on top of the downgoing Indian plate and normal faulting below the Tethyan Himalaya.

CODA-Q and its Frequency Dependence in the eastern Himalayan and Indo-Burman Plate Boundary System

Ajay Kumar, Supriyo Mitra
Department of Earth Sciences, Indian Institute of Science Education and Research, Kolkata

We use vertical component broadband waveform data for 305 local earthquakes (epicentral distance ≤ 350 km, $m_b \geq 3.5$) that occurred in NE India, Eastern Himalaya, Bengal Basin and in Indo-Burman ranges to estimate seismic attenuation parameter called CODA Q ($Qc_)$ and it's frequency dependence in the crust which is represented by parameter η. Q_c has been calculated for a range of central frequencies (1, 2, 3, 4, 5, 8, 10 and 12 Hz). These measurements then have been combined to estimate the frequency dependence of Q_c of the form $Q = Q_o f^{\eta}$. CODA Q value has been observed to range from ~80-360 with an average of ~ 156 +/- 29.301 and η ranging from ~ 0.85 - 1.45 with an average of 1.14 +/- 0.038. As CODA waves sample an ellipsoidal volume rather than a straight line path and Q_c measurements are averaged over that ellipsoidal volume, to produce lateral variation map of Q_c we use a back projection algorithm which works out a distribution of Q_c in the sampled region such that it's average is equal to the measured Q_c for a source receiver geometry and combining such measurements criss-crossing each other lateral variation map has been generated. We observe high Q_o (~160) in NE India with high frequency dependence, surrounded by low Qo regions including western and eastern part of Shillong plateau (~120) and lowest in Arunachal basin and Naga Hills (~80). We observe higher Q_o in comparison to northeast (~210 - 280) in Bengal basin due to underlying Indian oceanic crust and highest Q_o value in the region (~300 - 360), with high gradients in increase of Q_o east of IBCZ which we conclude as a result of subducted Indian oceanic crust with the highest frequency dependence in the entire region. This lateral variation pattern of CODA Q is same at all the central frequencies.

b-value characterization of the north-eastern region of India during 2001-2014

Santanu Manna*, Supriyo Mitra
Department of Earth Sciences, Indian Institute of Science Education and Research, Kolkata
**smsantanu@gmail.com*

We studied the frequency-magnitude relationship for earthquakes in the North-eastern (NE) region of India (Eastern Himalaya and Indo-Burman plate boundary system) using the Gutenberg-Richter relationship. In our analysis, we used earthquakes of magnitude $Mb \geq 4$, which occurred between 2001 and 2014 recorded by our temporary broadband deployments in NE India. We performed the same analysis for earthquakes obtained from global catalogues of ISC, to compare and contrast our results. The analysis is done as a two-step process first one is estimation of the moment magnitude *(M_w)* of the earthquake by fitting the P-wave source spectra, assuming a circular fault model; and second step is linear regression to the frequency distribution of earthquakes within given ranges of moment magnitude using the Gutenberg Richter relationship. The magnitude of completeness for the set of earthquakes used in our study was found to be $M_w = 4$. Accordingly, the range of earthquake magnitude was chosen to be in increments of 0.1 between M_w 4.0 and 6.5. We studied the b-value of earthquakes for both cumulative and interval range of

magnitude. Our estimated b-value in NE India for the entire dataset is 0:97 (cumulative) and 0:86 (interval) for the duration between 2001 and 2014, whereas the b-values for the whole Earth for the same period have been estimated to be 1.08±0.04 (cumulative) and 0.97±0.08 (interval). We observed a distinctive variation in the b-value for plate boundary and intra-plate earthquakes. We sub-divided NE India into three zones and estimated their b-values. These zones are (i) Eastern Himalaya (ii) Indo-Burman convergence zone and (iii) Shillong Plateau and Bengal Basin. We also explored possible relationship between cumulative b-value and interval b-value in NE India and a relation of stress drop and fault plane area of earthquake. The global average b-value is known to be ~1. b-value lower than the global average indicate that the cumulative energy released by earthquakes is lower than the accumulated energy through plate convergence. This can also be empirically related to stress accumulation in a region. Using this understanding, we infer that the intra-plate region of NE India and the Eastern Himalayan plate boundary are accumulating elastic strain to be released in future large earthquakes.

Imaging the Hales discontinuity beneath the eastern Dharwar Craton using Pwave receiver functions

Jashodhara Chaudhury, Ajay Kumar, Supriyo Mitra
Indian Institute of Science Education and Research Kolkata, Mohanpur 741246

The Hales discontinuity was first discovered by A. L. Hales using travel time observations from explosions in Lake Superior of North America. It was observed that the seismic P-wave velocity increased from ~8.05 to 8.45 km/sec between a depth of 80 and 90 km. It was suggested that this velocity increase is caused by the transition from spinel to garnet peridotite within the upper mantle and should be present underneath old cratonic regions with thick (>150 km) lithosphere. We image this discontinuity beneath the eastern Dharwar Craton (HYB) in south India using receiver function analysis. Receiver functions are time series computed from three component seismograms which show the relative response of Earth structure (mainly velocity discontinuities) beneath the receiver. Receiver function waveforms are a composite of P-to-S converted phases that reverberate in the structure beneath the seismograph site. We select the Hyderabad (HYB) station for imaging this discontinuity for two reasons. Firstly, the crustal structure beneath this station is simple and acts as a window for imaging the upper mantle. Secondly, this station has been operational for two decades and the data is available from the IRIS-Data Management Centre (DMC). Receiver functions computed with low pass filter at 1 Hz reveal a simple two layer crust (~33 km thick) followed by a positive arrival at ~10 s. We ascribe this phase to the Hales Discontinuity and jointly invert receiver functions with Rayleigh wave phase velocity data to constrain the depth and impedance contrast across this boundary. This boundary is modelled to be at a depth of ~98 km and has an S-wave velocity increase from 4.50 to 4.67 km/s beneath the eastern Dharwar Craton. Using this S-wave velocity model, we compute synthetic receiver functions corresponding to the observed data, which show a close match.

Extensive seismic anisotropy in the lower crust of Archean metamorphic terrain, south India inferred from ambient noise tomography

Ritima Das*, S. S. Rai
Indian Institute of Science Education & Research- Pune, Homi Bhabha Road, Pune 411008
** ritima08@gmail.com*

We use Rayleigh and Love wave empirical Green's function (EGF) recovered from the cross correlation of seismic ambient noise to study the spatial distribution of radial anisotropy in the southern India crust. The corresponding dispersion curves in the period 2 to 32 s are measured from ambient noise data recorded at 57 sites, and the strength of anisotropy computed from the discrepancy between shear velocities obtained from Rayleigh (V_{SV}) and Love (V_{SH}) at various depths down to 40 km. In the upper crust (up to a depth of 20 km) the region is characterized by anisotropy coefficient of -2 to +3% that could be explained largely due to the presence of fluid-filled open cracks. At deeper level (beyond 20 km), except for the Archean metamorphic terrain, most part of south India has anisotropy of up to 5%. This may be explained as due to varying percent of rocks with granulite composition. Beneath the Archean metamorphic terrain, the anisotropy is recorded up to 9% in the depth range of 20-40 km. This high anisotropy is unlikely to be the manifestation of any recent geodynamic process, considering that the region has low surface heat flow. Alternately, the observed strong anisotropy in the metamorphic belt of southern India crust could best be explained as due to the presence of micaceous minerals or amphiboles in the deep crust that are formed possibly during the evolution of granulite terrain at ~2.5 Ga.

Lithospheric deformation beneath the Dharwar craton: Evidence from upper mantle anisotropy

Utpal Saikia*, S. S. Rai
Earth and Climate Science Program, Indian Institute of Science & Education Research, Pune
** ngriutpal@gmnail.com*

Our study of the upper mantle anisotropy from west to east coast of Dharwar craton, reveals significant lateral variations in its magnitude and direction. The Dharwar craton consists of mainly Archean Western Dharwar craton (WDC) of age 2.7-3.0 Ga and Eastern Dharwar Craton (EDC) of age 2.5 Ga., Proterozoic Cuddapah basin and the passive continental margins along the west and east coast. We used high quality SKS and SKKS waveform from 172 teleseismic earthquakes recorded over an east-west trending 600 km long seismic array consisting of 38 broadband seismographs operated during April 2012 to February 2014. Along the profile, the fast polarization direction (φ) is consistently oriented to NW direction beneath WDC, while it is NE directed in the Cuddapah Basin (CB) and combined with Eastern Ghat (EG). In the EDC, it varies from N-30^{o} to N30^{o}. The delay time (Δt), varies significantly across the region, from 0.4 to 2.0 s with an average of ~1 s, close to the global average for continental shield. A two layer anisotropy model suggest complex scenario of anisotropy beneath the region. In the lower layer, it is aligned with absolute plate motion (APM) direction caused by asthenospheric flow, while the upper layer shows significant variation from west to east and correctable with the local geological features like shear zone, fault and continental rift. The source of anisotropy is confined to a depth of ~170 km estimated by non-overlapped parts of the Fresnel zone at stations with different splitting parameter and correlates with the lithospheric thickness. We conclude that fast polarization direction beneath

the WDC correlates with the strike of the regional shear zone while, the eastern part is greatly influenced by both present and past tectonic process.

Geotechnical characterization of soil of Ahmedabad for seismic hazard assessment

V.K. Dwivedi, V. Pancholi, S. Maibam, R. Ranjan, S. Kumar, R.K. Dubey, S. Chopra, B.K. Rastogi
Institute of Seismological Research, Raisan, Gandhinagar 382009
Indian School of Mines, Dhanbad

The Gujarat is the only state in India where all the four seismic zones, II to V, are assigned to different areas as per Bureau of Indian Standard. The Kachchh area of Gujarat is prone to great earthquakes whereas Saurashtra and mainland regions are prone to large to moderate earthquakes. The cities of Gujarat are located in various geological formations which vary from Proterozoic to Quaternary. The cities located on thick quaternary sediments are prone to site effects during large earthquakes. Several multistory buildings got damaged and collapsed in the Ahmedabad city though these are located at a distance of 225 km from the epicenter of the 2001 Bhuj earthquake. The Ahmedabad city is in zone III where an intensity of VII or VIII can be expected due to large regional earthquakes or local earthquakes of magnitude 6 and above, which can damage single to multistory buildings. Thus, site characterization and seismic hazard mapping of the area is very important. It has been highlighted that there is a vital need for understanding geotechnical properties of soils of such regions to determine site effect. Around 16 boreholes were drilled in Ahmedabad city to characterize the soil. SPT-N values were calculated in the field whereas soil properties like grain size analysis, specific gravity, Atterberg's limit, density, void ratio, porosity, and shear parameters were studied from undisturbed sample in the laboratory. The 3D soil model has been prepared to get information about the sub-surface lithology. Liquefaction hazard analysis was carried out and factor of safety against liquefaction is determined for some locations with the help of index properties of soil.

Observation of atmospheric and ionospheric anomalies for the Nepal earthquake of 25th April 2015

C.P. Simha*, K.M. Rao, M.S.B.S. Prasad, R. Dumka
Institute of Seismological Research, Department of Science and Technology, Gandhinagar
**simha.prasanna@gmail.com*

Pre-earthquake atmospheric and ionospheric anomalies are still challenging, particularly for different earthquakes with variations in magnitudes, focal depths as well as focal mechanism. In this paper, the Lithosphere-Atmospheric-Ionospheric (LAI) disturbances related to the Nepal Earthquake (25th April 2015, M=7.8) are investigated using atmospheric and ionospheric parameters like Vertical Total Electron Content (VTEC) of IGS GPS station, Out Going Long Wave Radiation (OLR), Cloud Mask, Vertical Temperature Gradient and Aerosol Optical Depth from the KALPAN INSAT 3D data from the IMD. Statistical analysis of 6-days before and 5 days after the earthquake have shown significant enhancement in TEC before this earthquake at 89% confidence level. The coupling of high amounts of energy from earthquake breeding zones of higher magnitude and shallower focal depth enhance the anomalous patterns in TEC. The Single Spectral Analysis (SSA)

has been performed using the MATLAB coding for the ionospheric and atmospheric parameters; detailed synthesis of 3rd Principal Component Analysis (3rd PCA) has also been computed among the other outputs of SSA within the interval of 24hrs for span of 12 days with reference to the event. TEC varied from 10TECU to 40TECU with standard deviation of 0.2, raise of 60% of its 3rd PCA signal were observed 2 days before the earthquake. OLR has varied from 240 to 340 Watts/m^2 with standard deviation of 0.8, raise of 55% of its 3rd PCA signal 4 days were observed before the event. Cloud Mask has varied from 1 to 7 with standard deviation of 0.6, raise of 40 % of its 3rd PCA signal 4 days were observed before the event. Vertical Temperature Gradient has varied from 4.3 to 23.2^{0}K with standard deviation of 0.8, raise of 44% of its 3rd PCA signal 2 days were observed before the event. Aerosol optical Depth has varied from 0.2 to 1 with standard deviation of 0.9, 48% of 3rd PCA signal 3days before the event.

Density modelling of the Kachchh basin, Gujarat using EGM 2008 gravity data

Nawneet Kumar*, Selam V. Rao, Avinash K. Chouhan, K. M. Rao
Institute of Seismological Research, Gandhinagar
**kumarnawneet87@gmail.com*

The Kachchh basin occupies the entire district of Kachchh in Gujarat state of the western margin of India and is one of the important Pericratonic Mesozoic-Tertiary sedimentary basins of India. The Earth Gravitational Model EGM2008 has been publicly released by the National Geo spatial-Intelligence Agency (NGA) EGM Development Team, which provides the Bouguer gravity anomaly data (satellite data) anywhere in the world. We collected the EGM data for Kachchh region and imported to Geosoft software. We applied all corrections and prepared Bouguer anomaly map. We observed high Bouguer Gravity values of 40 mGal and 32 mGal at Rann of Kachchh and Dholavira, respectively. Similarly, we also observed low Bouguer gravity value of -12 mGal, in the Samkhiyali area. Our observations are similar to the previous published results of gravity studies using a number of field measurements. Our observations with satellite gravity data are well correlated with in situ measurements and further validate the EGM 2008 data for Kachchh region. In order to study the lineaments, horizontal gradient of the Bouguer anomaly is calculated in north-south direction which is perpendicular to the major faults in the study area. The horizontal gradient is found to be high along the faults. The detailed analysis and modeling of EGM data is under way and we may expect to get good results and would be able to mark faults and crustal structure in this area.

A review on Probabilistic Seismic Hazard Assessment (PSHA) in the Himalayan seismic belt (HSB)

Rajiv Kumar
Department of Geophysics, Kurukshetra University, Kurukshetra 136119

The Himalayan seismic belt (HSB) is one of the most active and hazardous regions in the world and capable to generate earthquake of magnitude 8 and 7 in near future. A number of researchers have attempted to study the Probabilistic Seismic Hazard Assessment (PSHA) in this region. Basu and Nigam (1977) prepared probabilistic seismic zonation maps in terms of peak

ground acceleration (PGA) for a return period of 100 years. Khattri et al. (1984) divided India in 24 source zones and prepared hazard maps in terms of PGA for 10% probability of exceedance in 50 years and obtained maximum PGA of 0.70 g in HSB. Bhatia et.al (1999) carried out a probabilistic seismic hazard analysis under the Global Seismic Hazard Assessment Program (GSHAP) framework over India and its adjoining region for 10% probability of exceedance in 50 years and obtained maximum PGA 0.35 g in HSB. Sharma et al. (2006) performed seismic hazard analysis in northeast India for 10% probability of exceedance in 50 years and obtained maximum value of PGA 0.50 g in HSB. Iyanger et al. (2010) prepared a report on seismic hazard analysis over India for 2% and 10% probability of exceedance in 50 years and obtained maximum PGA around 0.55 g and 0.35 g, respectively in HSB. Mahajan et al. (2010) carried out seismic hazard analysis in the NW Himalaya and its adjoining areas for 10% probability of exceedance in 10 years and 50 years and obtained maximum PGA around 0.35 g and 0.70 g, respectively in HSB. Sharma et al. (2011) studied PSHA in the Dehradun (Uttrakhand) region for 20% probability of exceedance in 50 years and obtained maximum PGA around 0.21g in the region. Nath and Thingbaijam (2012) prepared a detail probabilistic seismic hazard maps for India for 2% and 10% probability of exceedance in 50 years and obtained maximum PGA 1.93 g and 0.94 g in HSB is respectively, which are quite high than the previous studies. Recently, Thapa and Wang (2013) prepared a seismic hazard map for the Nepal for 2% and 10% probability of exceedance in 50 years and obtained maximum PGA around 1.07 g and 0.67 g, respectively. The previous studies were based on the past earthquake history and time-independent recurrence (Poisson) model using zonation approach and, therefore, there is urgent need to assess PSHA in HSB using contribution of faults-source and time-dependent recurrence models (e.g. BPT model) using both zonation and zone-free approaches.

Crustal structure beneath Jammu & Kashmir Himalaya

Swati Sharma[1], Debarchan Powali[2], Supriyo Mitra[2], Sunil K Wanchoo[1], Keith F. Priestley[3]

[1]School of Physics, Shri Mata Vaishno Devi University, Katra-182320, J&K, India

[2]Dept. of Earth Sciences, Indian Institute of Science Education Research Kolkata, Kolkata, India

[3]Bullard Labs, Dept. of Earth Sciences, University of Cambridge, UK

Kashmir is one of the seismic gaps in Himalayan belt and is lacking structural map. GPS studies in the region suggest locked decollement of ~ 200 km width which is currently seismically active. This work includes the inferences of Moho-depth in J&K Himalayas. The data has been recorded in continuous mode since 2013 at 20 different stations spread over Siwaliks, Lesser Himalaya, and Higher Himalaya and in the Kashmir valley as well. We have used teleseismic recordings of the 11 stations (AKNR, NGRT, SMVD, SUND, TAPN UDHM, RAMN TRUM, BADR, WANI, and PHAG) for the present study. All the data for events greater than magnitude 5.0 are analysed using Receiver Function technique, widely accepted for structural studies to calculate the structural constrains. H-K stacks were calculated to translate time information into possible depth (H) Poisson ratio (K) values. Waveforms were synthesized by forward modeling for possible H-K values certaining depth values. The stacked radial receiver functions were then jointly inverted with dispersion data-set for velocity structures. The results conclude Moho depth varying from 40 km to 54 km and velocity ratio varying from 1.68 to 1.85 along various stations distanced at 15-30 km on an average.

Accessing attenuation on spectra of microearthquakes in Kopili region, NER, India

Nilutpal Borah[1]*, Rajib Biswas[1], Dipok K. Bora[2]
[1]Geophysical Lab, Department of Physics, Tezpur University, Tezpur-784032, Assam
[2]Deaprtment of Physics, Diphu Government College, Karbi Anglong-782462, Assam
**nbora1608@gmail.com*

We examine microearthquake spectra of Kopili and its surroundings. We infer the attenuation prevailing in this region. By adopting spectral ratio method, we evaluate Q_p and Q_s for six stations. The study reveals an average estimate of Q_p and Q_s to be ~481and 966, respectively. Major part of the study region is found to be characterized by Q_s/Q_p greater than one. All these estimations are found to be well substantiated by site geology.

Seismotectonics and fault mechanism of Kishtwar region of northwest Himalaya

Shveta Puri*, G. M. Bhat, Shiv Jyoti S. Pandey, Neha Raina
P.G. Department of Geology, University of Jammu, Jammu 180006
**shvetapuri91@gmail.com*

Two moderate earthquake of Mw 5.7 of 1st May (06:57 UTC) and Mw 5.1 0f 2nd August (21:37 UTC) occurred in the Kishtwar region of Jammu & Kashmir in the year 2013. These earthquakes occurred between the Northwest of 1905 Kangra earthquake (Mw 7.8) and Southeast of 2005 Kashmir earthquake (Mw 7.6). Due to entire network of Broadband Seismographs in J&K, these events with their aftershocks were well recorded. The activity starts from March and continued up to November 2013. We conducted a study to locate and depict the sense of movement for these events along with their largest aftershocks and their triggered events. The 1st May event was followed by 81 aftershocks with magnitude ranges from Mw 2.3 to Mw 4.6 and 2nd August event was followed by 42 aftershocks with magnitude ranges from Mw 2.2 to Mw 4.2. Analysing the aftershocks of these events, the source parameters are estimated and interpreted to provide fresh constraint on the elements of seismotectonic model. The stress drop for Mw 5.7 was 71.1 bars and for Mw 2.2 was 2.20 bars. The low stress drop of small magnitude event reveals the brittle nature of the upper crust and high strain accumulation. The travel time inversion and wave form inversion method suggest focal depth up to 10 km. Fault plane solution of the aftershock (Mw 4.2, 09:19:46 UTC) of the main event of 1st May suggested that the source fault is striking at 299° with dip of 340 and rake value of 83°. Another aftershock of (Mw 4.1, 00:30:08 UTC) occurred on 2nd May reveals the value of strike, dip and rake as 151°, 77°, 120° respectively. Then the triggered event of Mw 4.6 on 14th May (20:00:01 UTC) gives the strike value of 307 °, dip of 250 with rake of 90°. It was found that these events form intense clustering of small and moderate events in a narrow zone between Panjal Thrust and Kishtwar Window. Fault plane solution of the events and their aftershocks indicates thrust type of movement is occurring in this region.

Estimation of epicentre location and source parameters of local earthquakes of J&K: an evidence of Kishtwar 2013 earthquake

Shiv Jyoti Pandey*, G.M. Bhat, Shveta Puri, Neha Raina
P. G. Department of Geology, University of Jammu, Jammu 180006
**shivjyotipandey@yahoo.co.in*

In this study, the epicentral location and source parameters were investigated from 128 local earthquakes with two main events of 1st May 2013 of Mw 5.7 and 2nd August 2013 of Mw 5.1 of Kishtwar region with Moment Magnitude (Mw) ranges from Mw 3 to 5.7, Source radius (r) 0.21 to 3.5 km. stress drop ranges from 1.90 bars to 71.1 bars and Comer frequency ranges from 0.39-6.06 Hz. We observed most of them are bounded between 32.9° N - 333° N latitude arid 754° E - 76.1° E longitudes. These parameters were then used to determine the b-value of the region. The study is purely based on the analysis of the local events recorded by the local seismic observatories which were installed at the various sites in the different parts of the J&K state. These sites were located at vicinity of Faults and Thrusts which covers the areas of Jammu, Ban, Poonch and Doru. The b-value for this region was found to be 0.74 from these events and most of the events were lies within the depth of 10 km probably above the detachment depth of the Himalayan region. The source parameters were computed with the help of Seisan software following Brune's spectral model and b-value was calculated by the Entire Magnitude Range (EMR) method. The calculated b-value at 0.74 for the region suggesting the region is under high stress and there ¡s probability of occurrence for moderate to strong magnitude earthquake. Most of the earthquakes were located between the Panjal Thrust and the Kishtwar window.

Moment Tensor Inversion of M_L4.9, Chamoli earthquake of 20th June, 2011 and it's aftershocks in Garhwal Himalaya

Arun Prasath R[1]*, Ajay Paul[1], Sandeep Singh[2]
[1]*Wadia Institute of Himalayan Geology, Dehra Dun 248001*
[2]*Department of Earth Sciences, Indian Institute of Technology, Roorkee*
**devanthran@hotmail.com*

An earthquake of M_L4.9 occurred on 20th June, 2011 near Chamoli in Garhwal Himalaya, which lies in the Central Seismic Gap, where a future great earthquake is expected with 52% probability (Khattri, 1999).The above mentioned earthquake has been recorded by a seismic network consisting of 10 Broad-Band Seismographs (BBS) deployed in June/July, 2007(Paul and Sharma, 2011). The preliminary locations of this earthquake have been estimated by HYPOCENTER program (Lienert et al, 1986). This earthquake had been located with theepicentral locationof 30.535 N and 79.292 E at ~12 km hypocentral depth. This earthquake had been followed by 16 aftershocks with magnitudes of $1.3 < M_L > 3.1$ located around the epicentral region of the main shock with varying depths between 6 and 17 km. Full waveform inversion has been performed to solve the Moment Tensor (MT) solution of the main shock and major aftershock (M_L 3.1) using ISOLA (ISOLAted asperities), a FORTRAN program developed by Sokos and Zahradnik (2008). The FOCMEC program developed by Snoke (2003) had been used in order to use the available polarity readings of the recorded waveforms to obtain focal mechanisms of the aftershocks, which are much smaller in size, to perform the full waveform inversions. The body wave spectra have been analyzed to calculate the source parameters of the mainshock and major aftershock using Brune's circular model (Brune, 1970).The micro-seismicity and recent-past moderate earthquakes (M_b 6.3 of 1991 and M_b 5.3 of

2005) of chamoli region have thrust fault mechanism (Kayal, 2003), suggesting compression tectonic regime, while the present study based on MT inversion and FOCMEC shows extensional mechanism (Normal fault with low dip angle) with centroid depth of 14 km for the M_L 4.9 chamoli earthquake of 20th June, 2011. Hence, it's needed to understand more about the local structures like Alaknanda fault. The Alaknanda fault is said to be merging with the detachment (Main Himalayan Thrust, MHT) at deeper levels ~ 15 km and few N-S trending normal faults are also reported earlier in this region south of Main Central Thrust (Kayal, 2003).Considering the epicentral location, depth and faulting mechanism of this earthquake, one of these local faults and MHT or the reactivation between these structures could be the factors for the occurrence of this earthquake. Hence, the seismicity of this region needs to be understood in terms of the relative roles of the local, regional and conjugate faults and this kind of studies should incorporate larger set of data.

Brune, J.N., 1970. Journal of Geophysical Research, 75(26), pp.4997-5009.
Kayal, J.R., Ram, S., Singh, O.P., Chakraborty, P.K. and Karunakar, G., 2003. Bulletin of the Seismological Society of America, 93(1), pp.109-117.
Khattri, K. N., 1999. Proceedings of Indian Academy of Sciences (Earth and Planetary Science) 108 (2) 87-92.
Lienert, B. R., Berg, E., Frazer, L. N., 1986. Bulletin of the Seismological Society of America 76 (3) 771-783.
Snoke, J. A., 2003. International Handbook of Earthquake and Engineering Seismology 1629-1630.
Sokos, E. N., and J. Zahradník (2008). Computers and Geosciences, 34, 967-977.
Paul, A. and Sharma, M.L., 2011. Journal of Asian Earth Sciences, 42(6), pp.1179-1186.

SWS measurements and source characteristics of local earthquakes in Garhwal region, northwest Himalaya

Rakesh Singh[1]*, Ajay Paul[1], Y.P. Sundriyal[2]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Department of Geology, HNB Garhwal University, Srinagar
** rakeshgosain@hotmail.com*

The region between the ruptured zones of the 1905 Kangra earthquake (M7.8) and 1934 Bihar-Nepal border earthquake (M8.1) has been termed as Central Seismic Gap (CSG) for a great earthquake in northwest Himalaya. Majority of events occur at shallow depths up to 20 km, and the maximum number of events occurs in the focal depth range between 5 and 15 km. The earthquakes in Garhwal region emanate from shallow depth coincides with the high conductivity zone (Rawat et al., 2014). Shear Wave Splitting (SWS) can be described in terms of two parameters: the fast polarization direction (ø) and the time lag between fast and slow shear waves (δt). The time delays observed between the slow and fast shear waves give information about the density of cracks in the medium. SWS measurements can be used to monitor stress levels in the earth and to map the network of the subsurface fractures. To delineate the network of these subsurface fractures, measurement of SWS parameters is being carried out by using MFAST technique (Savage et al., 2013). This is for the first time that this technique has been attempted in the Garhwal region to monitor the polarization and delay time.

To understand the upper crustal anisotropy of this region, shear wave splitting (SWS) measurements has been carried for local earthquakes of Chamoli region. The SWS measurements are computed for the events $M_L \geq 2.2$ magnitudes recorded at Ghuttu and Adibadri seismic stations in Garhwal region of Himalaya, between the periods Nov. 2014 to July 2015. During the analysis, a significant temporal variation in delay time has been observed at Ghuttu (GTU) station with respect to the moderate earthquake of magnitude M_L4.9 which occurred in the Chamoli region on 1st April,

2015 at 21:23:55 hrs (UTC). The preliminary observations of variation in SWS measurements at GTU station show the increase in delay time before the occurrence of the earthquake and it decreases gradually with time. The delay time in splintered S-wave shows the accumulated stress levels prevailing in the region. For source characteristics of the region, focal mechanisms and source parameters of the earthquakes have been also determined.

Rawat G, Arora B. R., and Gupta P. K., 2014. Tectonophysics 637: 68-79.
Wessel A., Savage M., and Teanby N., 2013. Manual for the Multiple Filter Automatic Splitting Technique (MFAST) processing codes, Version 2.0.

A preliminary one dimensional crustal velocity model for Himachal Pradesh, India

Mahesh Prasad Parija[1]*, Sushil Kumar[1], Shubhasmita Biswal[2], Narendra Kumar[1], Saurabh Kumar Mishra[3]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2]Indian Institute of Technology Kharagpur, Kharagpur
[3]University of Mysore, Mysore
**maheshparija@gmail.com*

A preliminary 1 D velocity model for Himachal Pradesh, India has been developed by utilizing the P and S-wave travel time data. A very steady and narrow velocity model was obtained with travel time inversion and a range of velocity models were tested with earthquake locations to derive the best-fit velocity model. The 1 D velocity model proposed for the study region has seven uniform layers with interfaces at depths of 0, 5, 10, 15, 20, 25 and 30 km with P-wave velocity of 5.219 km/s, 5.314 km/s, 5.391 km/s, 5.392 km/s, 5.964 km/s, 6.071 km/s, 6.073 km/s and S-wave velocity of 2.998 km/s, 3.015 km/s, 3.134 km/s, 3.135 km/s, 3.441 km/s, 3.482 km/s and 3.647 km/s respectively. According to the proposed model, the Moho in this part of the Himalaya lies at 60 km depth on an average. For P and S-waves the station correction ranges from -0.88 to 1.50 and -0.58 to 3.59 sec respectively. This low variation in station residuals indicates small lateral velocity changes that confirm the accuracy and stability of the proposed 1 D velocity model. Using the new derived 1 D velocity model the earthquake epicentres were relocated and we observe a shallow seismic activity in the region at < 30 km depth that clearly describes the ongoing convergence of the India-Eurasia plates in the study region. This study also infers a new highly active seismic window in the latitude range of 31.8°N to 32.8°N and longitude range of 76.8°E to 78.8°E in the study region across the Kaurik Chango fault, a causative fault for the 1975 Kinnaur earthquake.

Crustal structure beneath the Satluj valley, northwest Himalaya from receiver function analysis

Monika Wadhawan*, Devajit Hazarika, Arpita Paul, Naresh Kumar
Wadia Institute of Himalayan Geology, Dehra Dun 248001
**monika.geophysics@gmail.com*

The crustal configuration in the Satluj Valley region of Northwest Himalaya has been studied with the help of receiver function analysis of teleseismic waveform data recorded by a seismological

profile consisting of 19 broadband seismographs. This profile is unique that covers all the major geotectonic units of Satluj valley starting from Himalayan Frontal Thrust (HFT) to South Tibetan Detachment (STD). About 4500 receiver functions have been computed from ~250 teleseismic earthquake data recorded by 19 stations applying iterative deconvolution method. The data for this study were selected based on high signal to noise ratio, epicentral distance within the range of 30°-90° and body wave magnitude > 5.5. The modeling of RF at stations near HFT shows extremely low shear wave velocity (~0.7-1.2 km/s) in the upper most 3-4 km of the crust indicating the thickness of the sedimentary column of the Indo-Gangetic plains. The depth of Moho increases from ~46 km near HFT to about 60 km beneath Tethyan Himalaya (TH). The Main Himalayan Thrust inferred from RF data varies from ~15 km in the Sub-Himalaya to ~22 km in the Higher Himalaya with no crustal scale ramp within this segment of Himalayan Seismic Belt (HSB); whereas it increases from ~25 km near the STD up to ~40 km beneath the Tethyan Himalaya (TH). The H-K stacking algorithm was applied at some selected stations of the profile and average Poisson's ratio of the crust has been estimated. The Poisson's ratios are observed to be higher in the TH compared to the stations to the south of STD.

Crustal anisotropy in the trans-Himalaya (eastern Ladakh): constraints from splitting analysis of P to S converted phase at Moho discontinuity

Arpita Paul*, Devajit Hazarika
Wadia Institute of Himalayan Geology, Dehra Dun 248001
**paul.arpitageo@gmail.com*

The eastern Ladakh-Karakoram zone is the northwest part of the trans-Himalayan belt which bears signature of the India-Asia collision process in the form of suture zones and exhumed blocks that underwent deep subduction and intra-continental crustal scale fault zones. The crustal deformation owing to the collision and underthrusting is evident from geological studies. As the pervasive rock deformation can produce significant seismic anisotropy in the crust, we carried out splitting analysis of P-to-S converted phase (Ps) originated at Moho in order to gain insight into the deformation processes and its effect on seismic wave propagation. The Cross correlation method has been adopted for splitting analysis. The Ps phase is clearly observable in radial receiver functions of teleseismic earthquakes. Appearance of significant energy of Ps phase in transverse component suggests presence of anisotropy. Radial and transverse receiver functions have been computed from teleseismic earthquake data recorded by 10 broadband seismological stations deployed in eastern Ladakh-Karakoram zone during 2009-2012. The seismological profile covers significant geotectonic units e.g. Tso-Morari crystallines, Indus Suture Zone, Nidar Ophiolitic complex, Ladakh batholith and Karakoram Fault zone. We selected 158 pairs of radial and transverse receiver functions with high signal-to-noise ratio and unambiguous Moho converted Ps phases to measure the splitting owing to the crustal anisotropy.

The results obtained from shear wave splitting analysis reveals strong crustal anisotropy with delay time within the range 0.1-0.5 s and fast polarization direction oriented along NW-SE in most of the stations. The NW-SE orientation of FPD is roughly parallel to the strike of existing geological faults and the observed FPDs do not follow regional NE oriented stress field. This suggests that anisotropy is dominated by existing faults rather than the regional stress field.

Geomagnetic field variation associated with seismic activity in Garhwal Himalaya, India

Dhamodharan S.
Wadia Institute of Himalayan Geology, Dehra Dun 248001
dhamodharan@wihg.res.in

To establish the relationship between the Geomagnetic field and the earthquakes there have been studies for several decades. The geomagnetic data that have been recorded at multi-parametric geophysical observatory (MPGO) (30.53°N, 78.74°E) in Garhwal Himalaya region of Uttarakhand, India are analysed for the year of 2010. Adopting the methods polarization ratio, fractal dimension variability and principal component analysis the presence of seismo-magnetic disturbances superposed upon background geomagnetic variations are inferred. The disturbances in geomagnetic field have been studied in the background of local earthquakes within a zone of radius 150 km from observing station MPGO, Ghuttu. Fractal dimension variability indicates that average fractal dimension for first half of the year is increased as compared to average fractal dimension of in the second half of the year and there is gradual increase in the fractal dimension before earthquakes. Gradual increase in the fractal dimension before earthquakes, observed elsewhere in the world, is considered precursory signature of seismo-electromagnetic field emissions.

Crustal structure of Bhuj epicentral region, Gujarat using gravity data

Selam V. Rao, Avinash K Chouhan*, Nawneet Kumar, Pallabee Choudhury, K.M. Rao
Institute of Seismological Research, Gandhinagar
**akchouhan31@gmail.com*

Kachchh, a pericratonic and seismically active paleorift basin on the western margin of India is very important due to large occurrence of earthquakes and the presence of thick Mesozoic sediments. For the understanding of sedimentary thickness and crustal architecture, regional gravity survey has been done at 1 km station spacing using CG 5 autogravimeter. It is observed from Bouguer anomaly of the Kachchh basin that it spans from -10 to 35 mGal and has several high and low values. The high Bouguer anomaly in the Fatehgadh area (semi-circular in shape) and Pachham Island area indicates the presence of mafic intrusive (volcanic plug) in the subsurface. Keeping the constraint of seismological and well data, two and half dimensional density model of the Kachchh basin has been proposed. Following are the major features which has been delineated from the model: 1) Average Mesozoic sedimentary (of density-2.4 gm/cc) thickness is 2-3 km, 2) Presence of mafic intrusive (of density-2.8 gm/cc) found in the Fatehgadh area (below the Mesozoic sediments) and the Pachham Island area (at the depth of 400 meters), 3) Average crustal thickness is 38-45 km (44 km in the Wagad uplift area and 38 km in the Bhuj area), 4) Other layers which have been taken for the modelling are Granitic upper crust (of density-2.7 gm/cc), intermediate mid crust (of density 2.85 gm/cc), lower crust (of density- 2.9 gm/cc) and upper mantle (of density-3.3 gm/cc).

Landcover dynamics of a rainfed river basin in Bundelkhand region, (U.P), based on remote sensing and GIS

Tanzeel Khatoon[1]*, Akram Javed[1], Mohd. Aleem[2]
[1]Department of Geology, Aligarh Muslim University, Aligarh
[2]Geological Survey of India, Hyderabad
**tanzeelsiddiqui@outlook.com*

Landuse/cover is an important component that reflects the interaction between environment and human activities. Landuse/cover pattern is an outcome of natural and socio-economic factors and their utilization by man in space and time. The present study makes an attempt to monitor landcover dynamics in Shahzad river basin, a rainfed basin in Lalitpur district of U.P using remote sensing and GIS technique. Multi-temporal satellite data of IRS-1D LISS III and IRS-P6 LISS III of 1998 and 2005 has been analyzed based on visual interpretation technique. DEM was prepared using ASTER data and landuse/cover changes have been correlated with DEM/ elevation, which suggest that in Shahzad river basin major landuse/cover changes have been observed in southwest part where elevation range 330 to 415 m and represent gentle slope. The basin is mainly drained by Shahzad River and its tributaries. The drainage pattern is dendritic to sub-dendritic, the elevation ranges from 286 m to 502 m above MSL. The higher elevations are encountered in southern most parts of the basin whereas lower elevations are in the north. The slope is from south to north, as defined by the course of the Shahzad River. Two dams namely Govindsagar and Shahzad are built on Shahzad River, used for irrigation and drinking water supply. The major crops are wheat, barley, gram, maize, mustard etc. Mapping of IRS FCC data led to the identification of various landuse/cover categories viz. agricultural land, dense forest, open forest, open scrub, wasteland, stone quarry, water bodies, exposed rock, settlement and industrial land. Landuse/cover maps of 1998 and 2005 derived from satellite data were digitized in Arc GIS environment. Editing and topology building was carried out using Arc GIS 10 and area under each category of landuse/cover was computed in sq. km as well as in percentage. A comparison of 1998 and 2005 data analysis of the river basin suggests that the area under water body has decreased from 41.11 Km^2 in 1998 to 19.53 Km^2 in 2005, i.e. 21.58 Km^2 (1.96%), area under agricultural land has decreased from 444.04 Km^2 (40.36%) in 1998 to 429.52 Km^2 (39.04%) in 2005, showing 14.52 Km^2 (1.32%) decrease. Area under open forest and dense forest has reduced by 5.67 Km^2 (0.52%) and 1.16 Km^2 (0.11%) respectively during 1998-2005. Open scrub, stone quarry, built-up land, exposed rock and wasteland have also reported change in their respective areas. Open scrub has increased from 344.33 Km^2 (31.30%) to 376.16 Km^2 (34.16%), whereas stone quarry has increased from 0.55 km^2 (0.05%) to 4.75 Km^2 (0.43%), which suggests that quarrying activity has increased.

Assessment of groundwater potential zone using the GIS/Remote sensing data in Shahpur taluk, Karnataka, India

M. Thirumurugan , S. Manoj, L. Elango*
Department of Geology, Anna University, Chennai 25
**elango@annauniv.edu*

Groundwater is considered as one of the important natural resources for drinking, and agricultural purposes, which gets widely contaminated due to several geologic and anthropogenic

activities. Now-a-days the demand for groundwater is rapidly increasing due to agriculutal activity and demographic growth. Hence, the present study was carried out to assess the groundwater potential zones with the help of Geopraphic Information System and Remote Sensing techniques. This study was carried out in the uranium mineralized zone of Shahpur taluk, Karnataka, India. The region predominantly comprises sedimentary, granitic and gneissic rocks. Numerous lineaments due to fractures and faults in this area act as groundwater flow paths and also are indicators for groundwater resource. In order to represent the likelihood of existence of groundwater, the remote sensing and Geographic Information System were used to develop maps of rainfall pattern, lithology, recharge, lineament density, drainage density, slope, depth to groundwater level and groundwater quality. Further, the groundwater quality suitability map was overlayed with the groundwater potential map to identify the groundwater potential zones. The results shows the significant information to locate the groundwater potential zones can be used for groundwater exploration in future.

Geospatial techniques for curbing energy requirements

Deepak Kumar*, Sulochana Shekhar
School of Earth Sciences, Central University of Karnataka, Aland Road, Kadaganchi 585367
**deepakdeo2003@gmail.com*

Alternative sources of energy are being sought in the world today, as the availability of fossil fuels and other non-renewable resources are declining. Solar energy offers an encouraging solution to this search as it is a green energy resource and can easily be converted into electricity with the usage of photovoltaic systems. It is one of the clean, pollution free and renewable energy resources. The portion of the planet earth lying between the latitude of 40°N and 40°S is normally identified as the solar belt with an abundant amount of solar radiation. The measurement of solar radiation for renewable energy and other applications is a time-consuming and expensive operation. But measurement of broadband and spectral terrestrial solar radiation is important for the evaluation and deployment of any kind of solar renewable energy systems. The satellite based techniques (especially geospatial technology) have become an important segment used for assessment and deployment of solar renewable energy systems, demanding close attention to issues related to functionality, sustainability and usability. Whilst some research has begun to examine the functionality and assessment of solar systems but little attention has been paid. Usually global solar radiation during monsoon is less compared to summer and winter because of the dense cloud cover. The study identifies the parts of Kalaburagi city in Karnataka state having higher global solar radiation ideally suited for harvesting solar energy. ArcGIS version 10.x or greater with the Spatial Analysis extension with Solar Analyst module calculates Watt-Hours/meter^2 at the surface at the local scale. Inputs to this process are a digital elevation model, the latitude of the scene center, and the date and time where we wish to accumulate insolation. We can specify a portion of a day, or a range of days such as a week or month.

The current study provides the outline towards the application of geospatial techniques for assessing the amount of solar insolation available at a particular place, which can be well replicated into other parts of the country to explore potential of renewable energy.

Geomorphic characterization and diversity of interfluve river Vel - DEM base case study for watershed management

Sourav Mukhopadhyay
Department of Archaeology, Deccan College & PGRI, Pune 411006
iamsourav02@yahoo.in

Upland Western Maharashtra is drained by the Krishna and Godavari rivers and their tributaries. These rivers have their source from the Western Ghats and flow into the Bay of Bengal. The region is semi-arid (800-500 mm rainfall) due to its location on the leeward side of the Western Ghats. The major rivers therefore derive much of their discharge from the high rainfall source region (up to 6,000 mm), and bring water to the semi-arid zone downstream. The Vel River Basin displays a unique landscape setting. The focus of this study is on one such river, namely the Vel River, which is sandwiched between two larger river basins (Bhima and Ghod) and is losing its catchment area due to headward erosion by side tributaries of the Bhima and Ghod Rivers, minor river capture along the divide, and beheading. This study demonstrated that to identify and systematically evaluate the anomalous characteristics of the Vel River Basin and to ascertain the possible reasons for these anomalies.

Estimation of LST and NDVI of Pichavaram mangrove ecosystem using LANDSAT Data

Kripa M.K.[1], Ashwini M[1], T.V.R. Murthy[1], Archana U. Mankad[2]
[1] Space Applications Centre, ISRO, Ahmedabad 380015
[2] Department of Botany, University School of sciences, Gujarat University, Ahmedabad 380009

The Pichavaram mangrove forests, which is considered as the world's second largest mangrove forest area falls under the Coastal Ecological Sensitive Areas (ESA) and acts as a barrier during natural calamities like cyclones and tsunami. Extensive studies are going on worldwide to monitor mangrove ecosystems and to provide better means for its effective management and conservation. Remotely sensed data have been widely used in mapping, assessing and monitoring mangroves because, most of the major mangrove forests are swampy and inaccessible in terrain. Presently, environmental studies are being carried out globally by using air temperature and LST data to monitor the phenomena of surface energy and water balance, climate change and vegetation monitoring and thereby to understand the increase in the global temperature. This paper aims to quantify the relationship between the vegetation index- NDVI, and LST (Land surface temperature).NDVI derived from the remote sensing data is one of the widely and popularly used index to detect live green plant canopies, which is useful in monitoring the vegetation. Landsat satellite data acquired for this region for over two decades (from 1996 to 2014) were used. In this paper, it can be seen that the regressive analysis showed an inverse correlation relationship between LST and NDVI. According to the results obtained, NDVI and LST, can be used in understanding the status of mangrove with increase and decrease of temperature.

Integrated study of GIS technique and Electrical Resistivity Tomography (ERT) to evaluate groundwater prospects in the lower Mahanadi basin

P. Nayak*, A. K. Rai, S. Tripathy
Indian Institute of Technology Bhubaneswar, Bhubaneswar 751007
**pn11@iitbbs.ac*

Evaluating groundwater prospects is necessary for resource management in a region. In this study, an integrated analysis of GIS technique and electrical imaging was used to understand groundwater potential. The study area is the lower Mahanadi basin located in the eastern part of Odisha. An adequate supply of water is one of the prime concerns in this region. The south eastern part is of lower elevated land with sedimentary deposit while north western part is of hard rock terrain with elevation upto ~290 m. This varying elevated topography and metamorphic litho units do not favour groundwater availability in the north western part of the region. Various types of Laterite, Khondalite, Charnockite and Granite gneiss are the major rock types found in the north western part while south-eastern part is a coastal plain of quartenary deposit. GIS analysis of various parameter such as geomorphology, lithology, lineament, topography, soil type and drainage pattern, helped to prepare respective thematic layers. All these layers were assigned weights and were integrated by weighted overlay analysis technique to identify prospective groundwater zones. The results obtained by GIS analysis helped us in site selection for multi electrode resistivity survey. Ten high resolution 2D electrical resistivity profiles, of lengths 2x210 m, and electrode spacing of 10 m, were carried out at different locations. Resistivity images of depths up to ~70 m helped us to identify potential groundwater formations in respective locations.

From GIS analysis technique, it was found that (Fig. 1a) ~42% of the total area has relatively high potential whereas 21% area has relatively less prospects for a sustainable groundwater source. ~37% area of the region was found to be moderate potential. Results from resistivity imaging (Fig. 1b) further supports the GIS result. It was found that the elevated north-western part of the region is lack of saturated fracture zones while the south-eastern part profiles indicates the availability of adequate groundwater though these are not sufficient for long run purpose. Bore well drilled at a location found very little quantity of groundwater within 75m depth. But a saturated fracture zone was found at a depth of 130m with 5 lps yielding capacity. Therefore further investigation is needed for deep aquifer prospecting in the region.

Loke, M.H., Barker, R.D., 1996. Geophysical Prospecting, 44, 131-152.
Madrucci, V., Taioli, F., Arau´jo, C.C., 2008. Journal of Hydrology, 357, 153-173.
Ravindran, A.A., Mondal, N.C., Ramanujam, N., Srinivasamoorthy, K., 2015. Water Resources Management, 1, 137-154.

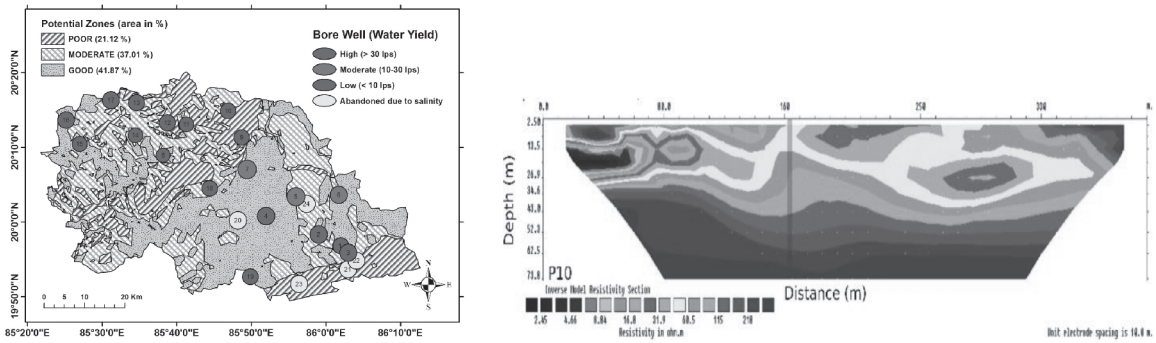


Fig. 1. (a) Potential groundwater zone of the region (b) Resistivity profile showing bore well location.

Development of a GIS based relative Flood Potential Index (FPI), implications on some Himalayan Rivers

S. Borgohain[1]*, J. Das[2], A.K. Saraf [1], G. Singh[1], S.S. Baral[1], K. Sharma[1]
[1]Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee
[2]Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee
**susantaborgohain@gmail.com*

Flood is the most common natural disaster in India. Flooding occurs when extreme volume of water is directed by the rivers during heavy rainfall in monsoon into areas where the water cannot be drained adequately. Numerous severe flood events in Ganga-Brahmaputra plain have occurred in the past. River basin configuration, sediment load, vegetation, land-use, channel slope, channel volume are the major controlling factors. Database representing these factors have been used and analyzed to make a channel based FPI. Historical flood events have been used to compare the resulting index. Some frequently flooding rivers like Koshi and Jiadhal in Northern and NE India, respectively, have been analyzed with this index. It is found that basin configuration of the Koshi River is very prone to floods. Sediment load, channel volume and channel slope of the river have increased the potential of flood in some regions to many fold. Similarly, the Jiadhal River basin also shows very high potential for flood. Moreover, channels of Jiadhal and Koshi rivers over Himalayan foothills are in an elevated condition, which may avulse in future flood event.

Hypsometric analysis of Mohand anticline, Uttarakhand, India using geospatial technologies

G. Singh[1]*, J. Das[2], A. K. Saraf[1], S. Borgohain[1], S.S. Baral[1], K. Sharma[1]
[1]Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee
[2]Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee
**iitr.gauravsingh@gmail.com*

Hypsometric analysis explains the segmentation of horizontal cross sectional area of a river with respect to elevation. Morphology of a river plays a major role in the study of tectonic activities. Aim of this paper is to carry out the Hypsometric analysis of Mohand Anticline, Dehradun District, Uttarakhand using Digital Elevation Model (DEM). Remote sensing and GIS are the best tools for such analysis. Hypsometric curves were derived and analyzed for each of the river basins over the Mohand anticline from 30 meter ASTER GDEM. It has been observed that some river basins over the anticline have been subjected to tectonic disturbances relative to others. This paper helps in mapping of faults and lineaments in the Himalayan Region.

GIS based analysis of suitability of groundwater for irrigation purposes in Hisar district, Haryana, India

Reeta Rani*, B.S. Chaudhary**
Department of Geophysics, Kurukshetra University, Kurukshetra
**reetakuk23@gmail.com; **bsgeokuk@gmail.com*

Groundwater quality plays a dominant role in determining its usage for irrigation and drinking purposes. To understand its variations both in time and space is one of the important pre-requisite for any natural resource planning of the area. The present study deals with the monitoring of

spatial variations in groundwater quality in Hisar district, Haryana for irrigation purpose over a period of 1998-2010. Hisar district, a part of the Indo-Gangetic alluvial plain is situated between 28°53'45" to 29°49'15" N latitudes and 75°13'15" to 76°18'15" E longitudes. It occupies an area of 3788 sq km and is bordered on the east by Rohtak district, on the west by Fatehabad district & Rajasthan state, on the south by Bhiwani district and on the north by Jind district. Hisar district comprises of three major physiographic units i.e. Aeolian plain, Older alluvial plain and Chautang flood plain. The area represents dry land topography and has constraints related to groundwater usage due to quality issues. Water samples of 87 observation wells for premonsoon period were analyzed for physio-chemical parameters like Electrical Conductivity (EC), Sodium Absorption Ratio (SAR), Total dissolved solids (TDS), Percentage Sodium (PS) and Residual Sodium Carbonate (RSC) using standard techniques of analysis and compared with USSL standards for irrigational suitability for the period 1998-2010. GIS spatial interpolation technique has been used for preparing water quality maps of different parameters. The study demonstrates that the EC of groundwater ranges from 1450-10350 and 1090-12350 μs/cm during the study period. Range of TDS is from 240-6500 and 378-7900 mg/l for the study area. The water quality based on EC and TDS for agricultural use falls under moderate to unsuitable categories. 18% area in northern and eastern part of district had moderate water quality and 55% area had doubtful and 27% area in NW & SW had unsuitable level of salinity. From the analysis of SAR, groundwater in district had low to medium (0.6-26 & 0.4-11.8) alkaline hazard during the study period. Range of PS is from 2.3-77.5 & 0.8-64% for the period. It shows that groundwater in district was of good to doubtful quality. The RSC of study area ranged from 1.0 -5.2 meq/ l for period 1990 -2010 in premonsoon season. It is observed that for most of groundwater quality parameters, the values are good to moderately suitable for irrigation purpose. Groundwater quality maps can be used as a guide for future developments in the study area to minimize the adverse impact due to its use.

Landuse/ Landcover mapping of K-J watershed using remote sensing and Geographical Information System

Sanjeev Kumar*, B S Chaudhary**
Department of Geophysics, Kurukshetra University, Kurukshetra
sanju.sanjeev.k@gmail.com,bsgeokuk@gmail.com*

Landuse/ Landcover **(**LU/LC) change detection study plays a vital role in global environmental change research. The present study is an attempt to analyze the changes in LU/LC pattern in K-J Watershed which covers an area of about 134 km2 in districts Solan (Himachal Pradesh) and Panchkula (Haryana) and bounded by 31°0' to 30°45' east longitudes and 76°45' to 77°15' north latitudes. LU/LC mapping of K-J Watershed has been carried out by using Geographical Information system and Remote sensing technology. Remote Sensing data (Landsat 7 ETM+, Oct. 1999 & Feb. 2000 and Landsat 8, Oct. 2015 & Feb. 2016) have been used for the mapping and monitoring of Land use/ Land cover in the area. Global positioning system and topographical maps of scale 1:50,000 have been used for ground verification. The classification approach being used is a hybrid of unsupervised, supervised and on screen digitization. The comparison of LU/LC in 1999-2000 and 2015-2016 has been derived from toposheets and satellite imagery by using online visual image interpretation technique. In this study, LU/LC classification has been done under Level-3 classification and the main categories are Water body, Settlement, Open-Sparse built-up, Industry, Vegetation, Fallow land, Dense forest, Open forest and Scrub forest. Major Change is detected in area under category built-up which has increased from 7.17 to 25.61 sq kms over the study period from

1999 to 2000. The area under forest has decreased from 114.43 to 101.08 sq kms and agricultural land from 12.61 to 7.51 sq kms respectively over the study period. It is observed that there is a significant increase of 18.44 sq kms in built-up area. This indicates that substantial amount of agricultural land and forest land has come under urbanization. This is an unhealthy situation for land management in such a sensitive ecosystem. The area is facing increasing problems of erosion, deforestation and other land use conversions which are unsustainable in nature. This LU/LC change detection is useful for sustained land management of K-J Watershed.

A comprehensive evaluation of drought in Periyar River basin, southern western Ghats, India: A geo-spatial approach

Saranya P.[1]*, Krishnakumar. A.[1], A.K. Taxak[2]
[1] National Centre for Earth Science Studies, Thiruvananthapuram
[2]Department of Hydrology, Indian Institute of Technology Roorkee
**saranyaputhalath@gmail.com*

Recent analysis of rainfall trends and projections are showing significant changes in precipitation patterns over the country and also in Kerala State which is the "Gateway of summer monsoon" (Guhathakurta et al., 2007; Krishnakumar, 2009). The significant decrease in southwest monsoon rainfall and the increase in post-monsoon season are changing the climate and hydrological regime of the State. In a recent study, Thomas et al., 2016 highlighted the intense drought events during the twentieth century which is in consistent with the recent reports of drought in the highly humid tropical monsoon dominated State with around 120-140 rainy days per year.

As if most of the drought events are local, basin-scale/watershed based studies would be more significant, which is lacking in the State. Hence, an attempt has been made to evaluate the drought scenario of the Periyar River Basin (PRB), which hosts the highest rainfall receiving station of the State. Gridded rainfall (0.25^0 resolutions, 16 grids) and temperature (1^0C resolutions, 4 grids) data obtained from India Meteorological Department (IMD) over a period of 1951 to 2013 was analyzed using LOWESS regression curve to identify patterns over time. Also, the homogeneity of the series was tested and most probable change year was detected using Pettitt's test, Standard Normal Homogeneity Test (SNHT) and Buishand's test. The probable change year for T_{max} was 1978 in all the grids according to Pettitt's and Buishand's test and was variable for $T_{min.}$ In case of rainfall, a decreasing trend in annual rainfall was observed in lowlands and increasing trend was observed in most of the highlands.

As the drought events have become more prominent during the last decade, an analysis of drought events were performed for the basin in terms of SVI and SWI, which is first of its kind in PRB, the longest with largest discharge potential among Kerala Rivers. Ground water level data for the period from 2000 to 2013 of 29 observation wells of the Periyar river basin were collected from CGWB and analyzed. The water level fluctuation graphs were prepared, major parts of the basin is in the fluctuation range of 1 to 2 m. Also, temporal groundwater droughts have been determined using Standardized Water-level Index (SWI) along with spatial groundwater droughts using Spline interpolation in GIS. It is evident that the groundwater drought is varying locally throughout the study area. However, spatial assessments show that the major part of the study area falls in mild groundwater drought category which point towards the potential scope for groundwater storage

during dry spells and its continual exploitation. While considering the decreasing trends in southwest monsoon and recurring drought events, the situation is alarming.

The SVI explains the probability of vegetation condition deviation from "normal" based on calculations from weekly NDVI values. 16 daily MODIS NDVI product MOD13Q1 at a 250m spatial resolution from 2000 to 2013 were used. Maps produced using the SVI are quite useful for comparing the greenness at a time to average conditions.

Guhathakurta, P., and Rajeevan, M., 2007. International Journal of Climatology 28, 1453-1469
Krishnakumar, K.N, Prasada Rao, G.S.L.H.V, Gopakumar, C.S., 2009. Atmospheric Environment 43, 1940-44.
Thomas, J., and Prasannakumar V., 2016. Journal of Hydrology 534, 266-280.

Extraction of glacial lakes from high resolution satellite remote sensing data

Kavita Mitkari[1]*, R. K. Tiwari[2], M. Srivastava[3], M. K. Arora[1], H. S. Gusain[4]
[1]PEC University of Technology, Chandigarh 160012
[2]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001
[3]Chandigarh Engineering College Landran, Mohali 140307
[4]Snow & Avalanche Study Establishment- RDC (DRDO), Chandigarh 160037
**mitkari.kavita@gmail.com*

In the cryosphere, the lake ice cover is a robust indicator of climate variability and climate change. Because of the change in global mean temperature, most Himalayan glaciers have been retreating and many small glaciers (<0.2 sq. km.) have already disappeared, resulting in an increase in the number and size of glacial lakes and a concomitant increase in the threat of glacial lake outburst floods (GLOFs). Such climate changes have ultimate effects on the life and property of the mountain people living downstream. Therefore, it is important to map and frequently monitor glacier lakes.

The conventional field surveys are laborious, time consuming, expensive and can be risky in high mountainous regions, whereas, remote sensing offers the most pragmatic tool for their extensive, cost-effective, and repetitive study. Some significant studies have extracted glacier lakes based on coarse resolution images of Landsat ETM+, ASTER and MODIS sensors. However, these images contain information at medium scale and it is difficult to map smaller glacier lakes on these images due to coarse resolution. As the spatial resolution of an image increases, it is possible to detect smaller lakes too. However, the commonly used pixel-based analysis approach cannot completely utilize the properties (shape, texture, context etc.) of the high resolution remote sensing data. Therefore, the newly developed object-based technique i.e, object based image analysis (OBIA) which has increased spatial internal variability and extended mapping capabilities is gaining popularity.

The present study identifies and maps the glacier lakes of Gangotri glacier which lies in the Uttarakhand district of India from high spatial resolution remote sensing image of the WorldView-2 satellite using OBIA. The workflow included radiometric and atmospheric corrections, application of multi-resolution as well as multi-level segmentation algorithms, definition of classes and class hierarchy, application of nearest neighbour classifier and exporting the extracted output. Since we focused on the supraglacial lakes, in the initial segmentation (at coarse scale) process SGD and non-glacier (containing periglacial debris (PGD), valley rock and shadows) regions were delineated. The thermal data of Landsat TM satellite and slope data from ASTER GDEM of 30 m have been used to differentiate between SGD and PGD and to further separate PGD from valley rock respectively. Then,

at the fine scale segmentation, glacial lakes and other features of SGD like crevasses, exposed ice faces etc. were extracted. The training dataset was improved in the post classification step so as to reduce the misclassifications. For this, visual inspection and correction based upon the Google Earth image of the same date was done. After obtaining satisfactory results, the accuracy assessment of the automatically generated outlines of glacial lakes was carried out by randomly selecting some glacial lakes. These lake outlines were overlaid on Google Earth image of the same date. The results indicated the well matching in high resolution image by eliminating the difference in spatial resolution scale. The validation was performed against the reference dataset created by manually digitizing the outlines of the glacial lakes. Thus, a high quality final glacial lake dataset has been generated.

Junli, Li., Yongwei, S., 2012. International Journal of Remote Sensing 33, 5194-5213.
Rastner, P., 2014. Applied Earth Observations and Remote Sensing 7, 853-862.
Worni, R., Huggel, C., Stoffel, M. 2013. Science of the Total Environment, 468-469.

Remote sensing and GIS based studies of groundwater potential zones: A review

Mariya Hasnat*, Priyamvada Singh
Department of Earth and Planetary Sciences, University of Allahabad, Allahabad, U.P.
**mariyah7821@gmail.com*

Groundwater is a precious and the most vital requirement for life, widely distributed resource of the earth. It constitutes an important source of water supply for various purposes, such as domestic, industrial and agricultural needs. Groundwater flows very slowly in the subsurface towards points of discharge, including wells, springs, rivers, lakes, and the ocean. It is the largest available source of fresh water lying beneath the ground. At present time remote sensing and GIS become inevitable tools for the analysis of groundwater at local, regional and global level. Remote Sensing and GIS based concepts have found a very wide range of applications in different fields of soil science, environmental science, earth science etc. A standard methodology is proposed to determine groundwater potential using integration of RS & GIS technique. The composite map is generated using GIS tools. It is integrated with weighted overlay in ArcGIS. Suitable ranks are assigned for each category of these parameters. The groundwater potential zones are classified as very poor, poor, moderate, good & excellent. This review paper is based on about twenty research paper study. This paper describes the groundwater potential zones, discharge and exploration with the help of GIS and Remote Sensing .Thus the groundwater potential information will be useful for identification of suitable locations for extraction of water.

Estimation of river discharge using remote sensing based river width measurements - a case study from the Yamuna River

Nazima Bashir, Vimal Singh*, Sukumar Parida, Shashank Shekhar
Department of Geology, Chhatra Marg, University of Delhi, Delhi 110007
**Vimalgeo@gmail.com*

River discharge is the most essential parameter required to understand the fluvial dynamics. Measurement of river discharge plays an imperative role in ligating the hydrologic and geologic

cycles, planning and managing agricultural and water resources, ecological studies as well as climate modeling (Zhang et al., 2004). Besides this, discharge measurements also play a significant role in understanding fluvial morphology, using which, the overall structure of a river system can be perceived. Although, the importance of river discharge measurements is widely acknowledged, the worldwide repository of river discharge data is either meagerly accessible or badly scant (Gleason et al., 2014). This dearth in availability of discharge data is mainly due to various geopolitical constraints and enormous costs of traditional gauging station based methods (Gleason et al., 2014; Vorosmarty et al., 2001, Negrel et al., 2011). This widening gap of unavailability of discharge data can be narrowed down (if not entirely eliminated) by incorporating remote sensing methods. Estimation of discharge can be done by using the river hydraulic theory to construct the mathematical relations between hydraulics and allowing its use with remotely sensed data. The utility of satellite imagery in measuring various river morphology parameters, viz. width, channel stage and surface water extent, and make river discharge estimations based on these measurements has already been successfully demonstrated by few workers (e.g., Birkinshaw et al., 2014; Gleason et al., 2013). The present study is aimed at exploiting some empirical mathematical relations found to exist between river hydraulics and corresponding river morphology, enabling us to make discharge estimations based solely on river morphology measurements. This concept is applied for selected reaches of the Yamuna River - the largest tributary river of the Ganga river system, originating from the Yamunotri glacier in the uppermost region of the Lower Himalaya. Discharge estimation is solely based on water surface width measurements (taken from satellite imagery) of the river. The results are validated against realistic simulations generated using the HEC-RAS hydrodynamic model and are found to be in reasonable agreement. The HEC RAS simulations showed the error percentage of -0.07. This study takes the satellite-based discharge estimation one step further and paves way for future research in this direction. However, more work is required in terms of validation of results with ground measurements, application of this method to different geomorphic settings, and developing more robust empirical relations between river morphology and hydraulic parameters, before applying it to a regional scale.

Retrieval of glacier facies area of Gangotri glacier at sub-pixel level using AWiFS data

Bisma Yousuf[1]*, Aparna Shukla[1], M. K. Arora[2]
[1]Wadia Institute of Himalayan Geology, Dehra Dun 248001
[2] PEC University of Technology, Chandigarh 160012
**bismaqazi13@gmail.com, *bisma@wihg.res.in*

Glaciers are highly heterogeneous in nature, comprising of a wide variety of facies that develop as a function of spatial variations in surface melt and accumulation. Precise and quantitative information on these glacier facies are considered to be an important ingredient for glaciological research. Satellite based remote sensing has long been recognized as an effective tool for mapping and monitoring these facies in a comprehensive and cost-effective manner. To date, satellite sensors such as NOAA AVHRR, Landsat MSS, TM, ETM+ and Terra-ASTER have been used to serve this purpose which are inhibited by the saturation problems over glaciated areas. This sensor saturation over snow-ice facies can cause loss of detail in the snow-ice facies pattern and affect the albedo estimates. The increased availability of data from high radiometric resolution sensors such as AWiFS on-board IRS-P6 satellite has not only helped in overcoming the saturation problem but also facilitated the effective monitoring of large snow covered areas as a result of high temporal resolution

and wide swath coverage. However, the data provided from this sensor has a coarse spatial resolution (56m) which brings in the problem of mixed pixels (i.e. pixels containing more than one class). This problem can be addressed by the use of sub-pixel classification techniques which predict the proportional membership of each pixel to each class. Sub-pixel classifiers have been widely implemented in land cover mapping, however its use in cryospheric studies remains limited to snow cover mapping only. Therefore, this study concerns the sub-pixel mapping of various facies present on the surface of Gangotri and surrounding glaciers in Garhwal Himalayas using AWIFS data. Based on the spectral characteristics and visual interpretation of the image, eleven distinct glacier facies namely dry snow, firn, wet snow, ice, ice-mixed debris (IMD), supraglacial debris (SGD), periglacial debris (PGD), valley-rock, vegetation, shadow and water have been identified in the test site. The proposed technique uses three different sub-pixel classifiers namely Support Vector Machines (SVMs), Artificial Neural Networks (ANNs) and Spectral Angle Mapper (SAM) to retrieve proportions of these glacier facies within each AWIFS pixel. In order to assess the performance of these classifiers, the areal estimate of each facie will be compared with area derived from high resolution data and spectral indices (e.g. Normalised Difference Snow Index (NDSI)). Besides, the resultant fraction images of all the facies would be assessed for their accuracy with respect to the reference fraction images derived from ASTER data.

Debris cover variations and dimensional changes in the glaciers of western Himalaya using geospatial techniques

Purushottam Kumar Garg[1]*, Aparna Shukla[2]

[1] *Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehra Dun 248001*

[2] *Wadia Institute of Himalayan Geology, Dehra Dun 248001*

** garg.glacio@gmail.com, *gargpk@wihg.res.in*

Debris cover not only alters the glacier response to climate change as a function of its thickness but also serves as a proxy of regional mass balance guestimates as debris cover increase is often associated with negative glacier health (Herreid et al., 2015). Further, in response to increasing global temperature means, glaciers are receding worldwide with marked change in their dimensions (IPCC, 2007). Dimensional changes (e.g. area and length) of the glacier, though poor reflectors of overall glacier health as they present long-term climatic variations, are easy to estimate and directly observed terrestrial indicators of climate change (IPCC, 2007). Glaciers with varying extents of debris cover are expected to behave differently, therefore, generalized inferences regarding their dimensional changes should not be made (Sherler et al., 2011). Moreover, as field based monitoring of these glacier changes is difficult, especially when a large number of glaciers are involved, remote sensing offers the best alternative in this regard (Racoviteanu et al., 2008).

In present study, variations in glacier area, length and debris cover were assessed for 15 representative glaciers of Western Himalaya for the last two decades (~1993-2015) using ablation period (September- November) satellite images of Landsat TM (1993) and OLI (2015). The representative glaciers were selected based on multiple criteria such as topography, orientation, percentage of debris-cover, dimension etc. Glacier boundaries were delineated manually from well co-registered (RMSE < 1 pixel) temporal images utilizing different band combination (e.g. SWIR-NIR-Green, NIR-SWIR-Red, NIR-Red-Green) while unsupervised ISODATA technique was used for debris cover area extraction. Strips with offset of 50 m were drawn parallel to the central flow line of glaciers and frontal changes were estimated as an average of intersection of strips with the glacier

boundary. Debris cover classification uncertainty was assessed using ASTER VNIR band of 2014 at 200 points (collected via stratified random sampling) while uncertainties associated with area and retreat measurements were estimated as per Hall et al. (2003).

An inter-comparative analysis of results reveals the overall trend of glacier depletion during the last ~22 years but the rate of change is found heterogeneous for all the studied glaciers. Further, glacier recession appears to be accompanied by percent debris cover increase. Increased debris cover may also be the result of deglaciation (area change). Thus, shrinkage of glaciers seems to be intricately linked with debris cover extents. Moreover, development and enlargement of glacial lakes were observed near the snouts of some of the studied glaciers, which is probably the consequence of retreat, deglaciation and debris cover increase.

Hall, D.K., Bayr, K.J., Schöner, W., Bindschadler, R.A., Chien, J.Y., 2003. Remote Sensing of Environment, 86(4), 566-577.

Herreid, S., Pellicciotti, F., Ayala, A., Chesnokova, A., Kienholz, C., Shea, J., Shrestha, A., 2015. Journal of Glaciology, 61 (227), 524-536.

IPCC (2007). Cambridge University Press 996 pp.

Racoviteanu, A.E., Williams, M.W., Barry, R.G., 2008. Optical remote sensing of glacier characteristics: a review with focus on the Himalaya. Sensors, 8 (5), 3355-3383

Scherler, D., Bookhagen, B., Strecker, M.R., 2011. Nature geoscience, 4 (3), 156-159.

Extraction of lineaments from satellite images in part of Alrawdah, Shabwah, Yemen

Mohammed Sultan Alshayef*, Akram Javed
Department of Geology, AMU, Aligarh 202002
**alshayef2014@gmail.com*

Lineaments are considered one of the most important topographic features used in exploring resources such as minerals, groundwater, oil and gas, etc. Besides they are indicators of structural and tectonic of a basin. Satellite images become useful for extracting lineament features especially in high resolution images. Lineaments have been extracted by manual and automatic techniques successfully in part of Al-Rawdah, Shabowh, YEMEN. Various methods such as Filters and FCC were applied in manual technique whereas shaded relief and different default parameters have been applied for automatic technique. These, methods were used for removal of noise, sharpening of the linear feature and enhancement of the image. Number of softwares have been used such as Erdas Imagine, Arc GIS 10.2.2, PCI Geomatica13 and Rockwork15. Four geospatial analyses have been applied for assessing the extracted lineaments such as length, density, intersection density, and orientation analysis. The present study utilizes softwares for manual and automatic extraction of lineaments and their relationship with major structural features.

Modelling the redox series of felsic magma system and its relation to mineralization

Santosh Kumar
Centre of Advanced Study in Geology, Kumaun University, Nainital 263002
skyadavan@yahoo.com

KEY NOTE

Granitic rocks (*s.l.*) are strong indicator of tecton-thermal events and crustal evolutionary processes, and act as prime sources of ore elements and hydrothermal fluids. Species and amount of opaque and ferromagnesian minerals may vary from one to another felsic suite, and are mostly controlled by redox conditions of felsic melts, which indeed determine its potential to generate ore-bearing hydrothermal system. The aspect of granite melt generation, evolution and its bearing on ore mineralization can be evaluated in terms of magnetic susceptibility (MS), chemistry of hydrous ferromagnesian minerals, whole rock elemental and isotopic composition. MS of granites displays bimodal patterns such as magnetic or ferromagnetic (Fe-Ti oxides) and weakly magnetic or paramagnetic (ferromagnesian rock-forming minerals) corresponding to magnetite series (>310^{-3} SI) and ilmenite series (310^{-3} SI) granites respectively. Magnetite series magma is derived from partial melting of mafic components in the mantle wedge, and is hydrated, oxidized because of dehydration of subducting slabs, capable of generating sulphide rich Cu, Au, Mo, Pb and Zn deposits. Ilmenite series magma is, however, derived from metasedimentary protoliths or contaminated with crustal rocks containing carbonaceous materials in a continental back-arc setting as a result of crustal thickening or less commonly formed from melting of flysch deposit in a hot accretionary wedge, and is therefore reduced or low oxidizing in nature capable of generating oxide deposits rich in tungsten, tin, beryl, fluorite and tourmaline bearing pegmatite ore bodies. Magnetite series and ilmenite series granites should actually correspond to I-type (metaluminous) and S-type (peraluminous) granites respectively but in nature this is less commonly observed. In this paper, the redox states of felsic magmas and associated mineralization have been evaluated, which have implications on demarcating metallogeny and targeting the ore deposits.

Geology and geochemistry of Banded Iron Formation (BIF) of Narayanaposi area, Jamda-koira valley, Sundhargarh district, Odisha, India

Vadde Ramesh
Department of Geology, Andhra University, Visakhapatnam 530003, AP
vadde.ramesh@gmail.com

Narayanaposi iron is a part of the well known Jamda-Koira valley. It is in the sourthen end of the western limb of the famous Horse-shoe shaped belt. Regionally the deposits form a part of the famous Horse-shoe synnclinorium, strenching from south western part of west Singhbhum district of Jharkhand into Keonjhar and Sundhargarh districts of Odisha. The present study area is confined to the sourthern end of the western limb of horse shoe synclinorium where iron bearing formation occurs as a sedimentary formation of epigenetic origin. The host rock for Iron ore bearing formation is shale and BHJ/BHQ. Other lithounits are latertic soil, laterite, lateritic ore, SLO (soft laminated ore), HLO (Hard Laminated Ore), HMO (Hard Massive Ore), Friable ore, Blue dust, Goethitic and Limonite. The rocks within the study area belong to Iron Ore Series and the major lithounits are

Shale, BHQ/BHJ, Laterite and Banded Iron formation at some places the litho units are covered by soil and laterite.

The local Structural information are impregnated by the different linear and planer features, which are associated with the litho assemblages F1= N-S, F2= E-W, F3=N-S. The rocks of the Iron ore series have undergone 3 generation folding, out of which only the effects of F3 fold having axial plane trending ENE-WSW are prominent. These folds plunge to ENE and WSW at moderately steep angles. The second generation folds undergo superpose folding as result of which domes and basins are formed. The litho units of BIF usually trend NE-SW to NNE-SSW with moderate to steep westerly dips, dip varies from 20^{o} to 70^{o}. In the study area, iron ore divided into two types based on geological and mining point of view. From geological point of view the different types of ore are lateritic ore, hematite, goethite, limonite, blue dust, friable ore and float ore. From mining point of view the different types of ore occurring in the area are Hard Massive ore, Hard Laminated Ore, Soft Laminate Ore, Friable ore and Blue dust.

In the study area the grades of different types of ore are variable hard massive ore 61-66%, hard laminated ore 60-65%, soft laminated ore 58-65%, blue dust 61-67%, lateritic ore 45-58%, limonitic ore 45-56%, goethite ore 52-58% and Shale15-35%.

Concentration and distribution pattern of heavy minerals in beach sands and interrelationship of textural and heavy mineral abundance of the Nerella Valasa to Jalara Peta Visakhapatnam, Andhra Pradesh, India

Kandelli Navya
Geology Department, Andhra University, Visakhapatnam 530003
navya2120608@gmail.com

Visakhapatnam city is situated on the east coast of Andhra Pradesh, India. The area of investigation lies in between Narella Valasa to Rushikonda (Latitudes N17^{o}46' to 17^{0} 54', Longitudes E 83^{0}21' to 83^{0} 27'). At five stations from Nerella Valasa to Jalara peta 27 samples were collected at a distance of nearly 1 kilometer representing dune, backshore and fore shore environments respectively. At each station sediment sample weighing 250 grams were collected in each environment. This was done to study the placer minerals in terms of their occurrence, distribution chemical composition, texture, provenances and to understand the transportation trends of sediments. A very few studies were undertaken in micro environments of Indian beaches related it heavy mineral variation in respect of density and size. The weight percentage of heavy minerals ranges from 15 to 50% in the study area but some sediment samples contain more than 50% of minerals. Based on study the weight percentage of heavy minerals is very high in fraction and it decreases as the grain size of the particles of the particles increase, it can be concluded that heavy mineral fraction has good association with fine grained particles.

In the present study among the opaque minerals Ilmenite and Magnetite are common. The concentration of opaque minerals is very high in fine fraction than in the medium and coarse fractions. The percentage of heavies decreases as the grain size increases. Studies of sillimanite in study area suggest that, they are largely derived from the Khondalite occurring in the Eastern Ghats. The provenance of garnets is related to khondalite suite (garnet-sillimanite-graphite genisses and schists) of Eastern Ghats where some dark brown garnets are noticed in the present study. The weight

percentage of the Zircon in Dune environment of coarse fraction ranges from 1.2 to 9%, the concentration of Zircon in the medium fraction is from 1.7 to 9.5%. Monazites are present only in few samples in minor portions. The weight percentage of Monazite in dune environment of coarse fraction ranges from 0.5 to 10%. The concentration of the monazite in medium fraction is from 0.8 to 10%. In fine fraction their range is from 0.2 to 0.5%. Epidote is also one of the minor constituents of heavy minerals. It is derived from low grade metamorphic rocks e.g. Khondalites and Pyroxene Granulites.

All the microenvironments *viz* Dune, Back shore, Foreshore from Jalara Peta to endada coast have similar heavy minerals assemblage, which consist of dominantly Opaque, Sillimanite, Garnet Zircon, Epidote, Monazite and trace of Rutile with some other minerals like pyroxene, amphiboles, Biotite etc. The total heavy minerals content varies from 1.5 to 60%.

Environmental aspects of sensitive trace elements associated with coal and natural waters of Eocene coal field of Cambay basin and their impact on human health

Vijay Kumar Singh*, Pramod Kumar Rajak
Department of Geology, Centre of Advanced study, Banaras Hindu University, Varanasi 221005
** vijaygeologybhu@gmail.com*

Trace elements are released in the atmosphere through emission from coal combustion, coal mining activity, agricultural operations, and power generation from coal and industrial processes. The distribution of trace elements in the Eocene (Balasubramanyan, 2006; Sahni et al., 2006; Singh et al., 2010; Singh et al., 2012) coal/lignite seam mined in the Tadkeshwar, Rajpardi and Vastan mines from the Cambay Basin was investigated in relation to ash content and maceral composition. The lignite seam is mainly composed of Huminite group of maceral. For an environmental hazardous study, composite samples of coals from Tadkeshwar, Rajpardi, and Vastan open cast mines have been analysed using Atomic Absorption Spectrometer for Co, Cu, Cr, Mn, Cd, Zn, Ni, Pb, and As. The concentrations of these elements range from 0.12-40.04 ppm, 0.04-1604 ppm, 1.74-45.6 ppm, 4.24-155.2 ppm, 0.04-1.40 ppm, 0.36-20.96 ppm, 2.96-65.6 ppm, 0.10-9.12 ppm, 0.001-7.6 ppm respectively. These elements are mobile and reached at forests and soils by exploitation of coal and on combustion contaminate the farms, and affect the surface and ground water quality, and finally, human health. In developing countries, where local communities live closer to the mining land, people are more exposed to their geochemical environment and suffer many health problems (Bowie and Thornton, 1985). The study of trace elements in natural waters suggests that concentration of the above elements are above the safety limit in a majority of samples and are hazardous to human health.

Balasubramanyan M.N., 2006. Memoir 9, pp. 204.
Bowie, S.H.U., Thornton, I., 1985. Reidel, Holland, 140 pp.
Sahni N., Rose K. D., Singh L., Smith T., 2006. Indian Journal of Petroleum Geology 15, 1-20.
Singh P.K., Singh M.P., Singh A.K. 2010. International Journal of Coal Geology 82, 1-16.
Singh, P.K., Singh, M.P., Singh, A.K., Naik, A.S., Singh, Vikas, K., Singh, Vijay, K., Rajak, P.K., 2012. India. Energy Exploration and Exploitation 30, 131-152.

Lignite maturity and its oil/gas potential of Barsingsar lignite, Bikaner-Nagaur basin, Rajasthan

Pramod Kumar Rajak*, Vijay Kumar Singh, Deepak Kumar
Department of Geology, Institute of Science, Banaras Hindu University, Varanasi 221005
**bhupramodgeo@gmail.com*

Bikaner-Nagaur Basin extends in the East-West direction and fall in two districts i.e., Bikaner and Nagaur. In this basin, the Palana Formation is the main repository of lignite. The age of the Palana Formation is Paleocene to Eocene. It comprises of black shale, carbonaceous pyrite shale, lignite, Fuller's Earth and fire clays. Based on lignite repositories of the Palana Formation of Barsingsar in the paleo/geographical history of the basin and the oil/gas potential can be easily identified. A number of models based on petrology, geochemistry, vitrinite reflectance and rock-eval pyrolysis data have indicate the potential of oil and gas in the basin. The huminite varies from 81.2 to 90.1% (mean 86.3% (on mmf basis)); liptinite from 2.6 to 6.1% (mean 4.4% (on mmf basis)); inertinite from 4.7 to 13.6% (mean 9.3% (on mmf basis)) and mineral matter varies from 4.7 to 10.7% (mean 8.4%). Volatile matter (daf) varies from 54.4 to 60.5% (mean 57.8%). Atomic ratio of hydrogen and carbon varies from 0.78 to 0.93 (mean 0.87) and oxygen and carbon varies from 0.15 to 0.32 (mean 0.27). Vitrinite reflectance (VRr) varies from 0.20 to 0.22% (mean 0.21%); and in rock-eval pyrolysis S2 varies from 56.45 to 140.44 mg HC/g (mean 84.8 mg HC/g); Tmax varies from 406 to 415°C (mean 411.2°C); TOC varies from 36.99 to 50.57% (mean 43.7%); HI varies from 153 to 280 (mean 191.5); and OI varies from 36 to 49 (mean 42.7). Thus, on experimental basis as well as empirical formulae, we can state that the lignite of Barsingsar, Bikkaner-Nagaur Basin has excellent oil and gas potential.

Investigation of lignite deposits from Saurashtra basin, Gujarat: their depositional history and hydrocarbon potential in western India

Vikram P. Singh[1]*, Bhagwan D. Singh[1], Mahendra P. Singh[2], Runcie P. Mathews[1], Suryendu Dutta[4], Subhashree Mishra[3], S. Mahesh[1]
[1]Organic Petrology Group, BirbalSahni Institute of Palaeosciences, Lucknow 226007
[2]Department of Geology, Banaras Hindu University, Varanasi 221005
[3]CSIR-Central Institute of Mining and Fuel Research, Barwa Road, Dhanbad 826015
[4]Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400076
** vikramchauhan09@rediffmail.com*

An integrated approach of investigation has been adopted on the lignites and shales of Saurashtra Basin, western India. The lignite deposits in the basin (Surkha and Khadsaliya mines) are confined to Ghoga area of Bhavnagar district (Gujarat). The Surkha lignite mine, situated about 25 km (lat.21° 40' 248" N & long. 72° 11' 714" E) and the Khadsaliya lignite mine, located about 30 km (lat.21° 34' 091" N & long. 72° 14' 289" E) southeast of the city of Bhavnagar. The lignite deposits are associated with the Khadsaliya Clay Formation (Eocene) of the basin. The detailed investigation includes organic petrographical, palynofacies and bulk geochemical analyses. The nature, type, and amount of organic matters and their relation to palaeoenvironmental conditions have been determined and discussed along with significance in hydrocarbon source potential. Petrographically, the macerals of huminite group show dominance (Surkha: av. 61%; Khadsaliya: av. 60%) over the liptinite and inertinite groups. The petrographical indices (GI-TPI, GWI-VI models) are indicating

that the precursors of peat were deposited under limno-telmatic to the telmatic regime with mesotrophic hydrological conditions. Palynofacies-wise, the particulate organic matters are dominated by the phytoclasts (Surkha: av. 65%; Khadsaliya: av. 56%), followed by the amorphous organic matter and palynomorphs. The extrapolation of data on Tyson's APP diagram suggesting that the organic matters were deposited in a proximal depositional condition and were regularly influenced by brackish-marine water. The huminite reflectance values (av. R_r : Surkha: 0.31%; Khadsaliya: 0.34%) show a good correlation with calorific values (Surkha: av. 3917 cal/g; Khadsaliya: 3891 cal/g) and average T_{max} (Surkha: av. 416 ˚C; Khadsaliya: av. 418 ˚C) value; indicating immature nature of deposits. The relatively high moisture contents have a considerable influence on this immaturity. The lignites contain high TOC (Surkha: av. 35 wt.%; Khadsaliya: av. 33 wt. %) and low ash yields. The volatile matter yields and carbon contents are moderately high, whereas fixed carbon, sulphur, and oxygen contents are average. The hydrogen and nitrogen contents are relatively low respectively. HI *vs.* T_{max}, S2 *vs.* TOC, HI *vs.* OI and H/C *vs.* O/C plots of the studied samples indicate that the organic matters are of types II-III admixed kerogens (organic matters), and has the potential to generate hydrocarbons upon maturation.

Mineralogical and textural changes of Banded Hematite Quartzite to high grade iron ore, a case study from Dalli-Rajhara, Chhattisgarh

Atul Kumar Rastogi*, A.K. Sen
Department of Earth Sciences, IIT Roorkee, Roorkee 247667
**10rastogiatul@gmail.com*

World's most high-grade iron ore repositories are associated with the Banded Iron Formation (BIF) of Precambrian greenstone belt (> 1.8 Ga). The BIF is characterized by presence of iron ore (hematite, magnetite, siderite etc.) with alternate bands of silica and is popularly known as Banded Hematite Quartzite (BHQ), Banded Magnetite Quartzite (BMQ) etc. in India. In general, BIF contains 25-35 wt. % Fe which is converted into high grade (> 64 wt, % Fe) iron ore through various geological processes such as hydrothermal alteration and supergene enrichment, thereby indicating complete leaching/removal of silica.

Dalli-Rajhara iron ore belt hosts high grade ore zone closely associated with the presence of unaltered BHQ in the footwall eastern side but in the western extent of belt, BHQ is found both in footwall and hanging wall sides. The high grade ore here is dominated mainly by laminated ore which varies in physical properties like hardness and porosity. Massive ore and blue dust varieties of high grade iron ore are found in contact with unaltered footwall BHQ. However, there is presence of some patches of undigested BHQ named as corestone occurring especially within the soft laminated ore. There is hard goethitic duricrust near the top of the mineralized zone and most of the hill is covered with lateritic horizon. During this transformation, varities of changes in ore mineralogy, texture and structure have been noted. Least altered BHQ significantly contains kenomagntite with minor martite, suggesting that magnetite was pristine mineral phase for these iron formation. With the enrichment of iron ore the abundances of kenomagnetite also reduces and martite and hematite of varying crystal habits increases in high grade ore. Silica bands of BHQ have been replaced with microplaty hematite and these bands are characterized by higher porosity and sometime other secondary minerals such as goethite, lepidocrocite etc., are also present. But the laminated character of the protore remains persistent even in high laminated ore. Hardness and porosity in laminated ores are depended upon the degree of replacement and refilling of voids with secondary minerals. Hence,

these are further classified as hard laminated and soft laminated ore. Blue dust normally occurs as patches in the mineralized zone especially in the intensely folded/ deformed portions in contact with BHQ. Blue dust is finely powdered material composed of mainly martite and microplaty hematite. Massive ore is structureless, hard and compact having more or less uniformly distributed micropores, it is mainly composed of microplaty hematite and martite with lesser extent of relict magnetite.

The study determines that during the process of enrichment from the BHQ to high grade iron ore, selective leaching of silica and silica replacement with iron minerals is dominant phenomenon. Meteoric water played most important role in leaching of silica and also for the transformation from kenomagntite to recrystallized hematite and also transformations of other iron mineral species, if any. However, some earlier studies had indicated role of upward moving hydrothermal fluid is responsible for this alteration.

Limestone mineral resources in parts of Adilabad district, Telangana, India

P. Sateesh[1], P. Ravikanth[2]*, G. Vamshi Krishna[2], A. Narsing Rao[2], V. Sudarshan[1]
[1]Department of Applied Geochemistry, Osmania University, Hyderabad 500007
[2]Department of Geology, Osmania University, Hyderabad 500007
**ravikanth.geo1991@gmail.com*

India produces about 89 minerals which include four fuel minerals; 11 metallic minerals; 52 non-metallic minerals & 22 minor minerals. Mineral resource revenue contributes a major share to the Nation's GDP and a greater role in the Economic and Social Development in the Country. The total resources of limestone of all categories and grades as per UNFC system as on 1.4.2010 are estimated at 184,935 million tonnes, of which 14,926 million tonnes (8%) are under reserves category and 170,009 million tonnes (92%) are under remaining resources category (IMYB). Telangana is the leading producing state accounting for 20% of the total production of limestone (IMYB).

Telangana state is embodied with huge deposits of Proterozoic limestone in almost all the nine districts. About 95% of the limestone produced is used in Cement making; 3% in Iron & Steel and 3% in other industries. Limestone resources in Adilabad district meet the requirements of three Major Cement plants, Paper and chemical industries. The Proterozoic Pakhal basin, situated in the south-central part of the Peninsular Shield, extends through the states of Telangana, Madhya Pradesh and Maharashtra, in a general NW-SE direction along the Pranhita-Godavari valley. The sediments of the basin occur as two mutually parallel belts, with about 40 km wide stretch of Gondwana sediments separating them. The south western belt extends from Khamman in the South East to Adilabad in the North West.

Limestone samples have been collected from Devapur, Salvai Lodhi, Ada and Ralli villages in different locations representing purple, green, dark grey, light grey and white/brown varieties. Petrographic and X-Ray Diffraction studies have been carried out to assess the mineralogy of the limestones. The studies revealed that limestone is the study area is suitable for cement industry. Further few high grade patches are suitable for Blast Furnace (BF) and Steel Melting Shop (SMS).

Resource evaluation of dolomite resources in parts of Khammam district, Telangana, India

G. Vamshi Krishna, A. Narsing Rao
Department of Geology, Osmania University, Hyderabad

The dolomite deposit belonging to Pakhal Super Group occurring in Khammam district belongs to Mallampalli stage of Mallampalli group of Pakhal Super Group. Pakhals rest unconformably over the peninsular granites and gneisses with a thin horizon of conglomerate bed in between them. The Pakhals consists of arenaceous, argillaceous and calcareous formations. Planning Commission stressed the need for r-evaluation of all mineral deposits explored more that few decades ago in view of advancement in ore dressing/beneficiation technique and technological advancement in utilizing low grade ores in metallurgy and value added products and orientation of research and development activity in a way to ensure maximum economic recovery of the associated minerals and valuable metals during the 12th Five Year Plan.

National Mineral Inventory (IBM) dolomite resources are placed at 1146 M.T. Out of the 107 working mines in the Country 13 mines are in Telangana State. Production wise Telangana is production 25% of the Country's total production and is from the Khammam district.

Dolomites occurring over a large tract covering Madharam, Laxmipuram, Govindapuram, Nerada, Proddutur, Garlapadu villages, Chintakani mandal Khammam district falling in Survey of India toposheet No. 65 C/1,2,3,4,5,6,7,8. Geological mapping has been carried out to assess the vast dolomite occurring over a strike length of about 230 km, striking N 20º E - S 20ºW and dipping 25º to 55º. Dolomites are thick bedded, massive, compact, fine to coarse grained and associated with varying proportions of accessory minerals. Dolomites are traversed by three sets of fractures E - W; NNW - SSE & NE - SW. In all 60 dolomite samples from different areas covering the entire stratigraphic column has been collected systematically and subjected to qualitative and grade assessments viz., SiO_2; CaO; MgO; Fe_2O_3; Al_2O_3. Chemical analysis of dolomites in the study area is suitable for Blast Furnace (BF) and Steel Melting Shop (SMS). Reserves has been evaluated and classified as per UNFC.

Organic petrology and depositional environments of lignites of Nagaur, Rajasthan, India

Alok K. Singh*, Alok Kumar
Rajiv Gandhi Institute of Petroleum Technology, Rae Bareli 229316
**asingh@rgipt.ac.in; *drsinghalokk@gmail.com*

In present scenario, coal and lignite is an important source of energy in which the lignite is one of the coal types having low calorific value fossil fuel. Lignite is dark-brown to blackish-brown in colour, carries a good amount of moisture and represents an intermediate stage in the alteration of wood into coal. The occurrence of lignite in India has been distinct according to their occurrence, age and depositional features with a strong paleogeographic control. In India, lignite occurs in western, northwestern, and the southern part of the country. In the western part of the Rajasthan, large deposits of lignite present in the Tertiary formations of Middle-Lower Eocene age in the Barmer, Jaisalmer and Nagaur basins falling in Barmer, Jaisalmer and Bikaner-Nagaur districts, respectively. Nagaur district is occupied by the Delhi supergroup rocks (Lower to Middle Proterozoic), the Erinpura

Granite, the Malani Igneous suite and the Marwar supergroup (Upper Proterozoic) and the Palana Formation of Tertiary in age. In the northeast part of the Nawa Area of Nagaur district Mangalwar complex of the Bilwara Supergroup represented as few outcrops of gneisses.Lignite of study area occurs in Bikaner-Nagaur Basin in the Tertiary age of Palana Formation. In Nagaur at the Matasukh lignite mines, the lignite bearing sequence having a thickness of about 12 meters.

The objective of this study was to know about the petrographic characteristics of lignite deposits of the Nagaur district, Rajasthan and to decipher the evolution these lignite based on the petrographic based depositional models. To achieve the above said aim, Lignite samples have been collected from all the working and exposed lignite seams of Nagaur following the pillar sampling method. The petrographic study has been carried out on an advanced petrological microscope aided with MSP 200 photometry system and fluorescence attachment. The identification of maceral has been done as per the recommendation of I.C.C.P. (ICCP-94 system; 1998 & 2001). For the microlithotype analysis, 20 points Kotter graticule was used. The reflectance measurement was carried out as per the ISO standard (ISO, 7404-5). All the coal samples were subjected to proximate analysis (BIS, 2003) and petrographic analysis.

These lignites are mostly dominated by the huminite group of macerals. The most abundant macerals of huminite group were textinite, attrinite and ulminite. Densinite and gelinite were observed but recorded in small concentration rarely. The next most dominating group after the huminite group, was liptinite and represented by both primary and secondary liptinites. An internite group of macerals occurs in meager amount and represented mainly by the semifusinite, funginite and inertodetrinite. Mineral matters were mainly represented by argillaceous mineral followed by pyrite and carbonate. Reflectance of ulminite reveals that the Nagaur lignite may be classified as 'Low-rank B' (lignite B). The study reveals that lignites originated in Bog forest under ombrotrophic to mesotrophic hydrological conditions. Gelification Index (GI) and the Tissue Preservation Index (TPI), suggests an accumulation of peat in marshy environment and few in wet forest swamp.

Organic geochemical analysis of Sirbu Shale, Upper Vindhyan basin, India: implication to provenance and hydrocarbon characteristics

Deepak Singh Maurya[1]*, S. K. Rai[2], Uday Bhan[1], D. K. Gupta[1]
[1] University of Petroleum and Energy Studies, Dehra Dun 248007
[2] Wadia Institute of Himalayan Geology, Dehra Dun 248001
**dsmaurya11@gmail.com*

The Vindhyan Supergroup sediments represent the mineral compositions of past eroded continental crustal material and preserve geochemical signatures of paleo-tectonic and volcanic events. The geochemical study of these sediments provides understanding into tectonic events that shaped the face of the Earth surface. Further, the organic geochemical methods of hydrocarbon prospecting comprise the classification of sedimentary organic matter in terms of its abundance, source and thermal maturity, which are essential conditions for a hydrocarbon source rock. In the present study, evaluation of organic matter in projection of shale formations from the Kaimur and Bhander groups of the Upper Vindhyan basin was carried out using the Rock Eval pyrolysis. The adsorbed low molecular weight of the hydrocarbons, methane, ethane, propane and butane has been considered in the near surface soils to infer the generation of hydrocarbons in the Upper Vindhyan basin. The organic matter in Sirbu shales has the maximum Total Organic Carbon (TOC) content. The

parameters S1 (thermally liberated free hydrocarbons) and the S2 (hydrocarbons from cracking of kerogen) show higher values. High concentrations of all thermogenic hydrocarbons are specific to areas around Sagar, Narsinghpur, Katni and Satna in the Son valley. The light gaseous hydrocarbon anomalies are equivalent to the wrench faults (Kota - Dholpur, Ratlam - Shivpuri, Kannod - Damoh, Banspur - Rewa) in the Vindhyan basin, which may provide conducive pathways for the migration of hydrocarbons at the near surface soils.

Petrographical characterization and modeling of shales and associated tight reservoirs

Thakurdas S.M.[1]*, Desai Bawanising[1], Kulkarni U.D.[2]
[1]N. Wadia College, Pune
[2]P.D.P.U., Gnadhinagar
**sagarthakurdas@gmail.com*

Shales and Tight reservoirs are one of the most important reservoirs across the globe these days. Tight gas reservoirs are those reservoirs which have very low permeability (<0.1 md).Recent researches have shown that gas can flow through these shales and can also be considered as potential reservoirs (Shale Gas) although with much lower permeability. Most of the commercial hydrocarbon discoveries in India are from Cenozoic succession. However, some of the Mesozoic horizons, including Middle-Late Jurassic of Kuchchh, could prove fruitful if their sweet spots are identified after studying their petrophysical responses.It was decided to undertake the geomorphological, geo-chemical and petrophysical studies of the shale and tight sands in the region of Kuchchh, especially within the Jhuran Formation.The objective is to characterize the shale rock samples into different petrotypes based on the similarities and dissimilarities in porosity and permeability along with other major petrophysical properties. Variations in vertical and horizontal permeability within the plug samples need special mention in this type of study. Methods such as thin section, SEM, Clay mineral identification TOC content determination will be employed during the study.

Genetic type and rank determination of coals of Chano - Rikba block of north Karanpura coalfield, Jharkhand (India)

Moti Lal Banra[1]*, Anup Kumar Sinha[1], Bacha Ram Jha[2]*****
[1]CSIR - Central Institute of Mining and Fuel Research, Unit Ranchi
[2]University Department of Geology, Ranchi University, Ranchi
**banra_moti@rediffmail.com, **anup007geologist@gmail.com; ***brjha123@gmail.com*

The present paper deals with the petrographic constituents of coals of Chano - Rikba block of North Karanpura Coalfield. It has been observed that the maceral composition indicates that Vitrinite, Inertinite, Liptinite, mineral matter and Vitrinite reflectance ranges from 16.3 to 46.6, 34.9 to 65.6, 0.4 to 11.4, 2.0 to 23.2 percent, respectively, and Composite Genetic Type - Trimacerite, rich in inertinite over vitrinite and Exinite (Liptinite) “fuso-vitric” and Trimacerite, rich in vitrinite and Exinite over inertinite group macerals “vitro-fusic”. The Vitrinite Reflectance Percentage and Genetic Type of Coal suggest that coals are high volatile bituminous a stage of rank.

Metamorphic evolution of silica deficient Mg-Al granulites from Jagtiyal section, Eastern Dharwar craton, India: constraints from thermobarometry, quantitative phase equilibria modeling

P. Chandra Singh[1], D. Prakash[2], Puneet Singh[1]
[1]*Wadia Institute of Himalayan Geology, Dehradun 248001*
[2]*Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi 221005*
pcsinghgeo21@gmail.com

The Southern Indian Shield represents a section of deep continental crust and offers a unique opportunity to study crustal processes at depth. Jagtiyal section lies in the northeastern part of the Eastern Dharwar Craton, and situated at about 250 km NNE of Hyderabad (Andhra Pradesh). It comprises a portion of the granulite facies terrain of the Precambrian Shield of the southern India and covers a number of sapphirine-spinel bearing localities. The dominant rock types are granites (Pl-Kfs-Qtz±Bt±Hbl), charnockites (Opx-Pl-Perth-Qtz±Bt±Grt) and granite gneisses, basic granulites (Cpx-Pl-Qtz±Opx±Hbl), gneisses (Opx-Crd-Bt-Pl-Qtz-Perth±Sil±Grt±Spl; Bt-Qtz-Pl±Crd±Hbl±Spl) and silica deficient Mg-Al granulites (Spr-Spl-Bt-Crd-Kfs-Crn±Opx; Bt-Crd-Kfs±Crn±Spl±Krn; And-Bt-Kfs-Chl). Besides these banded magnetite quartzite, metadolerites (Cpx-Pl±Bt±Qtz±Chl), quartzite and altered ultramafic rocks (Chl-Trem-Tlc) are also present. Silica deficient Mg-Al granulites and basic granulite occur as enclaves within granite gneiss and charnockite. Mg-Al granulites which preserve their metamorphic history in the form of reaction textures and symplectites have tremendous potential to reveal high temperature metamorphism of the study area. The sapphirine-bearing granulite of study area shows complete absence of sillimanite, but the presence of corundum in the mineral parageneses. Textural observations of silica deficient Mg-Al granulite suggest that biotite and corundum were present during the prograde stage and other minerals progressively developed from them. The later stage is characterized by reaction textures and formation of spectacular symplectites, diagnostic of decompressional regime. During late stage, a few samples show textural evidence of retrogression where chlorite, corundum, spinel and andalusite were completely/ partially replacing sapphirine and cordierite. The P–T evolution of Mg-Al granulites has been constrained through the use of TWEEQ and PERPLE_X programs. On the basis of mineral assemblages and their compositions, KFMASHTO (K_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O–TiO_2–Fe_2O_3) model system has been chosen to calculate P-T pseudosections. The P–T conditions derived through the composition isopleths of X_{Mg} of biotite, cordierite, sapphirine, orthopyroxene, X_{Ti} biotite and X_{Al} orthopyroxene gave peak temperature around 850ºC at 8.2 kbar. The peak P-T condition obtained with TWQ program for core composition is 8 kbar and 800°C. At the retrograde stage solid-back reaction took place at 2.5 kbar and 500°C. Integrating the relict assemblages, textural imprints, mineral compositions, metamorphic reaction history, P-T pseudosection modeling, and thermobarometric data of silica deficient Mg-Al granulites from Jagtiyal section defines a near-isothermal decompression P-T path.

Lineament vis-à-vis spatial distribution of landslides between Uttarakshi and Gangnani in the Bhagirathi valley, NW Himalaya

Meenakshi Devi*, Vikram Gupta
Wadia Institute of Himalayan Geology, Dehradun
**meenakshi@wihg.res.in*

Lineaments are linear surface features that differ distinctly from the patterns of adjacent features and presumably reflect the subsurface phenomena. These are generally tens of meters to few kilometers long and can be easily mapped using satellite images. These are of either tectonic or geomorphic origin and are represented by weak zones such as joints, shear zones, faults, thrusts etc., and thus greatly influence the occurrence of landslides. The present study encompasses the mapping of lineaments and landslides between Uttarakashi and Gangnani located between longitudes 78.38º and 78.72ºE and latitudes 30.68º and 30.87ºN. Geologically, the area occupies a complex geological and tectonic setup. The northeastern part of the area lies in the Main Central Thrust (MCT) zone that demarcates the Higher Himalaya and the Lesser Himalaya. The Lesser Himalaya is located to the west of the village Jakholi. The MCT zone, located to the east of Jakholi is divisible into Lower Crystallines (Chail Group) exposed between Jakholi and Malla and the Middle Crystallines (Jutogh Group) exposed between Malla and Bhatwari and further upstream. The Lower Crystalline is separated from the Garhwal Group of the Lesser Himalayan rocks by MCT-1 (Chail Thrust), whereas, it is separated from Middle Crystalline by MCT-2 (Jutogh Thrust). The MCT zone has also been designated as Higher Himalayan Crystalline zone (HHCZ). All the major thrusts in the area are demarcated by major lineaments. The lineaments have been mapped using multispectral LISS-IV image on 1:25000 scale. MCT-1 and MCT-2 have been identified and marked well using the aforesaid data. The image has been ortho-rectified and enhanced using high pass filter and edge detection techniques for better visual interpretation. Landslide inventory map has been prepared using merged images of high spatial resolution Cartosat-1 (2.5 m spatial resolution) and LISS-IV (5.8 m spatial resolution). The landslides have been demarcated as polygon features. More than 300 lineaments have been mapped in the study area. The dominant length of the lineaments varies between 500 and 1000 m, having 110 m as the shortest and 5500 m as the longest length. The majority of the lineaments are directed towards NE-SW direction. Further, the Bhatwari region and south of Uttarakashi region shows higher density of lineaments. More than 25 major and minor landslides have been identified in the study area of these 60 % of the landslides fall in the very high lineament density zone. It has also been noted that greater densities of landslides occur near the zone of lineament intersection point. The present study has implied that occurrence of landslides is positively correlated with the lineament density.

Author Index

H.V.TECHNOLOGIES

CHEMICAL & SCIENTIFIC INSTRUMENTS

Authorized Distributors-

SIGMA-ALDRICH, HIMEDIA FOR LIFE IS PRECIOUS, BROOKFIELD

SHIMADZU Solutions for Science since 1875, OLYMPUS, NSW INDIA

MILLIPORE, REMI, Cole-Parmer Delivering Solutions You Trust

EQUITRON YOUR ASSURANCE OF QUALITY, EUTECH INSTRUMENTS Technology Made Easy ...

Whatman, Labnet Labnet International, Inc., ABDOS LABWARE

Address:-

B-7, Phase II, Transport Nagar, Dehradun 248 001.
Phone 0135- 264 1535 , 264 5523, 7500464464
Email ID-info@hvtdoon.co.in

LTSS No.....

WADIA INSTITUTE OF HIMALAYAN GEOLOGY

Publication & Documentation Section
33, General Mahadeo Singh Road, Dehradun – 248 001, India

REGISTRATION FORM

LIFE TIME SUBSCRIBER SCHEME
for
"HIMALAYAN GEOLOGY"
(for individuals only)

1. I would like to become a Life Time Subscriber for "Himalayan Geology".

2. The Life Time Subscriber fee for Rs.1000.00 (India) US $ 100.00 (Foreign) is enclosed herewith by Draft in favour of Director, Wadia Institute of Himalayan Geology. Kindly send the publications on the following address :

   Name ……...…

   Address ……...…

   ……...…

   ……...…

   E-mail/Fax ……...…

I certify that the subscription is for my personal use only and that print subscriptions will not be released to libraries or reading rooms for at least 2 years after publication.

SIGNATURE

Note: A free set of old volumes (1971 to 2005, subject to availability) of Himalayan Geology will be provided to the newly registered Life Time Subscriber Scheme Members for a limited time (Postage to be borne by the Subscriber).

Phone : 91-135-2525430 **Fax:** (91)0135-2625212 **Web:** http://www.himgeology.com
E-mail: himgeol@wihg.res.in, kaushikrb@wihg.res.in, publications@wihg.res.in