2nd NATIONAL GEO-RESEARCH SCHOLARS MEET

Abstract Volume

An initiative of:

Wadia Institute of Himalayan Geology

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

33, G.M.S. Road, Dehra Dun - 248 001, Uttarakhand (India)

2nd National Geo-Research Scholars Meet
WIHG, Dehradun, India
May 17 – 20, 2017

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WADIA INSTITUTE OF HIMALAYAN GEOLOGY
(An autonomous Institute of Department of Science & Technology, Government of India)
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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)
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WADIA INSTITUTE OF HIMALAYAN GEOLOGY
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प्रो. एस. के. टंडन, FTWAS, FNA, FASc, FNASc
अध्यक्ष, शासी निकाय
Prof. S.K. Tandon, FTWAS, FNA, FASc, FNASc
Chairman, Governing Body

Message

I have great pleasure in extending my very best wishes to the Second National Geoscience Research Scholars meet that is being held at the Wadia Institute from the 17th to the 20th May, 2017. I recall with some sense of satisfaction that the GB of the Institute applauded this initiative and unanimously accepted the proposal to make this meet as a part of the annual calendar of events of the Institute.

I am given to understand that there has been an overwhelming response this year from the research students from all parts of the country; almost sixty institutions consisting of a mix of Universities, IIT's and IISER's and National research laboratories are likely to be represented at this forthcoming event. I trust that the academic fare at this Meet will be so rich that in course of time this academic event will be looked upon as one of the most important in the country in the area of Geosciences- an event that all research scholars will look forward to attend every year.

The opportunities for the exchange of thought and the movement of knowledge are exceedingly important; there is much in this direction that happens through the internet but there is no substitute for face to face interactions in research deliberations.

I look forward to a highly successful event under the able guidance of the Director of the Institute and the colleagues who are steering this event.

Date: 12.05.2017

Professor S.K. Tandon

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Director's message

The Wadia Institute of Himalayan Geology (WIHG), named after Dr. D. N Wadia, is a premier research Institution of the country with a mandate to carry out fundamental research to unravel the geological truths related to mountain building of the youngest mountain chain - the Himalaya, with an aim to improve our understanding of the geodynamic processes, climate-tectonic interactions, evolution and extinction of fauna and flora, health of glaciers, changes in fluvial systems, seismicity and processes of ore formation. The outstanding contributions made by the Institute are internationally recognised that have earned acclamation to the Institute as centre of excellence for carrying out research in the field of Himalayan geosciences.

I am glad to share that the National Geo Research Scholars Meet is now an annual event of the Wadia Institute of Himalayan Geology. I am extremely happy to share that the first National Geo Research Scholar Meet received an overwhelming response and was a great success. The Second National Geo Research Meet (NGRSM) dedicated to the research scholars, working on various aspects of Geosciences in our country will be held during 17th to 20th May, 2017. This National level conference is solely for young researches providing them a platform to share their ideas and pristine thoughts.

The Wadia Institute of Himalayan Geology is an ideal place to organize such an event of this scale as the Institute has several state of the art laboratories wherein more than 80 research scholars and research associates from different streams of geosciences are working under one roof. I hope that, this conference will be able to generate a future road map to meet the challenges in the field of geosciences by the country.

I wish the organizers of this conference a great success.

Date: 09.05.2017

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

Contents

Fluoride hydrogeology in Malwa Punjab, India

Chetan P.S. Ahada*, Surindra Suthar
School of Environment and Natural Resources, Doon University, Dehradun 248001
**Email: chetanahada@gmail.com*

Fluoride is an essential micronutrient required by humans for skeletal tissue development and teeth protection. Intake of its higher than required concentration causes serious health hazards. The groundwater is the major source of fluoride in humans. The fluoride is an endemic problem in a majority of areas in India due to its geogenic origin. Most of aquifers in India bear fluoride rich rocks viz., fluorite, appatite, cryolite, etc. The present study is aimed to investigate the assessment of groundwater hydrochemistry in terms of fluoride concentration in Malwa belt of Punjab, India. A total of 76 groundwater samples were collected from different urban and sub-urban sampling stations across 14 districts (Patiala, S.A.S. Nagar, Rupnagar, Fatehgarh Sahib, Sangrur, Ludhiana, Barnala, Mansa, Bathinda, Moga, Faridkot, Firozpur, Muktsar and Fazilka) of Malwa Punjab and analysed for fluoride contents. Results revealed the range of fluoride in the area as 0.6 to 5.07 mg/L and more than 95% samples showed the higher range than the safe limit as decided by WHO (1 mg/L) and BIS (1.5 mg/L) standards. The average fluoride load in groundwater was 2.64 mg/L for this region. Results suggested that fluoride has serious natural contamination in groundwater of these areas and can cause serious health hazard if consumed without treatment for longer duration. However, the groundwater is the major source of potable water. So, dental fluorosis and skeletal fluorosis could be major issues in most of rural population who rely on groundwater for drinking purposes. There is an instant need to tackle the issue of fluoride contamination in this area to safeguard the human health.

Holocene climate variability: Evidence from the southeastern Arabian Sea

Siva Chandiran Alagudurai[1]*, Yoganandan Veeran[1], Selvaraj Kandasamy[2]
[1]Department of Marine Science, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India
[2]State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, China
**Email: geosiva1987@gmail.com*

The Indian Summer Monsoon (ISM) system is a very important component of the worldwide climate, and has a significant role in the socio-economic life of the people of the Indian subcontinent. Our goal is to reconstruct the ISM history during the Holocene. In this study, 291 sediment samples were analyzed for benthic foraminifera from marine sediment core SK-313/GC-1 located off Cochin in the Southeastern Arabian Sea to understand paleo-monsoon changes in the surface productivity during the Holocene. The sediment core was sub-sampled at 1 cm intervals for the top 1 m and 2 cm interval for the rest of the core. Processed dry samples containing benthic and planktonic foraminifera were sieved over 125 ì m size sieve, and were split into suitable aliquots of ~300 specimens, identified and counted. From the >150 ì m fraction planktonic foraminifera were picked for ^{14}C accelerator mass spectrometer (^{14}C-AMS) dating in Rafter Radiocarbon Laboratory, New Zealand. Seasonal changes in the oceanography are reflected in benthic and planktonic foraminiferal productivity. We identified benthic and planktonic foraminifera, characteristic of specific environments, to understand The Holocene monsoonal variability. We focused on oceanographically important benthic and planktonic foraminifera species, such as *Bulimina marginata, Bolivina spathulata*, *Globigerina bulloides, Globigerinoides ruber, Neogloqudrina dutertrei, Uvigerina perigrina*, and *Uvigerina proboscidea,* etc. Higher population of mixed layer species *Globigerinoides ruber* coincides with low *Globigerina bulloides* abundances, a well-recognized Indian Summer Monsoon proxy. The population flux of planktonic foraminifera

Globigerina bulloides and *Neogloqudrina dutertrei* suggests phases of weak summer monsoons during the early to mid Holocene and a strong summer monsoon during the late Holocene.

Hydrogeochemistry of groundwater around north and central part of Chennai, Tamil Nadu, India

M. Balasubramanian*, S.G.D. Sridhar
Department of Applied Geology, School of Earth and Atmospheric Sciences, University of Madras, Guindy Campus, Chennai 600 025
**Email: geobala1721990@gmail.com*

Most of the groundwater is being polluted by anthropogenic and geogenic activities. The coastal aquifers suffer saline water intrusion that becomes worldwide concern. The study area covers 250 sq km along the Chennai coastal region and in the west towards 10 km inland. Along the coast, the study area starts from Fore shore estate to Ennore creek. Fifty-five groundwater samples were collected from bore wells during June 2015 and January 2016 to represent pre- and post-monsoon seasons of the study area. They were analyzed for the geochemical parameters such as pH, EC, TDS, Ca^{+}, Mg^{+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{2-}. The results of the analyses were interpreted by various geochemical diagrams, like, Gibb's plot, Wilcox diagram, USSL diagram and spatial distribution diagram. Based on TDS (mg/l), it is found that most of the samples are fit for irrigation and some of the samples are fit for both irrigation and drinking purpose. Comparing BIS (2012), Na, Ca, Mg, and K; Cl, HCO_3, and SO_4 concentrations were above permissible limit in most of the samples, indicating contamination in groundwater for drinking and other domestic purposes in the study area. Most of the groundwater has been contaminated due to the heavy down pour of December 2016 unprecedented cloud burst that caused flood in Chennai where the water was stagnant in the city for almost a week, is attributed to the higher concentration of some parameters during post-monsoon (January 2016).

Morphometric study and tectonioc aspects of Zilpui Watershed, Aizawl district, Mizoram: An integrated approach of remote sensing and GIS

Binoy Kumar Barman*, K. Srinivasa Rao
Department of Geology, Mizoram University, Aizawl 796004
**Email: barman_binoy@yahoo.com*

The present work on morphometric analysis of the Zilpui watershed has been carried out by using the earth observation data and geographical information system (GIS) techniques. To achieve the morphometric analysis of the watershed, Survey of India (SOI) toposheets on 1:50,000 scales are used for the drainage boundary line extraction by joining the crestal points of the ridges. Thematic Mapper (ETM+) data and DEM data are used for delineation and corroboration of the drainage networks and demarcation of sub watersheds in the study area.

Morphometry is the measurement and mathematical evaluation of earth's surface, form and the dimension of the landforms. A quantitative evaluation of drainage system in an area is significant aspect of the watershed analysis.

The morphometric parameters calculated for the analysis includes the linear, areal and relief aspects of the Zilpui watershed. The Zilpui watershed covers an area of about 56.35 sq km in the Aizawl district of Mizoram. The total drainage network of the Zilpui watershed spreads over the dominant lithology of sandstones of Teritiary age. The mean Bifurcation ratio of Zilpui watershed is

3.66, which indicate that the basin developed in an undulating topographic terrain and basin having structurally controlled. The drainage density of watershed is 3.06 km/sq km indicating the closeness of spacing of channels, thus providing a quantitative measure of the average length of stream channel for the whole watershed. The values of form factor is 0.31 indicates the basin is elongated shape and circulatory ratio of 0.43 indicate that the watershed is characterized by low relief and impermeable surface resulting in lower basin lag time. The Relief ratio of the watershed is 0.07 which shows less resistant rocks in the study area like shales, siltstones and weatherd sandstones. The sub watersheds in the study area show that highly asymmetric in nature, which indicate that the study area is tectonically active.

Genesis and tectonic significance of back-structures: a case study from the Sikkim Lesser Himalaya, India

Narayan Bose*, Soumyajit Mukherjee
Department of Earth Sciences, Indian Institute of Technology-Bombay, Mumbai
**Email: narayan.bghs@gmail.com*

In the foreland part of the Himalaya, earthquakes generally take place due to movement along the basement decollement (i.e., Main Himalayan Thrust) and its splay fore-thrusts (e.g., Main Central Thrust, Main Boundary Thrust etc.). Although, much less in number, back-thrusts (thrusts verging and propagating towards the hinterland) are quite common in fold and thrust belts. In the field exposure scale (or smaller) back thrusts are manifested as back-structures (i.e., shears having top-to-hinterland sense, or folds verging towards the hinterland). The back thrust mechanisms acting on a smaller scale also generate back-structures. Hence, like the back-thrusts, the back-structures also indicate locations of excessive strain build up and recent seismic activities.

A field study was carried out in the Lesser Himalaya of Sikkim to document the back-structures. Sikkim is India's least populous state with only 610577 inhabitants (2011 census). It falls in zone IV (high) in the seismic zoning map of India. Between 1975 and 2016, Sikkim hosted 26 earthquake epicenters (magnitude >2.5), all of which are shallower than 70 km and concentrated towards the southern part of the state (source: USGS). Geologically, this part of Sikkim in undergoing active deformations mainly through the mechanisms of duplex and transverse tectonics. The locations where the back-structures were encountered fall on the northern limbs of the Lesser Himalayan duplex stack. Hence their genesis can be described by strain accumulation on a ramp model. Evidences of 'passive roof duplex' were also seen. These observations support the prevailing critical taper mechanism of deformation for this region. The cross cut relationship between the fore- and back-structures indicate the younger nature of the later. Back-structure locations need to be studied more to get an idea about the ongoing deformation activities.

Decoding the winter "Fog Code" through environmental magnetism

Munmun Chakarvorty
Department of Earth and Planetary Sciences, University of Allahabad, Allahabad 211002
Email: mchakarvorty@gmail.com

Physical and chemical characterization of 1102 leaf dust samples (LDS), collected between 2010 and 2013, of a severely winter fog affected and polluted urban environment of Indo-Gangetic plain, Allahabad, are presented in this study. Both organic as well as inorganic phases having variable particle size, magnetic susceptibility, trace metal content and source characteristics are observed in

the LDS. The temporal changes are grouped into three effective annual seasonal phases- winter fog, pre-monsoon and post-monsoon. Leaf dust sediments (LDS) deposited upon the road side tree leaves in Allahabad city were collected in different sampling periods from 2010 to 2013 in fog, post-monsoon and pre-monsoon. A total of 500 particles were analyzed by SEM-EDX and classified on the basis of their chemical compositions and particle morphology as anthropogenic, geogenic and biological. It is clear that the LDS in the urban area are contaminated by urban sources. The pronounced impact of seasonal variations is observed in the LDS characteristics, as ~46% of the winter fog period samples ranges in size between 2.5 and 20 µm having high magnetic susceptibility (up to 938.22 $x10^{-8}m^3kg^{-1}$). In comparison, 35% of the LDS from pre-monsoon period are in the size range of 100 to 300 µm with low magnetic susceptibility (up to 43.29 $x10^{-8}m^3kg^{-1}$). The toxic metal (Pb, Zn, Cd, Cr and Ni) concentration in LDS belonging to winter fog and post-monsoon periods is more as compare to samples from the pre-monsoon periods. Multivariate statistical analysis of trace element data suggests that the LDS collected from winter fog and post-monsoon periods are derived predominantly from anthropogenic source whereas those collected during pre-monsoon owe their origin to crustal and anthropogenic sources. The present study has unambiguously demonstrated the role of seasonal variation in controlling the physical and chemical proprieties of particulate matter based on multiple parameter analysis in a marginally industrialized yet highly polluted and severely winter fog affected area of north India.

Morphotectonic study of frontal Siwalik hills between Beas and Chakki rivers, Kangra, western Himalaya

A.R. Chaudhri, Yoginder Singh, Rajesh Ranga, Vikram Sharma
Department of Geology, Kurukshetra University, Kurukshetra 136119
Email: yogi89geokuk@gmail.com

The frontal Himalayan terrain of the western Himalaya between Beas and Chakki Rivers is being critically examined using Resourcesat-1: LISS III Ortho satellite imagery. Lineaments have been identified using ERDAS and ARCGIS 10.3.1. An active left lateral Strike Slip Fault has been identified which is influencing the present day drainage in the region. Quantitative morphometric analysis, viz., Hypsometric Integral, Drainage Basin Asymmetry, Valley Floor Width to Valley Height Ratio, Stream Sinuosity Index, Stream Length Gradient Index and Mountain Front Sinuosity Index reveal that the terrain is tectonically active. Shutter ridges which are 140m, 265m and 330 m long have been located in the field. The active fault is being named as Gandhiri Active Fault after the Gandhiri *khad* which this active fault crosses.

Morphometric analysis of Chhokranala micro-watershed, district Raipur, Chhattisgarh, India using remote sensing and GIS

Shalini Choubey*, Prabhat Diwan
Department of Applied Geology National Institute of Technology-Raipur, Raipur 492010
**Email: geology.shalini@gmail.com*

The use of GIS and remote sensing to prepare management and planning of natural resources of the Chhokranala Watershed is employed that ultimately fulfills the requirement of water for food production. Progress in these technologies offers many advantages of taking a synoptic view of the natural resources, natural features at a glance to quicker planning and management of the end user related issues. This research work focuses on management of Natural resources used in water

conservation, such as primarily drainage development, watershed evaluation and its characterization, harnessing the morphometric parameters of the topography. It is helpful in management of drought affected area and agriculture practices; finally enhancing water table. The results were obtained with a DEM (90 m resolution). The watershed of the study area covers an area of 1731 ha that falls in the SOI toposheet no.64G. Morphometric analysis is utilized by using the linear parameters such as bifurcation ratio, drainage density, stream frequency, texture ratio, length of overland ?ow and shape parameters (such as form factor, shape factor, elongation ratio, compactness constant, and circularity ratio). The different prioritization ranks are assigned after evaluation of the compound factor. Digital elevation model from Shuttle Radar Topography Mission, digitized contour, and other thematic layers like drainage order, drainage density, and geology are created and analyzed over ArcGIS 10.1 platform. Combining all thematic layers with soil and slope map, the best feasibility of positioning check dams in mini-watershed has been proposed after validating the sites through the field surveys.

Delineation of groundwater potential zones in the GV-33 watershed of Vaijapur taluka, Aurangabad district, Maharashtra, India - A remote sensing and GIS approach

S.M. Deshpande[1], A.R. Borgawkar[2], G.D. Gaikwad [2], K.R. Aher[3]

[1]Joint Director, Higher Education, Solapur Region, Solapur

[2]PG Department of Geology, Institute of Science, Nipatnirnjan Nagar, Aurangabad (MS)

[3]Groundwater Survey & Development Agency, Central Administrative Building, Aurangabad (MS)

The water resource management is the key to mitigate the water scarcity situation. Most of the Indian river basins have plenty of water flow during the monsoon months which goes out without utilization, while after monsoon season the tributaries become dry and flow in major rivers dwindles to mere channels. The maximum part of the rainwater flows without use because of inadequate water harvesting structures and management plans. One has to create adequate structures for storage and diversion conveyance of water and operate them to meet various demands in sustainable manner. The main source of water, the rainfall is not uniform over space and time, therefore construction of water storage structures on rivers and rivulets at surplus locations in the river basin are required for storage of surplus flow during the monsoon period. The present research is an attempt to find out the groundwater potential zones within in the GV-33 Watershed of Vaijapur Taluka, Aurangabad District, Maharashtra, India supported by scientific investigation of lithology, geomorphology, geohydrological characterization of geological formations and their interrelationship. Thematic layers of drainage, lithology, geomorphology, lineaments, slope, soil, Digital Elevation Model (DEM), rainfall, land use and land cover have been generated by using Remote sensing and GIS data. The study revealed that in the study area groundwater potential zones are of five categories like very poor, poor, moderate, good and excellent. The potential zones were obtained by weightage overlay combination using the special analysis tool in ARC GIS 10.1. The current paper discusses the use of Remote sensing and GIS tool to understand sustainable water resource management in the GV-33 Watershed of Vaijapur Taluka.

Topographic influence on dimensional changes of glaciers in the central Himalaya, India

Purushottam Kumar Garg[1,3]*, Bisma Yousuf[2], Aparna Shukla[2], Avtar Singh Jasrotia[3]
[1]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
[3]Post Graduate Department of Remote Sensing & GIS, University of Jammu, Jammu 180006
**Email: garg.glacio@gmail.com*

There is strong evidence linking climatic perturbations and glacier wastage in the third pole. However, glacier response is highly heterogeneous and varies from glacier to glacier even if they share similar geographic and climatic settings. This signifies the role of local topographical factors because if climate is the driving force, topographical factors control the individual glacier response. A comprehensive assessment of topographical factors, thus, becomes imperative in order to develop a clear understanding of the glacier behaviour.

In the present study an attempt has been made to investigate the dimensional changes in 18 glaciers, spread over the central Himalaya (CH), for the period of 1994-2015 and to assess the influence of topography on these changes. Satellite remote sensing data from Landsat-TM/ETM/OLI (1993-2014), Cartosat-1 PAN (2011) and Resoursesat-2 LISS-4 (2014) along with Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) have been used for deriving various glacier (area, length) and topographic parameters (area, length, compactness ratio, altitude, slope, aspect, hypsometry and area accumulation ratio). Cumulative influence of topographic factors was assessed using an ordinal scale relative weighting-rating technique. This technique helped computing a Topographic Influence Index (TII) and frequency of TII were then used to identify the glaciers that experienced different degree of topographic influence.

Results show that the total glaciated area decreased from 313.34 ±13.25 km^2 in 1994 to 306.36 ±13.40 km^2 in 2015 whereas individual glacier area loss varied from 1.38 ±0.16% to 8.87 ±1.24%. The retreat rate also varied from 4.75 ±2.25 m/y to 28.25 ±2.25 m/y during the study period. Assessment shows that, out of 18, 5 had modest, 8 had moderate and 5 glaciers had strong influence of topography on area loss. Likewise, 4, 8 and 6 glaciers had strong, moderate and modest influence of topography on retreat, respectively. Further, it is also observed that glaciers which had strong influence are also the ones which are showing high area loss and retreat.

Factors responsible for the formation and enlargement of the moraine dammed lake on Dulung Glacier, Jammu and Kashmir

Siddhi Garg*, Aparna Shukla
Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: g.siddhi86@gmail.com*

Himalayan glaciers have been retreating in response to the climatic warming and has resulted in the formation of glacial lakes. Once a lake has formed, it expands due to differential thermal regimes of warm water and ice. In order to have a comprehensive picture of the glacier behavior to the ongoing climate change, it is important to assess the causative factors for the formation and development of these glacial lakes. As these lakes are mostly located at high altitudes, therefore, remote sensing has proved to be an efficient tool. In the present study, a moraine-dammed lake (MDL), present at the snout of Dulung glacier, Suru-sub basin, western Himalayas, Jammu & Kashmir, has been investigated using LANDSAT series of data during the period 1977-2015 along

with the incorporation of Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM). Despite the fact that Dulung and a glacier adjacent to it, named Chilung, share similar geographical and climatic settings, the latter does not have any such glacial lake.

In the present study, glacier topography, valley morphology and ELA change (as a proxy for mass balance) have been used to obtain information about the formation and subsequent enlargement of the MDL. Dulung has attained a gentler (17.29°) mean slope than Chilung (18.26°), with a slope in their accumulation/ ablation region as (21.06°/ 12.63°) and (19.21°/ 16.78), respectively and a much gentler slope of MDL (5.88°). Unlike Chilung, the gentler slope gradient of Dulung must have been one of the important factors in the formation of the MDL. Investigation of the longitudinal and transverse profile of Dulung glacier valley reveals an initial steep (5.44°) slope for ~500m, followed by a flat terrain that ends into a mound of height/ width: 9/195 m. This mound is restricting the lake at one end. Furthermore, Dulung has initially a wider (226 ± 5 m) glacier valley and narrows (109 ± 5 m) down later, while Chilung exhibits an opposite trend. This terrain of Dulung must have contributed in the accommodation of lake in the wider and sustenance in the narrower end of the glacier valley. The equilibrium line altitude (ELA) shows a decreaseof 221 m and 85 m for Dulung and 11m and 18m for Chilung during (1977-1980) and (1980-1993), respectively, which could be correlated to the slow growth of the lake area at the rate of 0.09 km^2/y and 0.12 km^2/y during these time intervals. On the contrary, ELA increased drastically by about 195 m and 105 m for Dulung and 55 m and 29 m for Chilung during (1993-2005) and (2005-2015), which was synchronous to the rate of increase in lake area by 0.24 km^2/y and 0.34 km^2/y, respectively. These results suggest that themore pronounced increase in the ELA of Dulung after 1993 is the prime reason for the expansion of the MDL.

Fluvio-geomorphological response to recent climatic variability and human intervention: An analysis of channel characteristics of Damodar river in West Bengal

Prasanta Kumar Ghosh*, Narayan Chandra Jana
Department of Geography, University of Burdwan, Golapbag, Burdwan 713104, WB
**Email: gprasanta05@gmail.com*

As a system, River always tries to make a balance between input and output. Any type of climatic variability or human intervention may affect the whole system and alluvial rivers give response to this interference through changes in its morphology. Keeping in view this concept, we have carried out a study on channel characteristics of the Damodar River in West Bengal, India. During the 20th Century, the Damodar Valley Corporation (DVC) came into existence and the Damodar basin was extensively engineered for irrigation and flood control. Since that time up until the present, the hydrology and morphology of the Damodar River has been controlled by dams and embankments, and now another intervention, i.e., large-scale excavation of river sand has been added. The floodplain undergoes great changes as a result of the confinement of river flow due to construction of embankment. In addition, sand mining disturbs the equilibrium of a river channel because it intercepts material load moving within a dynamic system and triggers an initial morphological response to regain the balance between supply and transport. Through historical satellite images, hydro-meteorological data, and cross sectional surveys, we demonstrate that the influence of the climatic variability, upstream dam, embankment and sand mining are the major controllers of river dynamics and adjacent landscape. Field mapping, sedimentological investigations and geomorphological analyses in combination with a series of temporal ancillary data, i.e., hydro-meteorological data, sand excavation data and satellite data define a record of Anthropocene landscape change along 282.7 km stretch of the Damodar River in West Bengal, India.

This case study considers the use of various statistical approaches like Mann-Kendall test, Sen's Slope estimator to detect the possible trend in seasonal rainfall pattern, Gumbel's extreme value distribution (EV-I), Extreme value distribution-III (EV-III), Log-normal (LN) and Log-Pearson Type III (LPT-3) to detect the probable stream flow and discharge pattern and illustrates the applicability of Goodness of Fit (GOF) and D-Index tests procedures in identifying which distributional model is best for the specific data. The results of this study would help in maintaining the health of rivers in the Anthropocene world.

Digital elevation model generation and accuracy assessment for active fault mapping in the Trans-Yamuna segment of the northwestern Himalaya

Swakangkha Ghosh[1]*, George Philip[1], Suresh Kanaujiya[2], Prerna Sarkar[2]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Indian Institute of Remote Sensing, Dehradun 248001
**Email: swakangkha@wihg.res.in*

Mapping and delineation of terrain features in highly inaccessible Himalayan terrain is found to be one of the most promising applications of satellite remote sensing. However, satellite images and aerial photographs are geometrically distorted which needs to be corrected in order to quantify and extract reliable information. The digital elevation model (DEM) derived from stereo images is one of the most important components for terrain evaluation. In order to accurately delineate the terrain features, the horizontal and vertical accuracy of the DEM plays a crucial role. The present study focuses on the use of satellite photogrammetric techniques to delineate active tectonic features in the Trans-Yamuna Segment of Doon Valley in the northwestern Himalaya. Cartosat-1 remote sensing satellite, launched by ISRO in May 2005, offering in orbit stereo images with 2.5 m nadir resolution and 27 km swath have been used. This data can be directly processed for satellite photogrammetry along with the Rational Polynomial Functions (RPC) s and generate DEM.

The present study aims at generating an absolute DEM of 10 m spatial resolution from Cartosat-1 stereo pair using Ground Control Points (GCP's) collected by Differential Global Navigation Satellite System (DGNSS) survey. A relative DEM without using GCP's, using PCI Geomatica's, Satellite Orbital math model method using image correlation technique has been prepared. The overall accuracy for Cartosat-1 absolute DEM (RMSE) is 0.3180 pixels and the relative DEM is 0.480 pixels. The absolute DEM was also evaluated using 14 GCPs collected by DGNSS survey and the mean vertical error is computed to be 0.277 m with RMSE 1.9 m. An error magnitude of this range is only possible due to highly accurate and well-distributed collection of GCPs. The relative DEM generated, using image correlation shows an RMSE of 9.99 m. Thus, this technique can be used to produce DEMs in highly inaccessible terrain where collection of GCPs is extremely difficult. Further, study for accuracy assessment between the 19 DGNSS derived GCPs and freely available SRTM DEM of 30m resolution which uses single pass interferometry and ALOS PALSAR DEM that is another active microwave sensor providing DEMs at a resolution of (~12.5m) was also considered. The RMS error for SRTM and ALOS PALSAR calculated is 8.83 m and 10.722 m respectively which is much less than the specifications given by the respective nodal agencies. In the present case, the overall accuracy assessment proves that, Cartosat-1 stereo images using DGNSS are ideal for generating of high resolution DEM with least RMSE in terms of vertical accuracy. The explicit expression of the Doon Valley active fault in the above DEM substantiates the potential of Cartosat-1 DEM in mapping such active faults in highly undulating mountainous terrain like Himalaya.

Geochemical investigation in fluoride rich groundwater region of weathered rock aquifer of southern India

G. Gowrisankar, L. Elango*
Department of Geology, Anna University, Chennai
**Email: 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 collected during January to June 2014 from wells located in the area were 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. The preparation of various major ion correlation diagrams suggests 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 the Bureau of Indian Standards. Based on the concentration of TDS, sodium, chloride and fluoride the groundwater samples collected during January and June 2014 from a few wells are not suitable for drinking purposes. Chemical indices like Na^{+}%, sodium adsorption ratio, residual sodium carbonate and permeability index (PI) were calculated. Most of the samples from June 2014 are 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.

Assessment of land use / land cover changes by using support vector machine and maximum likelihood classification algorithm

Sridevi Jadav*, Tajdarul H. Syed
Department of Applied Geology, Indian Institute of Technology (ISM), Dhanbad, Jharkhand
**Email: sridevi.jadav89@gmail.com*

Land use and Land cover (LULC) mapping and its change assessment is one of the important part of the remote sensing application. Over the last decades, a number of classification techniques have been introduced for the analysis of remote sensing data. In order to derive reliable information from the satellite data, it is essential to choose the most appropriate classification techniques. So the main objective of this research involves comparison of two classification techniques for the landsat images, which are maximum likelihood classification (MLC) and support vector machine (SVM). Two landsat images were acquired for this analysis in the years of 1988 and 2016. The results of overall accuracy are obtained about 82 % between the two classification methods and suggest that the Support vector machine classifiers perform better than the maximum likelihood classification method. The findings also demonstrate that the choice of model parameters and kernel types play an important role on support vector machine classification technique. This study also quantifies the LULC changes in the Chilika watershed region over the period of 28 years.

Evaluation of potential surface instability in Kharsali village, upper Yamuna valley, NW Himalaya

Imlirenla Jamir[1,2]*, Vikram Gupta[1], Vipin Kumar[1], Glenn T. Thong[2]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Department of Geology, Nagaland University, Kohima Campus, Meriema 797004
**Email: renshijamir@gmail.com*

Kharsali village located in the Uttarkashi district, Uttarakhand lies between latitudes 30°58'10" & 30°58'30"N and longitudes 78°26'00" & 78°26'50"E at an elevation of 2610 m above msl. The village is situated near the confluence of the Yamuna River- Unta gad on ~150 m thick paleo landslide deposit, covering an area of ~ 3.6 km^2 and has a population of 1068. The village is historical and houses the ancient Shani Temple. Most of the houses in the village are of traditional Koti Banal type architecture, consisting mainly of stone wood combination, designed to resist earthquake.

Field observation reveals the presence of numerous ground fissures. Many houses, particularly those located towards the southern segment of the village shows 4°-7° tilting towards NE. The deposit on which the village is situated is continuously being eroded at its base by the Yamuna river flowing towards the north of the village and by the Unta gad flowing towards south of the village.

Evaluation of potential slope instability of the Kharsali village was determined from 2D Finite Element Method (FEM) using Shear Strain Reduction (SSR) analysis in Phase^2 software. Based on the surface failure condition, three slope sections (S-1, S-2, S-3) were analysed and modelled. The S-1 section is located to the south of the Shani Temple. It trends NNE-SSW and cuts across the Unta Gad. The S-2 section is located near the confluence of the Yamuna River - Unta Gad and trends NE-SW, while S-3 is located to the north of the village, trending in the NNW-SSE direction. It cuts across the link road and the Yamuna River.

Results revealed that the southern part of the village housing the Shani Temple (S-1) indicate a critical SRF of 1.5. The development of failure surface at its lower portion signifies the propagating progressive nature of the slope. Further, the S-2 slope section is most vulnerable to slope failure, with a critical SRF of 1.08. This has been inferred by the formation of failure surface with a total displacement of 5-8 mm. The S-3 section in the northern part of the Kharsali shows highest critical SRF of 2.76. The un-metalled road section in the north of the village near S-3 has developed a failure surface with displacement of 0.2-0.3 mm, and a zone of subsidence. It has been concluded that S-3 section is relatively stable, whereas S-2 section is the most vulnerable portion in the village.

The outcome of this study would be useful to the planners and decision makers since developmental activity in the form of rope way, connecting Yamunotri Temple with the Kharsali village is being planned.

Tectono-climatic study and landscape evaluation along Kulur river valley, Kumaun lesser Himalaya, India

Lalit M. Joshi, Manmohan Kukreti*, Anoop K Singh, Yogesh Barola
Centre of Advanced study in Geology, Kumaun University, Nainital 263002
Email: manmohankukreti12@gmail.com

Quaternary tectonic reactivation in the zones of intra-crustal boundary thrust in the Central Kumaun Himalaya has resulted in landforms pertaining to active tectonics. The present endeavor is to study the tectonic landforms developed along the Kulur River valley, Kumaun Lesser Himalaya.

The combined data of geomorphic indicators and morphometry of fluvial channel are used to decode the drainage network evolution under neotectonic activity along Berinag Thrust. Various geomorphic evidences viz., unpaired terraces, abandoned river channel, huge fluvial fans, active and stabilized fan deposits, lineament, waterfalls, springs, paleolakes deposits, saw cutting hills, straight course of river, V-shaped valley, fault facets are clear evidences of landscape evolution along the Kulur valley. Further, it is proved by computed morphometric parameters, such as The Standard Sinuosity Index (SSI), Hydraulic Sinuosity Index (HSI), Topographic Sinuosity Index (TSI) Valley Floor Width to Valley Height (V_f), Stream length gradient index (SL index), Asymmetric factor (Af), Transverse topographic factors, Gradient Index (GI), elongation ratio (Re) and basin shape (Bs). The documented geomorphic indicators and morphometry suggest that the Kulur river basin is elongated, tilted, V shaped and controlled by lithology, climate and tectonic activity. A NNE-SSW trending lineament/fault is documented in the upper catchment, running parallel to Kulur River as manifested by fluvio-lacustrine sediment, deflection and offsetting of stream, low SL index and wide and straight river channel. A detailed study is required to corroborate it further as the area falls in seismically active segments of the Kumaun Himalaya.

Reconstruction of paleoenvironmental history: Using two core sediment samples off Lakshadweep and Goa, Arabian Sea, northern Indian Ocean

Neelavannan Kannaiyan[1]*, S.M. Hussain[1], S.J. Sangode[2], Abhishek Tyagi[3], P. John Kurian[3]
[1]Department of Geology, University of Madras, Chennai 600025
[2]Department of Geology, University of Pune, Pune 411007
[3]Earth System Science Organization, National Centre for Antarctic and Ocean Research, Goa 403804
**Email: k.neelavannan@gmail.com*

The environmental magnetic investigation were carried out in two sediments gravity cores GC-01 (length, 4.3 m) and GC-02 (length, 5.4 m) collected from off Lakshadweep islands (western side of the Laccadive-Chagos Ridge) and off Goa, Arabian Sea, Northern Indian Ocean during the August 2015 using RV Sagar Kanya. The water depths of these two sampling locations are 2057 m and 517 m (surrounding water column depth is 1500 m, Seamount). Down core profile of magnetic concentration, grain size and mineralogy of magnetic minerals were assessed using magnetic susceptibility (÷), ÷$_{ARM}$, SIRM, ÷$_{fd}$%, ÷$_{ARM}$/÷, SIRM/÷, B(0)CR, S-Ratio, SIRM, Soft IRM and Hard IRM, respectively. Based on these magnetic parameters, we have distinguished six zones in the sediment core. The magnetic parameters showed the low biological productivity during reducing (less ventilated) condition in bottom water probably due to increase in the sea level or reduced upwelling. Thus, the study indicates that the environmental magnetic technique is a reliable tool reconstruct the palaeoenvironmental history.

Geospatial assessment of physical vulnerability of buildings and risk assessment in Arithang ward, Gangtok, Sikkim

Harjeet Kaur[1]*, Srimanta Gupta[1], Surya Prakash[2]
[1]Department of Environmental Science, University of Burdwan
[2]National Institute of Disaster Management
**Email: harjeet0909@gmail.com*

Gangtok town, being a natural hazard prone area, has experienced huge development in terms of urbanization since past decades. This development makes landscape more vulnerable and

exposed to higher risk of hazard than ever before. In the present study, risk assessment is carried out for Arithang ward, one of the major wards within Gangtok municipal corporation (GMC) having 2220 household which is about 8% of total households in Gangtok. This ward covers 0.35 km^2 area with 9,333 population, which makes it one of the densely populated areas in Gangtok. The methodology involves different steps, such as (a) landslide and earthquake hazard mapping with heuristic approach, (b) physical vulnerability mapping for buildings in Arithang ward, and (c) qualitative risk analysis. Landslide susceptibility map (LSM) of Gangtok is derived by weighted overlay method (WOM), where, weights of twelve triggering factors are evaluated through expert opinion and subsequently validated by past landslide information. Susceptibility map predicts that 50.92% of the GMC area falls under high susceptible zone and 30.95% and 18.11% areas come under medium and low susceptible zones respectively. On the other hand seismic susceptibility map, prepared with the help of 9 input factors, depicts that 51%, 26.55% and 22.45% areas are categorized as high, medium and low susceptible seismic zones respectively. Physical vulnerability assessment is calculated in terms of buildings at risk for both the hazards. The input data for physical vulnerability are building material, floor space and type of use. In the present study, physical vulnerability is assessed in vector formats, where vulnerability scores are calculated by scripting in ArcGIS environment. From, vulnerability score, the buildings are assigned under three classes, *viz,* low, medium, and high. The spatial distribution of vulnerability of buildings was prepared. Qualitative risk map is categorized into three classes *viz,* high, medium and low, where it is found that with respect to type and category, 7% of Government buildings, 21% of buildings made up of wood material and 44% of RCC constructed buildings falls are under high risk zone. 48.45% residential building, 40.35% wood building and 83.4% office/business buildings are under low risk zone. Results predict that buildings situated at the northern and eastern part of the Arithang ward are under high risk category with respect to earthquake and landslide.

A baseline study on trace elements concentrations in reef associated sediments of Koswari Island, Gulf of Mannar biosphere reserve, southeast coast of India

S. Krishnakumar[1]*, S. Ramasamy[1], N.S. Magesh[2], T. Simon Peter[3]
[1]Department of Geology, University of Madras, Guindy campus, Chennai 600025
[2]Department of Geology, Anna University, Chennai 600025
[3]Centre for GeoTechnology, Manonmaniam Sundaranar University, Tirunelveli 62701
**Email: coralkrishna@yahoo.co.in*

Extensive field work was conducted in order to assess the sediment pollution level and potential ecological risk on coral reef ecosystem. Thirty three surface samples were collected using grid sampling technique. The calcium carbonate and organic matter were primarily controlled by the distribution of coral rubbles and seagrass meadows. The concentration of trace elements is higher than the crustal average in a few locations and the same result was derived from index calculations. However, the significant concentration of lead was observed throughout the study area. The elevated level of lead is probably due to coal incinerating power plants, and confluence of urban runoff from the nearby coastal areas. Based on the sediment pollution index, the majority of the sediments belong to highly polluted to dangerously polluted category. The ecological risk indicates that the sediments are under low to moderate risk category and this result is supported by correlation matrix results.

Surface and ground water chemistry of Payaswini - Chandragiri river system, southwest coast of India

Nisha B.K.*, K. Balakrishna, H.N. Udayashankar, Sruthi Balakrishnan
Department of civil engineering, Manipal Institute of Technology, Manipal 576104
**Email: nisha.bk@manipal.edu*

Seasonal investigation of the water chemistry of the Payaswini-Chandragiri river system on southwest coast of India was carried out to study the suitability of surface and groundwater for domestic purposes. A total of 50 representative samples were collected from various stations across this river system to monitor the spatial and temporal variability of water chemistry using the concentrations of various ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO^{3-}, SO_4^{2-}, NO_3^{-}, Cl^{-}, F^{-}), trace metals (Cu, Pb, Zn, Cd, Ni, Co and Fe) and physico-chemical parameters.

The results showed that pH, total dissolved solids, and alkalinity (HCO_3^{-}) were within the permissible limits. At a few locations, the electrical conductivity was found to be high owing to sea water intrusion. Total dissolved oxygen was found to be lower than the permissible limits in a few groundwater samples. Based on the analytical results, groundwater in the area is generally fresh. The abundance of the major ions is as follows: $HCO3^{-} > SO_4^{2-} > Cl^{-}$ and $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$. The concentration of trace metals is relatively lower in the river basin samples. Most parameters showed no pronounced seasonal variation, whereas their spatial variation suggests a strong control by lithology, soil type, slope, and vegetation.

Comparison of physicochemical parameters of the river and ground water samples with WHO 2006 and BIS limits indicated that the surface and ground waters of Payaswini- Chandragiri river system cannot be categorized as contaminated.

Integration of DGPS, total station and GPR Data for 3-D mapping of Himalayan glacier

Pawan Kumar[1]*, Milap Chand Sharma[1], Sanjay Deswal[2], Syed Umar Latif[1]
[1]CSRD, Jawaharlal Nehru University, New Delhi
[2]Govt. College, Dujana, Jhajjar, Haryana
**Email: pawan57_ssf@jnu.ac.in*

Himalayan Glaciers, a major source of fresh water for the South Asian region, are considered highly sensitive towards climate change. Glacier size and volume are critical factors for timely evaluation/assessment for both near-term and long-term changes in both temperature and precipitation and the cryosphere thereupon. Glacier area and surface morphology are mapped from both satellite imageries and aerial photographs. With the help of remotely sensed data and GIS analysis, glacier surface areas have been mapped with mean spatial resolution of 10 meters. The surface mapping with such resolution is neither able to assess the exact volume nor determine sensitivity of glacier to the recent climate. Most satellite maps are applicable for two-dimensional mapping of crysophere. Henceforth three-dimensional maps of glacier hydrological systems are necessary for volumetric assessment and long-term planning. Therefore, the integration of survey instruments such as DGPS, Total Station with millimeter accuracy, and simultaneous simulation with Ground Penetrating Radar (GPR) surveys over the mapped conduit systems will help in accessing glacier mass accurately and define sub-surface geometry for the 3-D modeling of glaciers for better understanding and estimation of fresh water resource. Further, the 3-D mapping of cryosphere will help us to assess the accurate volume of fresh water in the Himalayan cryosphere, along with contemporary dynamics. We show an

integrated approach to assess and quantify the Himalayan cryosphere by integrating such techniques for a better management and understanding of the Himalayan cryosphere vis-a-vis climatic parameters and management of future water requirements. It is an established fact that glaciers show varied sensitivity to climate over time and space, both in growing and receding. Therefore, monitoring this fresh water resource is most essential for an agrarian country like India where demand for irrigation is great in the Great Plains. Present study will represent the seamless integration of field based 3-D Total station mapping of snout of Gangotri Glacier, its GPR Profiling at selective locations, Volume estimation and annual change in the volume and its integration with the MODIS LST data in a way to assess the present glacier sensitivity to climatic variability, as well as help model future scenarios more accurately for robust management of this finite water resource.

Applications of remote sensing and GIS for identification of groundwater potential zones in K-J watershed, India

Sanjeev Kumar, B.S. Chaudhary
Department of Geophysics, Kurukshetra University Kurukshetra 136119
Email: bschaudhary@kuk.ac.in

Groundwater Potential Zone (GPZ) mapping has become more efficient with the inputs from RS and GIS techniques. Various thematic maps like geology, geomorphology, drainage density, slope and Land use/Land cover (LU/LC), etc. can be easily generated using RS and GIS. The present study deals with the groundwater potential zone (GPZ) mapping in Koshalya Jhajhara (K-J) watershed, the tributaries of Ghaggar in North-western India. K-J watershed covers an area of 134 sq kms which falls in the districts of Solan (Himachal Pradesh) and Panchkula (Haryana). The area forms rugged topography having elevation range from 399 m to 1810 m MSL. Geologically, the K-J watershed corresponds to Siwalik range in South Western (SW) part and Lesser Himalaya or Pre-Siwalik in North Eastern (NE) part. Lesser Himalaya corresponds to Subathu, Kasauli and Dagshai formations. Satellite data, SOI topo sheets, and ASTER DEM have been used for generating various thematic maps like geology, geomorphology, LU/LC, slope, drainage density. Each layer has been assigned weightage and rank and are integrated in Arc GIS so as to prepare final GPZ map of K-J watershed. It is observed that the area falls under five categories- Very good, Good, Moderate, Poor and Very Poor depending on the prospects of availability of groundwater. After analysis, it is found that only 5.83 km^2 and 4.91 km^2 area falls under very good and good category of groundwater availability whereas an area of 24.48 km^2 falls under moderate category. Maximum area of K-J watershed, i.e., 61.83 km^2 falls under poor and 37.87 km^2 area under very poor category of availability of groundwater. Suggestion have been made for the sites for check dams, earthen dams and sub-surface barriers so as to ameliorate groundwater conditions in the area.

Identification of rainwater harvesting sites using SCS-CN hydrological modeling, remote sensing and geographical information system techniques

Tarun Kumar[1]*, D.C. Jhariya[2]
Department of Applied Geology, National Institute of Technology Raipur, Raipur 492010, Chhattisgarh
**Email: tkumar.phd2015.geo@nitrr.ac.in*

This study has been carried-out at Tandula watershed, Chhattisgarh to identify potential rainwater harvesting sites using Soil Conservation Service Curve Number (SCS-CN) Hydrological

Model, Remote Sensing and Geographical Information System (GIS) Techniques to enhance the water resource. In this study, the runoff derived by SCS-CN method is a function of runoff potential which can be expressed in terms of runoff coefficient. The augmentation of water resource is proposed by construction of rainwater harvesting structures like check dam, percolation pond, farm pond, and gabion/boulder check dam. The site suitability for different water harvesting structures are determined by considering spatially varying parameters like slope, infiltration, runoff potential, land use, land cover, stream order, soil texture, land capability class, hydrological soil group, and micro-watershed area. The determined suitable site has been validated with existing recharge structures of the study area and it has been found that it is 82.60% accurate, reflecting that the applied techniques are reliable and effective.

Potential landslide damming of Satluj river: Case study of Urni landslide, Kinnaur, Himachal Pradesh

Vipin Kumar[1,2]*, Vikram Gupta[1], Imlirenla Jamir[1]
[1]Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand
[2]H.N.B. Garhwal University, Srinagar, Uttarakhand
**Email: v.chauhan777@gmail.com*

The Urni landslide (31°31'15"N, 78°7'34"E) is an old chronic one, situated on the right bank of the Satluj river in the Kinnaur district of Himachal Pradesh. The landslide has partially dammed the Satluj river since 2013-2014 with ~ 0.076 M m^3 (during October, 2016) debris on the river channel. The crown of the landslide lies at an altitude of 2160 m (above msl), close to the Urni village, which has a population of 500 (Census of India, 2011) . The landslide has damaged ~300 m stretch of the National Highway (NH)-05 and is considered to be complex type since it involves debris slide movement in the central part and rockfall at both right and left flank.

The Google Earth imagery, Cartosat-1 and LISS-IV images were analysed to see the spatio-temporal growth in the landslide. The digital elevation model was used to extract landslide slope geometry for the shear strength reduction -finite element method based slope stability analysis. The joint mapping data was used to perform the kinematic analysis. In the absence of any rain gauge station in the vicinity, tropical rainfall measuring mission rainfall data (3B42RT) was used to understand the rainfall variation in the region. Since, rainfall has been considered to act as a landslide triggering process, it may result into possible debris flow. To understand the possible impact of such debris flow, run-out analysis was performed. Finally, for predicting the potential height of the landslide dam, in case of further slope failure, volume estimation of detached debris mass and of valley sink, accumulating the debris, was also performed.

It was observed that landslide has attained 0.1 km^2 areal increase from 0.008 km^2 in year 2004 to 0.112 km^2 in year 2016. Approximately 86 % of this 0.1 km^2 areal increase occurred after 2013. Such increase in the landslide dimension was found more pronounced towards the crown since its position has moved ~ 200 m upward from 2004-2016 year. An abrupt increase in the annual mean rainfall has also been observed after 2013. The slope stability analyses revealed shear strain in the order of 0.01-0.03 with 15-20 cm displacement in the detachment zone. Further, kinematic analysis indicated planar failure condition in the rockmass. Run-out analysis showed a debris flow velocity of 20-30 m/s with a flow height of 15-20 m while confronting river channel and temporary NH-05. Thus, there might be a possibility of complete vandalization of the bridges (worth 40 million Indian rupees), connecting the temporary NH-05 with the main NH-05. Finally, it is noted that further slope failure may detach 1.15 M m^3 debris which may dam the river to a height of ~ 60 m. Such damming may also result into landslide lake outburst flood (LLOF). Thus, this study attempts to present the

existing as well as temporal trend of this landslide which may cause an irreversible socio-economic disaster in the region.

Evaluation of hydrochemical data using multivariate statistical methods to elucidate heavy metals contamination in shallow aquifers of the Manipur valley in Indo-Myanmar Range

Premananda Laishram*, K.S. Kshetrimayum
Department of Earth Science, Assam University, Silchar 788011
**Email: laishramp@gmail.com*

Descriptive statistics, factor analysis, correlation matrices and cluster analysis were used to gain insights on regional hydrochemical process and contamination in the shallow aquifers of Manipur valley in the Indo-Myanmar Range. Groundwater has remained as prime source of water supply for a population of nearly 3 million people living in this valley at present. seventeen variables (pH, T, ORP, TDS, Ti, V, Cr, Cu, Ge, As, Rb, Sr, Nb, Mo, Hf, Ta, and W) were monitored from 28 shallow wells in the year 2015. Mean pH and TDS values (6.8 and 800mg/l, respectively) suggested the fresh quality in terms of acidity/alkalinity and salinity. Most of ORP values (mean -6.75mV) were found as negative, indicating anoxic occurrence. The order of abundance of 13 trace metals was Sr>As>Rb>Ti>Cu>V>Cr>Mo>Ge>W>Hf>Ta>Nb. Sr, As, Cr, Cu and Mo were found well exceeded the WHO limits. Higher Sr elevation may be attributed to weathering of gypsum, evaporate and rock salt intercalation in Disang shales and depicted reflected factor 5 in factor analysis. Factor 2 reflected Cr, As, and Mo elevations and was attributed to geogenic origin of ultramafic rocks from Manipur Ophiolite Melange Zone. Factor 3 represented Rb, V and Cu elevations owing to natural weathering of clay, Fe-oxyhydroxides along with dissociation of solid organic carbons. Factor 4 was related to prevailing conditions of reduce environment under low pH and vice-versa. Factor 1 reflected as occurrence of Nb, Hf, Ta and Ti together as insoluble oxides. Analysis on Pearson correlation strongly supported observation made by factor analysis. Hierarchical clustering further identified two regions of low and high Sr elevations in the valley. Thus, the present study demonstrated the applicability of multivariate statistical techniques in interpretation and revealing sources of contaminations for better future groundwater management in a valley located in the Indo-Myanmar Range.

Vertical distribution of benthic foraminifera of Marakanam estuary (Yedayanthitu Kailiveli) Tamil Nadu - its environmental conditions

Lalthansangi, M. Suresh Gandhi
Department of Geology, University of Madras, Guindy Campus, Chennai 25
Email: msureshgandhi@gmail.com; tsi91ralte@gmail.com

The present study aims to understand the distribution of benthic foraminifera and environmental conditions of the core sediments collected from the estuary region of Yedayanthitu Kaliveli, Marakanam along the east coast of India. The ecological parameters such as sand-silt-clay, calcium carbonate, organic matter and trace elemental studies were done to understand the estuarine environment. Sample were collected using a core catcher (Piston corer). Total length of the core was 90 cm. The sampling as done at at an interval of 5 cm. Total 18 samples were obtained and subjected to standard micro-paleontological and sedimentological analysis for the evaluation of different sediment characteristics. The widely utilised classification proposed by Locblich & Tappan (1987) is used for the identification of foraminifera in the present study.

Calcium carbonate percentage was determined by the titration method, organic matter, Sand-Silt-Clay. The geochemical studies for total Fe, Mn, Cr, Cu, Ni, Co, Pb and Zn were carried out using a Perkin Elmer AA 700 AAS equipped with a deuterium background.

Total 26 foraminifera taxa belonging to 18 genera, 12 family, 8 superfamily, and 4 suborder have been identified. Of these, the genera *Ammonia* and *Elphidium* dominate the total assemblage followed by *Quinqueloculina*. Importantly, *Ammobaculites subcatenulatus*, *Cycoforina contorta*, and *Quinqueloculina pygmaea* are reported for the first time from this region.

Based on the sand-silt-clay ratio, it is observed that the core sediments in the study area are dominated by medium and fine sand. The organic matter percentage ranges from 0.5 to 0.6. $CaCO_3$ percentage ranges from 6.23 to 7.37. The top and middle core receives more organic matter than the bottom core which indicates the mixing of recent sediments of top surface favouring enrichment of foraminifera due to tidal action, more number of dead shells drifted and deposited in this region. Compared to the top and middle of the TFN the organic matter is lesser in the bottom core. Rapid reduction in faunal frequency and diversity may be due to digenetic processes.

Based on the grain size studies, the top of the core is moderately sorted to moderately well sorted in nature (0.70 ö to 0.657 ö) whereas, the remaining core middle to bottom is moderately well sorted. Due to high energy conditions it is moderately well sorted.

Based on the trace element studies it is observed the Fe and Cr are predominant in this region possibly due to terrestrial input. The remaining trace element concentration in this region may be due to anthropogenic input.

It is observed that silty-sand and sandy-silt are more accommodative substrate for the population of foraminifera. Further, based on the foraminiferal studies it showed that the top core, upto 30 cm is mixing environment. The middle core indicates the reducing environment and bottom core reflecting the digenetic environment.

Evaluation of inland salinization in the shallow ground water in the eastern Manipur valley, northeast India

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

To understand the control of salinization and its distribution pattern in the eastern Manipur valley of northeast India, a total of 173 shallow groundwater samples from 32 locations were collected in the year 2016. The Manipur valley is an intramontane basin filled with alluvium of fluvio-lacustrine origin of Quaternary age in the central part of the Indo-Myanmar Range. Among the 32 locations, 21 were from piedmont, 6 from alluvial plain and 5 from flood plain. Temperature, pH, ORP, TDS, saline indicators, such as Na, Cl, Br, Ba, B, Sr, Li and major ions like HCO_3, K, Mg, Ca, NO_3, PO_4, SO_4 were considered for this study. Physical parameters were measured using digital kits. Anion, cation and trace elements were measured using ion-chromatograph, ICP-AES, ICP-OES and ICP-MS. The evolution of groundwater in terms of age indicates that the groundwater of the study area is in initial or ion-exchange stage of evolution indicating fresh and recent age. However, the fresh groundwater has been affected by the inland salinization process. Our studiy reveals that the groundwater of the study area may be classified into five hydrochemical facies, namely Na-Cl, Ca-Mg-HCO3, Na-HCO3, Na-HCO_3-Cl and Ca-Mg-Cl. Saline dominated water types of Na-Cl and Na-

HCO_3 facies were observed around the piedmont zone. The study also reveals that evaporation and crystallization processes lead to halite encrustations into the Disang shale which are exposed in the piedmont areas. Negative Eh values, low NO_3 and absence of SO_4 in the groundwater under reduced condition could have led to the concentration of salts in the soil layers. Hence, encrustation of halite deposits into the Disang shale along with reduced conditions of soil together lead to elevation of dissolved salts in the shallow groundwater and its dissemination from piedmont groundwater to alluvial plain and flood plain groundwaters along the flow path.

Landslide hazard zonation along Lengpui Airport road, NH-44, Aizawl (northeast India)

P.C. Lianthangpuii[1]*, Shiva Kumar[1], Rahul Verma[2], Laldinpuia[2]
[1]Department of Geology, Mizoram University, Aizawl, 796014
[2]Department of Geology, Pachhunga University College, Aizawl, 796001
**Email: lianthangpuii.pachuau@gmail.com*

Mizoram is one of the landslide prone states in India. The main causes of landslides in the state can be listed as immature topography, heavy rainfall, slopes, seismicity and human factors. The present work attempts to undetake Landslide Hazard Zonation (LHZ) of Lengpui airport road which is strategically important for the state of Mizoram because of its direct connection with Lengpui Airport. The study area falls within Survey of India topo-sheet Nos. 84 A/9 and A/10. The specific road starts at the coordinates of N23°44'21.2" and E92°42'54.2" and ends at N23°49'10.8" and E92°37'48.8". Lengpui Airport road is directly affected by a number of landslide especially during monsoon seasons. Considering this problem, for LHZ along the highway spatial data was generate based on landslide causative factors and observed features from geology, structure, geomorphology, slope morphology, hydrology and land use/ land cover pattern. Weightage for these factors are prepared from Landslide Hazard Evaluation Factor (LHEF) rating scheme and Total Estimated Hazard Zone (TEHZ) is calculated. Forty nine stations are taken along this highway. Based on TEHZ, the study area is categorized as Moderate Hazard Zone constituting 12.24%, High Hazard Zone constitute large area of 67.37% and Very High Hazard Zone constituting fairly large area of 20.4%. Prevention and mitigation measures for each station are also suggested in order to minimize the loss of life and property.

Groundwater and surface water quality assessment and its hydrogeochemistry in parts of Cauvery delta region, Tamil Nadu

V. Manivannan[1], E. Vetrimurugan[2], L. Elango[1*]
[1]Department of Geology, Anna University, Chennai, India
[2]Department of Hydrology, University of Zululand, South Africa
**Email: elango34@hotmail.com*

Groundwater and surface water quality for domestic and agricultural purposes and its hydrogeochemical processes were studied in part of Cauvery Delta region, Tamil Nadu. Thirty two groundwater samples and seven surface water samples were collected during January 2016. EC, pH, CO_3^- and HCO_3^- were measured in situ while the concentration of calcium, magnesium, sodium, potassium, chloride and sulphate were analysed in the laboratory. General order of dominance of cations in the groundwater of this study area is $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ while that for anions is $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^-$. Mixed Ca-Na-HCO3 and NaCl type groundwaters were dominant in this area. pH, magnesium and sulphate were present within the permissible limits for drinking whereas, some

samples exceed the permissible limits of the Bureau of Indian Standards for TDS, calcium and chloride. Based upon the water quality index, all the surface water samples fall under excellent to good category whereas maximum number of groundwater samples range between poor to unsuitable category due to the coastal region. Sodium adsorption ratio, sodium percentage and permeability index indicates that all the surface water and most of the groundwater samples are suitable for irrigation purposes. Rock water interaction, silicate weathering and ion exchange processes are the processes contolling the groundwater chemistry in this region.

Sediment connectivity and dynamics of Koshi river basin

Kanchan Mishra*, **Rajiv Sinha**
Department of Earth Sciences, Institute of Technology-Kanpur, Kanpur
**Email: kanchanm@iitk.ac.in*

Sediment connectivity, i.e., the degree of linkage between the sediment sources to downstream areas, is one of the most important properties that control landscape evolution in the river basins. Several factors influence the sediment connectivity, especially at the catchment scale. In particular, the degree of linkage between different areas within a catchment depends largely on the hinterland characteristics (e.g., catchment shape, relief, terrain roughness, elevation), channel characteristics (e.g., slope, stream network density), and the combined effect of vegetation, such as land use changes and land abandonment. Moreover, the analysis of the spatial distribution of sediment connectivity and its temporal evolution can be useful for the characterization of sediment source areas.

The study evaluates the sediment connectivity of the entire Koshi basin in India and Nepal at spatial scale. We have computed the index of connectivity for the upstream, midstream and downstream parts of the Koshi basin to evaluate the potential connection of sediment source areas to the main channel network. The results provide the first order information of the spatial sediment connectivity in terms of the channel connectivity (IC outlet) and source to channel connectivity (IC channel) of the upstream, midstream, and downstream of Koshi basin. The proposed method also helped in the characterization of sediment dynamics in the complex morphological settings with the mixed type of the environment. Our results match the sediment delivery ratios derived for different sub-basins based on USLE-based sediment transport capacity models. We demonstrate that this model can be very effective for large area basis, where systematic field investigations for mapping hillslopes-channel linkages are not feasible.

Use of biotic proxies in assessing Holocene climate variability from a lake record in the central Ganga plains

Pavani Misra[1]*, Rajiv Sinha[1], Sampat K. Tandon[1], Anjum Farooqui[2]
[1]*Department of Earth Sciences, Indian Institute of Technology-Kanpur, Kanpur 208016*
[2]*Birbal Sahni Institute of Palaeosciences, 53, University Road, Lucknow 226001*
**Email: pavanim@iitk.ac.in*

To gain insights on trends in future climate variability, the past variations in climatic parameters have to be reconstructed from various stratigraphic archives. Data from instrumental records is inadequate because of limitations of time scale, and shorter climate records over the past millennium and may reflect accelerated rates of change due to anthropogenic interferences. Therefore, high-resolution Holocene paleoclimate data over a relatively longer time scale are

preferred in order to obtain some insights on the natural climate variability of the past. Past climate of India during the Holocene is understood mostly from marine sediments and a few recently published high-resolution lake records from northern and western India. However, the floodplains of the Ganga River, which represent one of the most populated regions of the country, offer the possibility of obtaining high-resolution stratigraphic data from its lakes and ponds. These lakes have been investigated previously, but their chronological constraints do not allow for high resolution reconstruction on millennial/sub-millennial timescales.

This investigation is based on three trenches that were closely sampled from a lake in the Central Ganga Plains in order to create a high resolution archive from this region and then to use multiple proxies to reconstruct patterns of Holocene climate variability. Data on biotic proxies namely, pollen, diatoms, freshwater sponges, etc. studied from one of the trenches is presented here. This trench has been constrained by a high resolution chronology based on AMS C14 dates for the period between 4.8 and 13 kyr BP. Episodes of lake formation, expansion and contraction are inferred from the diatom and aquatic pollen assemblages. The relative abundances of diatom species show fluctuations in nutrient availability, pH and temperature conditions throughout. The bottommost sediments are rich in gramineae cuticles and pollen along with the presence of angular organic debris suggesting a fluvial influence at ~13 kyr BP. Initiation of the lake at ~10.9 kyr BP, is inferred by the occurrence of *Cocconeis, a* pioneer species found to grow in oligotrophic and alkaline conditions which is synchronous with the high percentage of *Artemisia* herb pointing towards enhanced winter monsoon. Between 10.6 to 5.6 kyr BP, an intensification of the summer monsoon and lake expansion is reflected in the increased abundance of *in-situ* aquatic pollen *Myriophyllum* and *Nymphoides*, quantitative and qualitative diversity of diatom species along with increase in hinterland arboreal and non-arboreal pollen. The lake ecosystem attained its maximum expanse and stability at ~6.9 kyr BP when a peak in the ISM strength is observed. During this period and until ~5.6 kyr BP, the lake transitioned into eutrophic state with the *in-situ* organic matter accumulation and high influx from land. Thereafter, a drastic reduction in diatoms, aquatic pollen and hinterland vegetation reflects a weakened monsoon and contraction of the lake in the post-5.6 kyr period.

Distribution, sources and eco-toxicological assessment of multi-elements in the surface sediments of Hooghly river estuary, West Bengal, India

Soumita Mitra*, Santosh Kumar Sarkar
Department of Marine Science, University of Calcutta, Kolkata 700019
**Email: soumitamitra9@gmail.com*

We examined the distribution and possible sources, and undertook eco-toxicological assessment of 51 trace elements covering 13 sampling stations in surface sediments of coastal regions of Sundarban mangrove wetland and adjacent Hugli river estuary. The element concentrations exhibited an increasing trend towards down-stream of the estuary (except lanthanides) with maximum enrichment for 22 elements at Gangadharpur (Sundarban region). According to Sediment Quality Guidelines (SQGs), the concentrations of Cu, As, Cr and Cd exceeded the Effects- Range-Low values, while Ni at certain stations exceeded the Effects-Range-Medium suggesting adverse effects on the sediment-dwelling organisms. The geo-accumulation index revealed that the stations were un-polluted to moderately-polluted. Risk Index (357.61) and Enrichment factor (11.42) depicted that Nimtala station (upstream) was in the high ecological risk zone. The result of PCA endorsed that organic carbon and clay fraction play crucial role in accumulating the elements in sediments. This pilot study contributes to a better understanding of the geochemistry of this complex deltaic ecosystem.

Nitrate contamination in groundwater of a mixed rural-agricultural setup

D. Mondal*[1], D.V. Reddy[1], S.Gupta[2]
[1]CSIR-National Geophysical research institute, Hyderabad
[2]University of Burdwan, West Bengal
**Email: Corresponding author: dali_mondal@yahoo.in*

This research work is carried out to find out spatial variation of nitrate in groundwater in Vilaipally and surrounding areas having mixed agri-rural set up in Nalgonda district, Telangana. Twenty one groundwater samples are collected from borewell/hand pump covering both agricultural as well as residential rural areas. Analytical results reveal that maximum nitrate contamination of 127 - 182mg/L is restricted to rural areas whereas most of agricultural areas have nitrate concentration below the permissible limit of WHO. Significant ($p<0.01$) positive correlations of EC, TDS, chloride and sulphate with nitrate justify the nitrate contamination from domestic sewage and sanitary system of the residential areas. Nitrate contaminated groundwater is Ca-Na-Mg-HCO_3-Cl which also signifies contamination from rural areas.

Sediment dynamics and heavy mineral concentrations of Kondurupalem-Durgarajupatnam coast, Nellore, east coast of India

K. Nagalakshmi[1], T. Lakshmi Prasad[1], N. Jayaraju[2], M. Pramod Kumar[1], G. Sreenivasulu[2], B. Lakshmanna[2]
[1]Department of Earth Sciences, Yogi Vemena University, Kadapa
[2]Department of Geology, Yogi Vemana University, Kadapa

The present study was carried out to investigate the interrelations of textural characteristics and heavy mineral concentrations of sediments. It also aims at finding the temporal and seasonal variations in distribution of heavy minerals in different micro environments and their dispersal pattern in Swarnamukhi river and Tupulipalem coast Nellore. Grain size characteristics, such as central tendency, kurtosis, and skewness were estimated using an updated version of the GRADISTAT programme. A total of 90 sediment samples from 15 stations were collected along the Swarnamukhi river and Tupulipalem coast (Pre and Post monsoon, and also studied the effect of Vardha cyclone). The textural studies clearly show that the sediments are medium to fine (0.95-0.28 Ø) grained with unimodal and bimodal characters, moderate to well sorted (0.34-1.067 Ø), very platykurtic to leptokurtic (0.70-1.30 Ø) in nature and deposited in high energy environment conditions with dominate rolling, bottom and graded suspension, and tractive current mechanisms. The heavy mineral distribution was controlled by mean size, sorting, density and erosion/accretion processes. The heavy mineral weight percentage ranges from 13.5% to 100% in August 2016 to 29.6% to 100% in December 2016. The heavy mineral concentrations ranges from 0.07% to 99.3% in dune environment, from 6.8% to 98.3% in backshore environment, from 20% to 100% in berm environment and 17.8% to 90.53% in foreshore in SW Monsoon season. However, in NE Monsoon season, the heavy mineral concentrations ranges from 4% to 100% in dune environment, from 6.6% to 100% in backshore environment, from 22% to 100% in berm environment and from 43.6% to 94.4% in foreshore. In the present study area the heavy minerals are increased from NE to SW monsoon season.

Anthropogenic spherules: connecting past to Anthropocene period in geoscience

Ambalika Niyogi
Department of Earth and Planetary Sciences, Nehru Science Centre, University of Allahabad, Allahabad 211 002
Email: ambalika.niyogi@gmail.com

Study of spherules and spherule layers, in general, is increasingly becoming more important in planetary geosciences with the increase in reports of various types of ejecta layers. Although spherules indicate that they are neither an indicator of impact processes nor of melting. The varying modes of spherule formation in nature with analogous morphology and distinct chemistry can be observed. The fly ash silica-rich spherules have a similar and striking morphology with microtektites, impact spherules and other terrestrial and extra-terrestrial spherules, but chemical disparity. This study pertains to the varying shape, size, colour, surface texture and chemical composition of anthropogenic fly ash spherules (Allahabad city, India) from terrestrial and extra-terrestrial spherules. The 8463 anthropogenic spherules were microscopically handpicked from the road-deposited sediments (RDS). The size of the spherules ranges between 2 µm and 3000 µm. The spherules types observed include, solid sphere, cenosphere and plerosphere. The shapes of spherule vary from spherical, ovoid, dumbbell, tear-drop to cylindrical. The major oxide composition in anthropogenic spherules with SiO_2 content ranges between 67.10 and 77.07 wt.%, Na_2O (0.19-6.79 wt.%), Al_2O_3 (1.21 and 3.63 wt.%) and K_2O (0.26-1.04 wt.%) values whereas the iron content FeO is low (0.07-0.40 wt.%). It is variable compared to microtektites and impact spherules while interestingly, the REE patterns amongst the spherules are similar with microtektites and impact spherules is relatively due to fO_2. Thus, anthropogenic spherules are morphologically identical and chemically distinct to microtektites and impact spherules. Therefore, anthropogenic fly ash spherules are equally important as the extra-terrestrial spherules and can be used as a connecting linkage from past to recent anthropocene period with other types of spherules.

Application of morphometric analysis for geo-hydrological studies of Harhora basin, Jharkhand, India

Pramod Kumar Pandey
Department of Earth & Planetary Sciences, University of Allahabad, Allahabad
Email: ppgeom@gmail.com

The morphometric analysis of the drainage basin and channel network play an important role in understanding its geo-hydrological behavior. It expresses the prevailing climate, geology, geomorphology and structural antecedents of the catchment area. An attempt has been made to study the drainage morphometry and its influence on hydrology of Harhora Basin, north-eastern Chhotanagpur Plateau, Jharkhand. Cartosat-I Stereo pair data is used for preparing Digital Elevation Model (DEM) at 10 m resolution. Geographical information system (Arc GIS 10) is used for evaluation of linear and areal aspects of morphometric parameters. The study reveals that *the Harhora Basin has 5th order river network with a dendritic drainage pattern.* The dendritic drainage pattern indicates that the basin has homogeneous lithology, gentle regional slope and lacks structural control. The low mean bifurcation ratio of the entire basin indicates that the basin has good permeability and the drainage pattern is not much controlled by the geological structures. Over all stream frequency, drainage density, drainage texture and Infiltration rate for Harhora river sub- basin are 2.13, 1.08, 0.52 and 2.30 respectively. The low drainage density and stream frequency are due to

the highly permeable subsoil, with good permeability of sub-surface material and dense vegetative cover with mature relief. The overland flow is significantly affected by infiltration and percolation through the soil, both varying in time and space. Harhora basin's Form factor, Circulatory ratio and elongation ratio are 0.46, 0.26 and 0.43, respectively. The form factor, Circulatory ratio, elongation ratio in association with some other areal (drainage density, drainage texture, etc.) parameters indicate that the basin is slightly elongated, has low discharge of runoff, generally permeable subsoil condition, moderate to high infiltration capacity and good groundwater resource.

A 312 years precipitation reconstruction of Anantnag district, Kashmir valley using tree-rings of *Cedrus deodara*

Uttam Pandey*, Santosh K. Shah, Nivedita Mehrotra
Birbal Sahni Institute of Palaeosciences, 53, University Road, Lucknow 226007
**Email: uttampandeygeo@gmail.com*

The available precipitation records in the Kashmir valley are of very short periods. To understand its variability and dynamics, long term data is required which can be achieved through proxy records. Tree-ring is one of the proxies which gives high resolution annual climate data. Hence with an aim to reconstruct annual to multi-decadal precipitation, tree-ring studies on Deodar (*Cedrus deodara*) were carried out in Lidder valley, Kashmir Himalaya. Three tree-ring chronologies were developed which showed good agreement among each other. The correlation between tree-ring chronologies and Anantnag district precipitation showed significant positive relationship with April-June precipitation. Based on this relationship, we reconstructed April-June precipitation since 1699 C.E. using principle component regression approach. On the basis of percentile distribution, the extreme dry and wet events have been identified in the reconstruction. The reconstruction has also been compared with documented extreme flood, famines and drought events in the Kashmir valley occurring in those 320 years.

Paleochannel mapping of terminal fans in the Ghaggar-Yamuna interfluve and its tectono-climatic implication

Narendra K. Patel*, Pitambar Pati
Department of Earth Sciences, Indian Institute of Technology-Roorkee, Roorkee
**Email: narendrap9@gmail.com*

Luminescence chronology of the terminal fans in the Ghaggar-Yamuna interfluve suggests that these were formed during cold and warm climates in the mid to late Holocene. Paleochannel mapping on terminal fans in the interfluve reveals the tectonic and climatic influence during and after their formation. Though at present, paleochannel mapping is of tremendous importance for the area in terms of groundwater exploration, however, this reveals the paleochannel characteristics influenced by neotectonics and climate change in the western Himalayan foreland basin. Using remote sensing, Cartosat DEM, and Survey of India toposheets possible paleochnnels were mapped and some of them were studied in the field.

We have analyzed the paleochannels orientation data and climatic data in the Ghaggar-Yamuna interfluve. Paleochannel geomorphology of six out of eight terminal fans suggests SW channel flow direction. The present channel orientation mapped from five terminal fans shows channel flow direction of SW. However, the presently active channels show orientation NE-SW to

NW-SE towards the eastern margin but remains same in the central and western part of the area. These changes may be attributed to tectonic tilting of the fault bounded block due to the influence of compression between the peninsular shield and the Himalaya. Recent literatures suggested SW compression due to Indian plate movement and hence most of the longitudinal faults show curvilinear nature. The Ganga plain geomorphology is mainly controlled by the Himalayan tectonics. Hence in the present study emphasis has been given to tectonic tilting of the area which is responsible for the change in drainage geomorphology. The present study suggests that most of terminal fans in the area were formed in warm climate while only two fans were formed in cold climate. It has been observed that, the fans formed in the warm climatic condition show calcrete development with the sedimentary sequence. However, such features are absent in the fans formed in the cold climate. But the fans formed in the cold climatic condition are rich in organic mud deposits. On the basis of climatic conditions prevailing during the formation of terminal fans, these can be divided into groups of warm and cold terminal fans.

A study on nature of colloids in groundwater of the Kalpakkam region, Tamil Nadu (India)

Pradeep K[1]*, Chidambaram S[2], Seshadri H[3], Banaja Rani Panda[1], Kaviyarasan R[4], Nepolian M[1], Vasudevan U[1]

[1]Annamalai University, Annamalainagar 638002, Tamilnadu, India
[2]Scientific officer, Kuwait Institute of Scientific Research, Kuwait
[3]Safety Research Institute, Atomic Energy Regulatory Board, Kalpakkam, Tamilnadu, India
[4]Environment and Water Resources Division, Department of Civil Engineering, Indian Institute of Technology, Chennai 600036, India
**Email: pradeep619rep@gmail.com*

Colloids are sub-micron level metastable particles usually ranging in size from 1 nm to 1000 nm. Because of their ubiquitous nature, they can be in any type of dispersed form. Two coastal bore wells namely, Kalpakkam and Anupuram were selected to study the nature of groundwater colloids by different analysis and techniques. Season wise data was used for an improved quality of the research finding. Morphology of the groundwater colloids was examined under the scanning electron microscope. It shows saccroidal structure present in the Kalpakkam region and these are finer than those of Anupuram. The surface charge of the colloidal particles was negative in nature. So, they could attach to positive ions. Also, the particles got finer during southwest monsoon season. The elemental studies like XRD, XRF and FTIR studies prove that the predominant minerals are Kaolinite, Illite, Chlorite and Feldspar. Strontium and Cesium concentration and heavy metals concentrations were analysed by four different fractions and it was good relation with colloid particles. Due to their size and capacity to attach ions and their migratory character, the study of the nature of groundwater colloids plays an important role in many fields of research, especially in radioactive waste depositary sites.

Medium scale seismic microzonation in Chamoli and Rudraprayaga districts of Uttarakhand using GIS techniques

Ramesh Pudi*, Tapas R. Martha, K. Vinod Kumar
National Remote Sensing Centre/ISRO, Balanagar, Hyderabad 500037
**Email: pudiramesh009@gmail.com*

Medium scale seismic microzonation map was prepared in the region of Chamoli and Rudraprayaga districts, Uttarakhand state. Chamoli region is seismically active since it has experienced Chamoli earthquake (Mw=6.8) in 1999 and recently on 6th February, 2017 (Mw=5.6). Tectonically, there are few active faults in this region, e.g., Main Central Thrust (MCT), Alakananda fault to the south of MCT and the North Almora Thrust (NAT). In the present work, we have used Geomorphology layers generated by Topographic Position Index (TPI) method using Cartosat 10 m Digital Elevation Model (DEM), Lithology layer of GSI which was modified based on propagation of seismic waves in different types of rocks, Soil maps from National Bureau of Soil Surveys (NBSS), Slope layer prepared from Cartosat 10m DEM and site classification done using shear wave velocity (Vs30). Vs30 was calculated from topographic slope gradients as a proxy, Site Response (SR) was estimated from Horizontal to vertical spectral ratio (also known as Nakamura technique). Strong motion data were used in this analysis. The strong motion stations are installed by the IIT Roorkee. The Peak ground acceleration layer was estimated from waveform data. Liquefaction potential map was prepared using geomorphology, lithology and few well data points. These layers were integrated using Analytical Hierarchy Process (AHP) in Geographic Information System (GIS). Following the AHP, weightages assigned to each layer are Site response (0.22), PGA (0.19), geomorphology (0.15), Vs30 (0.14), liquefaction potential (0.12), slope (0.10), soil (0.06) and lithology (0.03). Normalized ratings were assigned on 1-10 rank scale. Five hazard zones are demarcated. High hazard zones were identified below the MCT and on either side of the Alakananda fault. Preparation of seismic microzonation map at regional level will be attempted using geospatial data and site response analysis.

Recent Foraminifera from the beach sands of Kayalpattinam to Manapad coast, Tamilnadu, India

K. Radhakrishnan, S.M. Hussain*
[1]Department of Geology, University of Madras, Chennai 600025
**Email: smhussain7@hotmail.com*

In order to study the distribution of Foraminifera in the beach sands of Kayalpattinam to Manapad Coast, Tamil Nadu, 25 samples and equal number of water samples were collected. The microfauna were separated from the sediments by using various micropaleontological techniques. The widely utilized classification proposed by Locblich & Tappan (1987) for Foraminifera, has been followed in the present study. From this study, a total of 30 species of foraminifera belonging to 20 genera were identified. The species of formainifera recorded are characteristic of shallow, inner shelf and are tropical in nature. The collected water samples were used to analyze for temperature, pH and salinity, whereas the sediment samples were used for estimating the parameters such as $CaCO_3$, organic matter and sand, silt, clay ratio. Sand and siltysand are the substrate recorded in the study area and it appears congenial for the population abundance. In the present work, it is also found that some of the identified foraminiferal species got predated and some species exhibit different colouration on the tests. The light colour of tests indicate that these species were deposited under normal oxygenated

environment. Occurrence of a few broken and abraded tests indicates the high amplitude of tidal agitation and comparatively low deposition of sand in the beach environment of Kayalpattinam to Manapad coast.

Hydrogeology of Jilledubanderu river basin, Anantapur district, Andhra Pradesh, by using remote sensing and GIS

M. Rajasekhar*, G. Sudharsana Raju, R. Siddiraju
Department of Geology, Yogi Vemana University, Kadapa, Andhra Pradesh
**Email: sekhar.raja042@gmail.com*

Water is an essential natural resource for the sustenance of human civilization for drinking, municipalities, irrigation and industries. The largest available fresh water on the planet of Earth is Groundwater. Now a day's ground water is depleting faster in rural areas as well as urban areas of India and irrigation systems are expanding and converting from rain-fed agriculture to irrigated agriculture, to improving the food security and economic growth consequently threatening the water resources sustainability. The water demand is increasing everyday with the rising population, expanding of urbanization, agriculture and escalating industrialization with the passage of time. It will not be too long before fresh water becomes the limiting factor in biological, economic and social growth throughout the world. Geospatial technology has emerged as a powerful tool for monitoring the natural resources of Earth including Groundwater. Remote Sensing (RS) gives the detailed information in space and time not only from accessible areas, but also from inaccessible areas. The basic principles of Remote Sensing and GIS as well as their role in hydrological studies, including water quality monitoring of water resources of the study area deal with the aquifer response to the ground water exploitation of the Jilledubanderu basin situated in Anantapuramu district, Andhra Pradesh. The basin is located between 77°48'34"E to 78°58'11"E longitude and 14°05'35"N to 14°26'45"N latitude. The entire geographical area of the river basin is 459 km^2 falling in the topo sheets of 57F/15, 57F/16 of scale 1:50,000 and covers the Puttaparthi, Mudigubba, Pamdurthi and Mandals in Anantapur district, Andhra Pradesh. The study area experiences severe drought conditions very frequently nowadays due to lesser rainfall, as compared to average being less than 468.6 mm. Hence the available groundwater quantity is decreasing year by year. To overcome this, artificial recharge is one of the solutions to tackle the water problems of the study area by constructing artificial recharge structures. The geology and structural thematic maps will be useful to locate tentative sites for constructing artificial recharge structures through RS and GIS. The present research will definitely bring out more recommendations useful to invent more sources, but also more solutions to tackle the water issues of the study area.

A morphotectonic study in a part of Indo-Burmese range in Champhai district of Mizoram, India

Raghupratim Rakshit[1]*, Devojit Bezbaruah[1], Bubul Bharali[2]
[1]Department of Applied Geology, Dibrugarh University, Dibrugarh 786004, Assam
[2]Pachhunga University College, Aizwal 796001, Mizoram
Email: raghupratim@gmail.com

Mizoram fold belt situated in geologically complex Indo-Burmese Ranges, comprises arcuate sedimentary belt. This NS trending mountain series is cut by a number of parallel to subparallel NNE-SSW, NE-SW and NW-SE tectonic features. This tectonic characteristic is well

observed and studied in the easternmost part of Mizoram. The Study area lies in the Champhai district of eastern Mizoram, near Indo-Myanmar border. The Champhai town is actually a broad anticline with eroded hinge, dominantly composed of thickly bedded argillaceous facies. Data products used in the present study are topographic maps, satellite imageries, Digital Elevation Model (DEM), and geological data collected from field investigations. In this study, a morphodynamic model has been proposed for the region. Morphotectonic parameters, viz. Asymmetric Factor (AF), Transverse Topographic Symmetry Factor (T), Stream Length gradient index (SL), and Basin shape indices (Bs) were calculated for 40 basins of different order. Tuipui River had been originated near Champhai town which is supposed to be paleo-lake. The two major rivers Tuipui and Tayo have similar entrance meander patterns which might have been controlled by some structural features. Most of the other drainage shows rectangular, oval and circular pattern. The eastern basins of the Tuipui river mostly show WNW highly asymmetrical (|AF|=range IV) tilted basins whereas the western basins show SE moderately asymmetrical (|AF|=range III) tilted basins. The basins on the eastern part of the Tuipui water-divide show moderate to high asymmetry and SSE tiling. Although the basins near to the origin of Tuipui River and some of the surrounding areas, viz., Paleo-Champhai Lake, Khuai Lui and five others show symmetrical to moderately symmetrical basins (range I-II). On an average the elevation varies a little among the range I to range IV basins; the highly asymmetrical basins show 1500m to 1300m (in northern part and southern part respectively) and symmetrical basins have mean elevation of 1450m. Elongated to moderately elongated basins show many anomalous SL points which coincide with the lineaments and tectonic features in the area indicating activeness of the region. Macro and micro lineament plots indicate different trends in local stage although most of them follow the regional NW trends. This regional trend is quite opposite to the NNE stress component of the Indian plate w.r.t. Burmese plate. The activity of the area is said to be very low which is contradictory result as compared to the epicentral plots of recent time. This effect can be optimized through field data and understanding the regional subsurface activity in the region. The profile along different transects and the geological characterization across the study area reveals that the area is punctuated by many fault systems and they control the dynamic denudation processes. Most part of Champhai town is situated in the plain area with a number of small hillocks. This plain area is formed by sedimentation in a paleo-lake which was present earlier in the area. Similar feature is observed in the Rihdil Lake, 18 km away from the town. The study area experienced many tectonic processes. Tayo and Tuipui thrusts are the principal bounding components. Fold-propagating thrusts and faults along with denundation processes shaped the morphology of this area.

GIS based groundwater potential mapping of Hisar district, Haryana

Reeta Rani*, B.S. Chaudhary
Department of Geology, Kurukshetra University, Kurukshetra
**Email: reetakuk23@gmail.com, bsgeokuk@gmail.com*

Groundwater is a precious natural resource which is essential for life on the planet Earth. It is a fundamental natural resource for the economical and secure provision of drinking water and plays a critical role in human well-being. It is estimated that approximately one third of world's population use groundwater for drinking. It is a critical resource for which groundwater resource mapping is required. In the present study, Groundwater potential mapping of Hisar district has been done using weighted overlay analysis of groundwater depth, groundwater quality for Domestic and Irrigation purpose, and geology and geomorphology of the area in ARCGIS Software. Ranks have been given to individual parameters of each thematic map and weight has been assigned according to influence of the parameter. After integration of all parameters, groundwater potential map of Hisar district for year 2014 has been prepared. After overlay analysis of groundwater depth, groundwater quality for

Domestic and Irrigation purpose, geology and geomorphology of Hisar, study area is divided into four groundwater potential zones- good, moderate, poor and very poor. It is observed from the groundwater prospects map that 2345.40 sq. km area comes under moderate groundwater potential zone and very small area of 492.68 sq. km falls in good groundwater potential zone. It is found that area of the Barwala and Hansi-II blocks falls under good potential zones. Area of blocks- Hansi-I, Narnaud, Barwala and Uklana are covered in moderate category of groundwater potential zone. Most part of Hisar district falls under moderate category. A small part of Hisar-II and Agroha blocks are covered under very poor category. Adampur and Bhattu Kalan are the blocks which are completely covered in very poor category. The comparison between palaeochannel map and groundwater prospects map of Hisar district indicates that palaeochannel areas are found to be under good to moderate zones whereas the remaining parts comes in poor to very poor groundwater potential zones.
Keywords: Groundwater, Domestic, Irrigation, Hisar, Overlay analysis

Millennial-scale climate variability in the eastern Arabian Sea during the past 30,000 years BP

P. Saravanan[1]*, Anil K. Gupta[1,2], Mruganka K. Panigrahi[1], Aditya Kharya[2]
[1]Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721302
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: geosaran.jan26@gmail.com*

Millennial-scale climate changes on the time scales of glacial-interglacial cycles have been documented in numerous proxies such as deep-sea sediments, tree rings, lake sediments and speleothems. Benthic foraminifera and oxygen isotope ratio are one of the most significant proxies to decipher past climate variability. In the present study, we used benthic foraminiferal relative abundances and oxygen isotope ratio (ä^{18}O) as proxy to reconstruct the influence of glacial-interglacial cycles on benthic foraminifera during the Late Quaternary (30,000 cal yr BP) from sediment core SK291/GC11, eastern Arabian Sea (EAS). The core is located at a water depth of 101 m (12°52.25'N, 74°05.86'E). The statistical analysis (factor and cluster analysis) was performed on 25 highest-ranked benthic foraminiferal species that enabled us to identify seven biofacies, indicating the varied nature of environments during the past 30,000 cal yr BP. The biofacies Ba-Rs is indicative of dysoxic bottom waters with intermediate organic flux during ~29,079 to 23,746 cal yr BP. Biofacies Tc-Na reflects typical marine shelf environment with high speed of bottom currents over the ~24,687-18,098 cal yr BP. Biofacies La-Up reflects moderately eutrophic environment with organic rich sediments and low oxygen waters spreading over ~8,843-3,189 cal yr BP. Biofacies Ea-Gn reflects shallow, inner shelf marine environment with intermediate organic flux spread over ~17471 to 4,137 cal yr BP whereas biofacies Bm-Up indicates high organic carbon and low dissolved-oxygen bottom water conditions encompassing ~7,274 - 3,244 cal yr BP. Biofacies Cp-Ag reflects low-oxygen and shallow inner neritic conditions with high productivity ranging from ~3,115 to 3,060 cal yr BP. Biofacies Cc-Np biofacies reflects high organic productivity and low oxygen conditions during ~3,152 to 2,656 cal yrs BP. The ä^{18}O ratio of *Ammonia gaimardii* also indicates general cooling during 27,000-17,000 cal yr BP and 11,700-2,700 cal yr BP which is marked by increased ä^{18}O values. Our multiproxy records reveal several cold periods, such as Younger Dryas, Heinrich event 1 and 2 mainly influenced by the changes in hydrography and global ice volume.

Remote sensing and GIS based land use /land cover change detection mapping of Chitrakoot district of Bundelkhand region, Uttar Pradesh, India

Dev Sen Gupta[1]*, Umakant Rawat[2], Shashikant Tripathi[3], Parthopratim Ghosh[4]
[1,4]Department of Geology, Centre of Advanced Study, Banaras Hindu University, Varanasi 221005
[2,3]Department of Remote Sensing and GIS, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidalaya, Chitrakoot, Satna, M.P.
**Email: devsengupta.28@gmail.com*

Land use/ Land cover maps provide a statistical and vital data for spatial planning, management and utilization of land. The aim of this study is to detect land use/ land cover change from 2006 to 2016 using satellite images of Landsat-8. Land use / land cover change has become a central component in current strategies for managing natural resources of a region. Urban expansion has brought serious losses of agriculture land, vegetation and water bodies. Remote Sensing and Geographic Information System technology are providing new tools for monitoring these fast land use changes. The present study using Landsat-8 data demonstrates the scope, methodology and outcomes of land use/land cover change mapping of Chitrakoot district, Uttar Pradesh of Bundelkhand region. The land use/land cover classes are categorized into eight categories. Agriculture land has decreased between 2006 and 2016. Major changes that occurred from 2006 to 2016 are seen in built-up, agriculture land, water bodies and wasteland.

Active tectonic morphometric studies of the frontal Siwalik terrain in the vicinity of Ravi river, northwestern Himalaya, India

A.R. Chaudhri[1], Vikram Sharma[1]*, Rajesh Ranga[1], Yoginder Singh[1], Sarita Mann[1], Mahavir Singh[2]
[1]Department of Geology, Kurukshetra University, Kurukshetra 136119
[2]Govt. of Haryana Agriculture Department, Kurukshetra 136119
**Email: 12sharmavs@gmail.com*

Active tectonic morphometric studies of the sparsely investigated frontal Siwalik terrain south of the Surin-Masatgarh anticline in the vicinity of Ravi river reveal the presence of NW-SE trending active sinistral strike-slip fault with oblique slip component which is being named as the Goran Fault and has a surface expression of 100 km. The Ravi river, the Sahaar Khad, the Ujh river and the Tarnah Khad exhibit significant stream offsets where the fault crosses these channels. The stream offsets is of the order of 2,500 m in the Ravi river, 2,000 m in the Sahaar Khad, 3,000 m in Ujh river and 2,500 m in the Tarnah Khad. The terrain in the vicinity of Basantpur-Jugial region reveals a complex junction of three active faults that have been identified in the present study. Besides the Goran active fault, a fold-propagated fault exists between the rocks of the Upper Siwalik and the Middle Siwalik sub-group which trends in the NW-SE direction. The Ravi river breaches the frontal Siwalik hills through a NE-SW trending dextral tear fault with a conspicuous oblique slip component. This active fault is being named as the Mukteshwar-Ravi tear fault. The more significant tectonic morphometric indices have been calculated for the streams where the cross the active Goran Fault. For Ravi river the value of Stream Sinuosity index (Si) is 1.868, Stream Length gradient index (SL) is 183, Valley floor width to valley height ratio (Vf) is 0.121, Mountain Front Sinuosity index (MFSi) is 1.6, Asymmetry Factor (AF) is 22.34, basin Elongation ratio (Eb) is 0.580 and Hypsometric integral (Hi) is 0.421 suggests that the fault is tectonically active. The fold propagated fault and the Mukteshwar-Ravi tear fault induced river ponding resulted in the development of six

asymmetrical river terraces in the south-eastern block. The active tectonic study in the region reveals that terrain is tectonically active and can be placed in tectonic active class I.

A glimpse on the hydrogeochemical issues of water resources of Barak valley Assam, northeast India

Khangembam Sharmila*, K.S. Kshetrimayum
Department of Earth Science, Assam University, Silchar 788011
**Email: sharmikh88@gmail.com*

The Barak valley of Assam is one of the most fertile regions of northeast India covering an area of approximately 7000 km^2 in 3 districts. This fertile valley has been one of the main contributors in agricultural products of the state. Hydrogeochemical studies play an important role in managing the water resources which is vital in successful production of resources. The common hydrogeochemical issues prevailing in this valley have been identified as fluctuation of water resources in different seasons leading to water logging and shortage of water and elevation of Fe, Mn. In the Holocene sediments regional geotectonic influence on aquifers leads to anomalous characteristics. Despite this very limited studies have been attempted for eliciting the issues. Therefore, a through integrated hydrogeological studiy emphasing on surface water and groundwater interaction, water resources fluctuation, hydrogeomorphology, hydromorpho-tectonology and hydrogeochemistry is necessary for better water resource management of this valley.

Study of Kangra re-entrant and associated morphotectonic features based on remote sensing and GIS

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

The Kangra Re-entrant in the NW Himalaya is one of the most seismically active regions in the Himalaya. It is bounded by the HFT in south and MBT in north in Himachal Pradesh. Ongoing tectonic activity in the region is well indicated by moderate to large magnitude earthquakes, as well as prominent tectonically controlled geomorphic indicators. For this reason it has attracted the attention of geomorphologists for several decades. Identification of morphotectonic features, analysis of drainage network and finding out its relation totectonics are the main objectives of the present study. Therefore, an integrated approach of Remote Sensing and GIS is used to identify significant morphotectonic features in the area. In order to carry out the present study we collected satellite images of different years and DEM data from the USGS. We performed several operations to process those using ArcGIS and ERDAS Imagine. After processing, we analysed them to identify the morphotectonic features. We observed that due to Kangra re-entrant structure, a large number of landforms have developed which are marked by NW-SE trending linear ridges. Extensive river network have been formed in the area and rivers have crossed these ridges at several places. High density drainage has developed in the central part of the re-entrant. The longitudinal profile of the Beas River clearly shows the HFT, the Jwalamukhi thrust and the MBT. Among these, Jwalamukhi thrust and MBT are very prominent. River becomes braided within the Kangra valley after entering Jaisingpur and near Jwalamukhi thrust the sinuosity of the river increases and deep gorges can be seen before the thrust.

Combating climate change: a need for food and water security

Laishram Sherjit Singh
Department of Environmental Studies, North East Hill University, Shillong 793022
Email: sherjitlaishram@gmail.com

Climate change is a natural phenomenon that refers to the average increase or decrease in the earth's surface temperature. We cannot prevent it but, we can minimize its negative effects to some extent. Nowadays human enhances climate change rapidly and it becomes a global issue. The record of human modification of the environment spans at least 2.5 million years. The study of humans evolution shows that human have evolved over a long period of time in the face of environment challenges and opportunities. Human activities like burning of fossil fuels, using of air conditioners and refrigerators produce greenhouse gases (GHGs) that increase earth's surface temperature. The increase in temperature causes loss of land (due to sea level rise) and biodiversity (due to submerging of land), etc. that threatens the food and water security of the people. Combating climate change is not an easy task. Sustainable development (development without harming the environment), participatory management of land (may be forest or mountain) and water resources are the means to combat climate change. We should reduce the emission of GHGs as much as possible.

Implication of morphometric parameters of Rihand river, central India: Using GIS and remote sensing

S. Singh*, K. Prakash
Department of Geology, Banaras Hindu University, Varanasi 221005
**Email: geosaurabh@gmail.com*

Rihand River is one of the major tributaries of the Son River. The morphometric parameters of the groundwater-fed Rihand River, originating in the Gondwana's rocks, was analyzed using SRTM, satellite data. It covers an area of about 13,441 km^2. The analyses indicate dominance of first order streams, low surface run-off, and low sediment production. Overall drainage pattern of the Rihand River is dendritic in nature while trellis drainage patterns are also recognized. The bifurcation ratio and high gradient ratio indicate an undulatory topography. The bifurcation ratio value (3.8) of this basin describes that the drainage is carved naturally by slope and local relief. The Rho coefficient (0.16) for this basin indicates low water storage capacity, spreading of water and concentration of maximum discharge in the distal part of the Rihand basin. It indicates that whenever precipitation is high in the catchment area there is flood in the distal part of the basin.

Morhometric parameters provide valuable information for the forecast of basin behavior during heavy rainfall that generates floods. Suggest that water resource management planning should be done with reference to the morphometric parameters.

Flash flood records in the NW Himalaya over the last three millennium

Shweta Singh*, Anil K. Gupta, Som Dutt
Wadia institute of Himalayan Geology, Dehradun 248001
**Email: Eshweta@wihg.res.in*

Flash flood is considered to be the most destructive extreme event. Indian sub-continent has faced numerous flash floods in the last few decade like Kedarnath event of 2013; Kashmir flood of

2014; Chennai flood of 2015. These floods had cascading effects on society in terms of loss of life and property. The understanding of flood occurrences in the past would be useful in studying the frequency of these events in the future.

In the present study, we have analyzed a 15 m core sediment from the Rewalsar Lake (Himachal Pradesh) to reconstructing history of flash floods in the NW Himalaya over the last three millennia. The Rewalsar Lake is located in the vicinity of Siwalik Group of rocks to the south of Main Boundary Thrust or MBT. The lake possesses the catchment area of around 173.12 ha. The catchment is mainly comprised of fine grained sandstone, grey siltstone, and shales.

The grain-size composition of sediments is used to describe the changes in the sedimentary environment related to hydrologic energy variations. The temporal variation of the grain size distribution of the Rewalsar core sediments shows a high variability. Silt is the dominant grain size distribution in the Rewalsar core sediments. However, it also shows increased percentage of sand sized particles at ~ 1900 AD, ~1150 AD, ~650 AD. This indicates an abrupt increase in the erosion in the lake catchment due to intense floods and high rainfall in the region. During the Little Ice Age (LIA) the grain size composition shifted towards the finer sediments showing decrease in precipitation rate.

Estimation of evapotranspiration from terrestrial water budget computations over the major Indian river basins

Aarti Soni*, T.H. Syed
Dept. of Applied Geology, Indian Institute of Technology (Indian School of Mines), Dhanbad 826004
**Email: aartisoni2288@gmail.com*

The proper assessment of evapotranspiration (ET) is a fundamental issue around the world. Investigation of changes in the spatial and temporal distribution of key hydrologic variables, such as terrestrial water storage and ET has great socio-economic significance in India. Till date there have been a few concerted efforts towards a holistic estimation and characterization of these key variables. The objective of this study is to assess long-term (1980-2014) variations in terrestrial water balance estimated ET over the Ganga, Godavari, Krishna and Mahanadi river basins. For a short-term period (2003-2014) terrestrial water balance (TWB) computations utilize different GRACE solutions (CSR, GFZ, JPL, MASCON and GRGS). In this study a variety of approaches are used to compare ET estimates, which include Land Surface Model Simulations (LSMs), Atmospheric Water Balance (AWB), Energy Balance (EB) and MODIS satellite-based estimates. Additionally, terrestrial water storage changes from storage-based approach and terrestrial water storage anomaly from flux-based approach were compared with GRACE-based terrestrial water storage estimates. The comparative study of different ET products shows that the magnitude of AWB-ET is high in the Ganga, Godavari, Krishna and Mahanadi river basins. The lowest magnitude is observed in MODIS satellite-based ET estimates while moderate monthly mean is observed in TWB-ET, EB estimated ET and LSMs based ET in all the river basins. We also performed trend analysis which demonstrates that change in annual TWB-ET is statistically significant in the Ganga and Krishna river basins whereas insignificant trends are noted in the Godavari and Mahanadi river basins. Subsequently, this study also shows the factors controlling variations in ET which indicates TWB-ET is dominantly influenced by hydrologic fluxes.

Geochemical assessment of fluoride contaminated groundwater in Dwarka river basin, Birbhum, West Bengal using multivariate statistical analysis and geospatial modelling

Raju Thapa[1]*, Srimanta Gupta[1], D.V. Reddy[2]
[1]The University of Burwan, Burdwan, West Bengal
[2]National Geophysical Research Institute, Hyderabad
**Email: razoothapa44@gmail.com*

Dwarka river basin is located in the western most part of West Bengal sharing its boundary with Dumka in Jharkhand and Murshidabad and Burdwan district of West Bengal. In Birbhum district, Dwarka river basin is one of the highest fluoride contaminated areas with value as high as 13 mg/L. A preliminary GIS approach is carried out to demarcate the potential fluoride contamination zone (PFCZ) within Dwarka river basin. To delineate the PFCZ, various conditioning factors influencing fluoride contamination in groundwater i.e., geology, geomorphology, aquifer type, soil type, groundwater table level, land use land cover, lineament and fault density, drainage density, rainfall pattern, slope and elevation are integrated in ArcGIS environment. Very extensive water samplings are made by collecting 607 samples covering major areas along the Dwarka River with potential high fluoride areas. High fluoride zones accounts for approximately 11% of the total area with majority of high fluoride zones lying along the flood plain of Dwarka River basin with the fluoride concentration ranging from .001 to 10.6 mg/L. Person's correlation shows moderate positive correlation of fluoride with Na^+ (r = 0.354) and pH (r = 0.338) while negative moderate correlation is observed with Eh (r = -0.323). Fluoride contaminated groundwater mainly localized in certain restricted patches along the discharge zone of the Dwarka river basin. These patches are primarily restricted along the convex side of the meander bends. The groundwater in the study area is generally of six major types i.e., Ca-Mg-Cl-SO_4, Na-HCO_3, Ca-Mg-HCO_3, Na-HCO_3-Cl, and Na-Cl. About 46% and 35% of fluoride contaminated water samples (>1.5 mg/l) have Na-HCO_3-Cl and Na-HCO_3 type of groundwater, respectively. Gibbs diagram (Gibbs, 1970) indicates the sediments -water interaction can be major source of ions in groundwater in comparison to precipitation and evaporation. Approximately 98% of samples indicate significant contribution from non-carbonate source when represented in (Ca^{2+}+ Mg^{2+}) vs (HCO_3^-+SO_4^{2-}) plot. Principal component analysis (PCA), performed with 15 measured geochemical parameters for 607 groundwater samples, shows four major principal components (PC) (PC1, PC2, PC3 and PC4) explaining approximately 83% of the total variance. The PC1 exhibits a dominance of EC, TH, TDS, Na, K, Mg, Ca, Cl, HCO_3, NO_3 and SO_4 due to dissolution and hydrolysis of silicate minerals such as potassium-feldspar, muscovite and biotite minerals reported in the study area. PC2 represents a positive loading of pH, Na, Mg, HCO_3, CO_3, and F and negative loading for EH and NO_3 suggesting dissolution of silicate and carbonate minerals, evapotranspiration along with ion exchange phenomenon. The hydrogeochemistry shows that incipient chemical weathering and ion-exchange phenomena, occurring in the aquifer, enhance greater mobilization of fluoride in groundwater. The presence of zeolite with high cation exchange capacity in the alluvial aquifer is reported which, through sorption-desorption behaviour at variable pH acts as major controlling factor of fluoride in groundwater. The multivariate statistical method with the aid of GIS technique is found to be very efficient in understanding water chemistry and hydro-geochemical processes involved in the region.

Assessment of sea water intrusion on coastal aquifer from Poovar to Shangumugham, Kerala state in post-monsoon season

Tharun R*, Suresh Gandhi M
Department of Geology, University of Madras, School of Earth & Atmospheric Sciences, Chennai
**Email: itstharunr@gmail.com*

Kerala "Gods own Country" is rich in heritage and resources and is especially famous for its monsoon where the "Burst of monsoon" took place. Even though the area is benefited by both southwest and northeast monsoon, the status of water in Kerala is considered as semi-critical by the Central Ground Water Board (CGWB). The over exploitation in order to meet the demands of growing population together with unscientific methods of extraction of this precious resource led to such a worse scenario. The condition is pathetic even in the case of coastal aquifers where water is available with considerable ease and this advantage leads to its destruction since more people and industries directly rely on this. On other hand it enhances the sea water intrusion in to the fresh water system. In this background the condition of the aquifer and quality of water extracted from it need to be checked. So a study was conducted on coastal aquifers from Poovar to Shangumugham, Thiruvananthapuram district, Kerala in order to find out the areas prone to saline water ingress.

In order to achieve the goal groundwater samples were collected along three different strips aligned parallel to the coast, namely A, B and C which are at an interval of 1 km from each other. Twenty six open well samples were collected from each strip with an interval of 1 km and named A1 - A26 in the first strip, B1- B26 in the next one and finally C1 -C26 in the last strip. The quality and impact of saltwater intrusion were studied by determining the geochemical characters of 78 groundwater samples collected during the post-monsoon period. Chemical parameters, like major cations and anions are determined together with physical parameters such as pH, electrical conductivity, total dissolved solids and total hardness. The major cations in order of abundance are $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$. However, the major anions are $Cl^{-}>SO_4^{2-}>NO_3^{2-}$. The data were analyzed and the multi-variate analysis were carried out using SPSS 24. The correlation and R-mode factor analysis confirms the presence of sea water intrusion and using Q-mode factor analysis the areas affected by sea water intrusion are demarcated.

Proper management plans have to be derived before the geochemistry and saline water intrusion of groundwater reaches an alarming level. The groundwater of the study area has to be managed sustainably considering the geochemical nature and their seasonal variations, as region proposed for study has a coastal fragile environment.

Speleothem studies from the Indian subcontinent: An overview and assessment

Shivangi Tiwari*, Rajiv Sinha
Department of Earth Sciences, Indian Institute of Technology-Kanpur, Kanpur 208016
**Email: shtiwari@iitk.ac.in*

The speleothem archive offers high-resolution paleoclimatic information that can be derived by the use of multiple proxies. Paleoclimatic reconstructions can be facilitated by robust dating methods that provide highly accurate chronologies to proxy records. However, it is important to

develop records with a comprehensive understanding of speleothem formation, taking into account the various processes that may lead to obscuring the paleoclimatic signal.

The current study reviews 19 available speleothem records from the Indian subcontinent. These records cover a wide geographical extent from Kalakot in Jammu and Kashmir, to Baratang in the Andaman and Nicobar Islands, and from Akalagavi in the Western Ghats to Mawmluh and Wah Shikhar in North East India. While most of the records span parts of the Holocene, the longest record extends to 2,80,000 years BP. Speleothem records have traditionally made use of the ä^{18}O signal as a paleo-precipitation proxy, and this proxy is analysed in terms of the 'amount effect'. These studies have advanced our understanding of the behaviour of the Indian Summer Monsoon (ISM) by emphasizing the monsoonal variability, and the varying influence of its drivers at different timescales, not amply exhibited by the instrumental record. Several studies have also provided signatures of the Medieval Climatic Anomaly and the Little Ice Age from regions receiving precipitation from both ISM and the Westerlies.

This paper presents a synthesis of these records in terms of climatic regimes they are derived from, the proxies used, and the temporal resolution afforded by the use of different dating techniques. Contributions from speleothem records to our understanding of the Indian Summer Monsoon and the Westerlies are also highlighted, and state of the art methods for analysis of proxy records are discussed. Notwithstanding the growing body of speleothem records from the subcontinent, significant gaps still remain in our understanding of the ISM, particularly on the multidecadal and centennial scale. We suggest that developing high-resolution records from the Core Monsoon Zone may help plug these gaps.

Impact of stagnant water, pond of dirty water, and pit latrine, on ground water quality, in public places like schools of block Khalilabad, district Sant Kabir Nagar, Uttar Pradesh

Mahesh Kumar Tripathi, H. Govil, P. Diwan, Monika
Department of Applied Geology, National Institute of Technology, Raipur 492010
Email-tripathi.mahesh1@gmail.com

Assessment of sanitation drinking water sources is made in schools and religious places like temples. Pit latrines and stagnant waters are most common source and cause of discharges of chemical and microbial contaminants into groundwater in rural areas. Contaminated drinking water is harmful for health and is a cause of several health related problems. An assesment of ground water and 176 drinking water sources located in public places like primary schools and religious temples in the block of Khalilabad, district Sant Kabir Nagar, Uttar Pradesh was carried out. A methodology adopted for sanitation and ground water quality through knowledge based survey with their applications and standers methods for physicochemical analysis have been completed for ground water samples. This research has been carried out to identify various parameters and factors for contamination in and, around drinking water sources. The parameters are estimated and calculated through multi parameter field test water kit and factors derived through knowledge based sanitary surveys. The result of analysis carried out reveal the following ranges of concentrations pH (5-7), Cl (75-175 mg/l), Fe (0.2-1 mg/l), F (0.5-1.5 mg/l), NO_3 (10-250 mg/l), CO_3 (180-495 mg/l). Through assessment and comparative water quality analysis and sanitary survey, the source locations of drinking water have been classified in three risk classes low risk, medium risk and high risk.

Gender discriminations in disaster management: A case study from Rudraprayag district of Uttarakhand

Priyanka Tyagi*, Ravindra K. Pande
Department of Geography, Kumaun University, Nainital
**Email: tyagi.geog2008@gmail.com*

Gender relations are not fixed, they are learned or inherited behaviours that depend on location, culture, class, ethnicity and religion of a particular society which is subject to change over the time. Women occupy a subordinate status in the family as well as in the society. They are denied opportunities, access to resources and their rights as individual, and all these result in keeping a situation of inequality among society. Natural disasters affect people differently, and in spite of the natural factors, there are social, cultural and economic factors which impact the vulnerability of a particular group. From the previous experiences of disaster management activities, it is seen that women's particular needs, concerns and their potential have not been given importance which enhances their vulnerability. In this paper, the author has focused on accounting the status of women in households of Ukhimath block in Rudraprayag District of Uttarakhand through a survey. Villages selected for survey were worse affected in 2013 Uttarakhand tragedy. It is seen that there is a need to focus on group specific approach to disaster management and a neutral approach will not fulfil the motive of disaster management. To eliminate the gender gap from disaster management there is a great need to focus upon the pre-disaster activities and bearing in mind the effective pre-disaster activities, there will be an effective post-disaster response which will lessen the gender gap in disaster management.

Molecular distribution and carbon isotope of *n*-alkanes from Ashtamudi Estuary, South India: Assessment of organic matter sources and paleoclimatic implications

Ankit Yadav[1]*, Praveen K. Mishra[2], Prem Kumar[1], Anoop Ambili[1]
[1]Indian Institute of Science Education and Research, Mohali, Manauli 140306, Punjab,
[2]Wadia Institute of Himalayan Geology, Dehradun 248001, Uttarakhand
**Email: ankitvrishm22@gmail.com*

The distribution and ä^{13}C composition of n-alkanes were used to identify organic matter (OM) sources in river dominated Ashtamudi Estuary, Southern India. A number of n-alkane indices have been calculated to illustrate the spatial variability by considering separately river dominated northern reaches and marine influenced southern part of the estuary. The carbon preference index (CPI) and average chain length (ACL) provide evidence for recycled organic inputs in the tidal zone, whereas dominant biogenic contribution has been observed in the riverine zone. The Paq and TAR indices demonstrate maximum aquatic productivity in the tidal dominated region of the Ashtamudi Estuary. The quantitative apportion of organic matter sources in Ashtamudi sediments using compound-specific carbon isotope analysis (CSIA) of long-chain n-alkane shows dominance (56-86%) of terrestrial derived OM. The results clearly demonstrate the effectiveness of an integrated molecular and stable carbon isotope analysis for quantitatively assessing OM sources in estuarine environments.

Zero degree isotherm of the Dokriani Glacier, Garhwal Himalaya: Meteorological correlations and implications for melt modelling

Jairam S. Yadav[1,4]*, Anil K. Gupta[2,3], D.P. Dobhal[1], R.B.S. Yadav[4]
[1]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
[3]Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721302
[4]Department of Geophysics, Kurukshetra University, Kurukshetra, 136119
** Email: jai.au08@gmail.com, jai.geo08@gmail.com*

The zero degree isotherm ($Z_{T=0}$) is an elevation zone where temperature is considered to be nearly zero (~0-5°C). This threshold value of temperature varies spatially and temporally, and controls the melting of snow/ice and phase change of precipitation over the glaciarized region. The study of $Z_{T=0}$ over the glacier is important to investigate ice-air temperature relationship. Also, in the absence of sufficient equilibrium line altitude (ELA) data, $Z_{T=0}$ can often be applicable to estimate ELA position in the remote Himalayan terrain. The position of $Z_{T=0}$ generally notifies as how much time a glacier sustains at melting point throughout the year. The upward shifting of elevation of the $Z_{T=0}$ is likely to be alarming of climate warming and prevailing of precipitation as rain than snow. Very few attempts have been made so far on this aspect, even through found to be absence in the Indian Himalaya. To fill this gap, the present study was undertaken, which reports fluctuation of $Z_{T=0}$ in the Dokriani Glacier catchment (July 2011 to December 2015) using temperature dataset of three Automatic Weather Stations (AWSs). The measured and extrapolated air temperature was observed positive during the monsoon season (JJAS: June, July, August, September) in the ablation zone of the Dokriani Glacier as compared to other seasons (pre-monsoon, post-monsoon, winter). We observed a large variation in $Z_{T=0}$ ranging from 5000 to 5500 m asl during 2012-2015. Indeed, this is very large elevation range representing $Z_{T=0}$ that cannot point out accurate position of ELA. However, $Z_{T=0}$ computed by using annual lapse rate of corresponding year is very close to the ELA (average ~5065 m asl) of Dokriani Glacier as established between 1992 and 2000. Hence, it can be suggested that, in the lack of in-situ observations as noticed in several years, this may provide an important sign for validation of ELA derived by mass balance modelling. The maximum $Z_{T=0}$ is recorded in the monsoon months, mainly in July and August. The highest peak (~5565 m asl) of $Z_{T=0}$ was noticed in 2015 whereas it was at ~5400 m asl in remaining study years. In 2015, RH was weighed to be higher (~10%) in comparison to that of other years. From our analysis, it appears that the variation of $Z_{T=0}$ was mostly similar as variation of saturation vapour pressure (e_s) lapse rate. These scenario would enhance the melting of glaciers, leading to $Z_{T=0}$ at higher altitude. Contrast to ablation period, $Z_{T=0}$ varies from 2400 to 3300 m asl during accumulation period for four years (2012-2015). $Z_{T=0}$ is not consistent during winter months in all studied years. The lowest value of $Z_{T=0}$ is observed in January 2012 (~2500 m asl) whereas $Z_{T=0}$ falls at ~ 3000 m asl in January months of other years.

Findings of present study may be helpful for temperature estimates in gridded scale and then used for model development, calibration and generalization in the Himalaya. Higher the RH and e_s lapse rate, higher is the $Z_{T=0}$, indicates greater melting of glacier during monsoon period. The fluctuation in $Z_{T=0}$ might strongly be recommended in understanding processes forcing the phase change in the glacierized area and its impact on hydrological system in the drainage areas. It can also provide imperative inputs for modelling studies in the inaccessible Himalayan terrain. If we obtain the more accurate temperature lapse rate value for a particular season using differences in $Z_{T=0}$ analysed on the basis of seasonal and annual lapse rate, it may be retain constant for further

glaciological studies in the same areas. Additionally, $Z_{T=0}$ coupled with meteorological studies may provide information for monsoon arrival, duration and intensity in a high-altitude region.

Environmental assessment of heavy metals from Nanded city

Yannawar Vyankatesh B., Bhosle Arjun B., Mushtaq Ahmad Dar
School of Earth Sciences, SRTM University, Vishnupuri, Nanded 431606, Maharashtra
Email: vyanky@hotmail.com

The major environmental issues area related to investigations of tracing toxic substances including metals released to air, water and soil. This toxic substance affects the growth of flora and fauna in all region. Soil, as well as different geological structures, plays an important role in controlling the flow of potentially toxic substances and its superficial distribution along with toxic sources. This type of investigation has its own limitation in the form of trace pollutants and their sources which can be observed by taking the suspension of leaf sample. Frequent environmental methods are commonly used to investigate heavy metals from plants. The intentions of this study to compare the efficiency of extraction of heavy metals by different plant species and to watch the associated dispersion of pollution. This study examined the behavior of heavy metals' viz., copper (Cu), lead (Pb) and zinc (Zn) in urban areas plant leaves collected in the commercial, residential, and industrial area of the Nanded city, Maharashtra. The difference between the amount of pollution on plant leaves is simply recognized through observation in the urban and suburban area. Concentrations of heavy metals (Cu, Pb, and Zn) were exact using 65% nitric acid, 70% perchloric acid, wavelengths of 213.8 nm for Zn, 324.754 nm for Cu, and 283.3 nm for Pb. Using the absorption coefficients, the amount of Zn, Cu, and Pb in the leaf samples was calculated by a method of UV Spectrophotometer. Leaf samples collected plants (road side) from 18 different locations with three diverse habits: commercial, industrial, and residential. The heavy metals which were present on soil, get mixed with water and transported to leaves. Plants from commercial area shows the values of metals were (Zn: 3.35, Cu: 3.76, Pb: 2.63) residential area (Zn: 3.34, Cu:3.36, Pb: 1.46,) and industrial area (Zn: 2.74, Cu: 1.78, Pb: 1.45) indicating the percentage of Zn > Cu > percentage of Pb which can be written in terms of “highly contaminated” followed by “moderately to highly polluted,” and “low to moderately polluted”. This suggests there is a need of green belt through proper management strategies like remediation by planting bio-absorptive plants. Plantation of bio-absorptive plants implementation of such type of research promotes the urban system to control heavy metal pollution.

Selection of suitable ancillary layers for effective characterization of glacier facies at sub-pixel level using AWiFS data

Bisma Yousuf[1]*, Aparna Shukla[1], M.K. Arora[2]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]PEC University of Technology, Chandigarh 160012
**Email: bismaqazi13@gmail.com*

Glacier facies maps are significant resources to provide information regarding climate variability, snow line dynamics, glacier terminus position, glacier health, mass balance trends and changes in ice volume etc. With its high radiometric resolution (10-bit), Advanced Wide Field Sensor (AWiFS) data offers a significant potential for the delineation and characterization of

glacier facies. However, presence of mixed pixels is a common problem in AWiFS data (56 m spatial resolution) that can be resolved by performing classification at sub-pixel level. Also, there is a high degree of spectral overlap between glacier facies, particularly in shaded/crevassed/ transition zones. So, in order to avoid misclassification, data from other sources need to be incorporated in the classification process. Based on their attributes (like elevation, grain size, temperature, texture etc.), the most suitable ancillary data tends to minimize the spectral overlap between two or more facies and maximize the discrimination amongst them. For instance, texture, temperature and slope data maximizes the contrast between supraglacial debris (SGD) / periglacial debris (PGD) and valley-rock which are otherwise spectrally indistinguishable (Racoviteanu and Williams 2012). NDSI helps to detect the shaded snow in accumulation zones which normally gets misclassified as ablation facies due to its lower spectra in the VNIR bands. Snow grain size indices also help in the identification of different types of snow (dry/ wet snow or firn) due to the sensitivity of snow albedo to grain size particularly in NIR band (Dozier 1989). This study is, therefore, aimed at a) exploring the utility of AWiFS (56m spatial resolution) in the sub-pixel classification of various facies present on the surface of Gangotri and neighbouring glaciers; b) determining the significant attribute (ancillary) data for the enhancement of classification accuracy. After thorough spectral profiling, the test scene was classified into dry snow, firn, wet snow, snow under shadow, ice, ice-mixed debris (IMD), SGD, PGD plus valley-rock and vegetation. Ancillary data like slope, elevation, NDSI, ASTER derived kinetic temperature (KT), co-occurrence texture measures (variance and homogeneity), band ratios (NIR/SWIR, Green/SWIR, KT/NIR/SWIR, KT/Green/SWIR) and snow grain size indices (generated using green, NIR and SWIR bands) were used considering their potential in the differentiation of spectrally similar facies (SGD and PGD plus valley-rock); elevation dependent facies (snow facies and ice facies), and; snow under shadow. A series of support vector machine (SVM) based classifications was performed at sub-pixel level firstly using AWiFS imagery and then using AWiFS imagery in combination with one ancillary data. Fraction images obtained from sub-pixel classification were validated using the reference fraction images derived from ASTER data (15m spatial resolution) and World-View2 data (2m spatial resolution). Results showed significant improvement in the classification accuracy with the addition of ancillary data.

Planning model for climate change and glacier melt to achieve sustainable development of Himalayan region

Sakkeri Ramya, V. Devadas
Department of Architecture and Planning, IIT Roorkee, Roorkee
Email: ramyasakkeri@gmail.com

Climate change is the prime influencing factor in occurrence of monsoon that leads to runoff variations in Indian River basins. Hence, it is necessary to assess the impact of climate change on water resources (rainfall & Snow/ glacial melt are considered as important hydrologic process in the Himalayan basins).

The aim of the research is to provide a framework for the intercomparison of regional-scale risk models within and across multiple sectors and to enable coordinated multi-sectoral assessments of different risks and their aggregated effects. Present research uses community-agreed sets of scenarios with standardized climate variables and socioeconomic projections as inputs for projecting future risks and associated uncertainties, within and across seven subsystems (Physical, Socio-Economic, Ecology, Environment, Resources, Infrastructure and Institutional) of the system (study

area) which has significant impact on GDP of the selected study area (Tehri Garhwal region) using climate model database and Socio-economic database.

This investigation follows a systematic methodology including various steps like identification of project need and formulation of objectives followed by collection of data, analysis and identification of control parameters which decide the functions of the system, development of model, validating the model, forecasting, simulation, drawing of inferences, policy analysis and evolving a set of policy guidelines and recommendations.

It is considered important to study the fact that sustainable water management is a key concern intricately linked to livelihoods of the people in Tehri Garhwal and results of the project are expected to provide support for implementation of the sustainable development plan of the region.

Hydrological characteristics and suspended sediment dynamics of Chorabari Glacier, Garhwal Himalaya, India

Anupam Anand Gokhale[1]*, Amit Kumar[1], Dwarika Prasad Dobhal[1], Deepak Kumar[2]
[1]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Department of Geology, D.B.S. (P.G.) College, Dehradun 248001
**Email: anupamgokhale2007@gmail.com*

Present study deals with hydrometeorological analysis conducted on temporal scale near the terminus of Chorabari Glacier during the ablation season (June-September). Mean surface air temperature was higher in July followed by August month. Highest monthly rainfall was observed in the month of August followed by July, while June and September received lowest rainfall. Diurnal temperature range (DTR) has a tendency to reduce over the ablation season because of Indian Summer Monsoon (ISM) onset and then further increases during ISM withdrawal indicating humid-temperate conditions. Magnitude of peak discharge (Q_{peak}) was found higher during July and August implying significant ISM influence on discharge variability. Snow and glacier melt contributed ~75% of total suspended sediment transfer during peak ISM months (July and August). Monthly and seasonal variations in suspended sediment yield (SSY) correspond to the high discharge reflecting sediment mobilization processes during extreme events. Relationships between monthly mean air temperature and mean discharge ($R^2 = 0.88$) reflects a higher degree of linear relationship than on a daily scale ($R^2 = 0.20$) while the coefficient of determination (R^2) for each ablation season 2009, 2010 and 2012 was 0.52, 0.72 and 0.75, respectively. Discharge intensity ratios (Q_{max}/Q_{min}) on a seasonal scale for each ablation season (2009-2012) were 0.98, 0.97, 0.78 and 0.73, respectively. The hydrometeorological variability and suspended sediment dynamics of Chorabari Glacier provides an insight on rate of erosion and melt generation processes in the data scarce Indian Himalayan region (IHR).

Petrology and geochemistry of ultramafic-mafic volcanic rocks from Sargur Group and Dharwar Supergroup greenstone belts, western Dharwar craton: Implications for evolving tectonic processes

K.R. Aadhiseshan
Department of Geology, University of Delhi
Email: aadhi.geo@gmail.com

Komatiites and komatiite-basalt are dominant lithologies in the Sargur Group in JC Pura, Banasandra and Nagamangala greenstone belts whilst basaltic rocks dominate the Dharwar Supergroup in the Chitradurga greenstone belt. Spectacular pillow lavas/flow top pillow breccia and spinifex textures as well as vesicular structures reveal their eruption in marine to continental transitional environments. On the other hand the studied basaltic rocks of Chitradurga do not preserve the primary volcanic structures as they were affected by strong regional shear deformation with steep foliation. Komatiites contain serpentine, talc, tremolite, actinolite, chlorite, rarely with remnant olivine, pyroxene whilst komatiite-basalt contains tremolite, actinolite with minor plagioclase. On the other hand, basaltic rocks of Chitradurga greenstone contain chlorite-actinolite-plagioclase and in some instances hornblende-actinolite-plagioclase. The observed mineral assemblages indicate that the rocks are affected by green schist to lower amphibolite facies metamorphism. Elemental data show that the Sargur Group komatiites are Al-depleted Barberton type while komatiite-basalts are Al-undepleted Munro type. Komatiites show high MgO content (22.46-42.41 wt %), whilst komatiite basalt contains moderate to high MgO (9.81-16.18 wt %). On the other hand Chitradurga basalts display low to moderate MgO (7.09-10.85 wt %). The observed chemical characteristics, such as major, trace and REE indicate that komatiite magmas came from different depth of deeper mantle. Incompatible elemental ratios imply that rocks have heterogeneous source ranging from depleted to primitive mantle in hot spot environments associated with plume. On the other hand lower MgO with higher total REE and moderately fractionated REE patterns of Chitradurga basaltic rocks indicate arc mantle source with significant crustal contamination. CaO/Al_2O_3 and $(Gd/Yb)_N$ ratios show that the komatiite magma was generated in the depth of deep mantle with or without garnet (majorite?) in the residue. Widespread komatiite volcanism, low content of incompatible elements, sub-contemporaneous TTG imply earlier large scale mantle differentiation and crustal growth during 3.6-3.2 Ga. On the other hand basaltic volcanism with arc signatures and crustal contamination during 2.7 Ga indicate shallow melting of mantle. These changes indicate a transition in tectonics from plume to arc setting which could be related to cooling of planet earth from 3.6-2.6 Ga.

Protocol for boron isotope measurement in tourmaline using laser ablation technique

Kumar Abhinay*, Dewashish Upadhyay
Department of Geology and Geophysics, Indian Institute of Technology-Kharagpur, Kharagpur
**Email: abhinay15oct@gmail.com*

Boron is a volatile light element. It has two stable isotopes, i.e., ^{10}B and ^{11}B with ~ 10% relative mass difference. It is highly soluble and mobile in aqueous solution and incompatible in most magmatic systems. Isotopes of boron are strongly fractionated among coexisting phases and can be used as a powerful tracer for various geological processes. The Geology and Geophysics Department at IIT Kharagpur houses a New Wave 193 nm ArF excimer laser ablation system and a Thermo Fisher Neptune Plus multi collector inductively coupled plasma mass spectrometer. Using this analytical

setup, we have set up protocols for in-situ measurement of boron isotope ratios in the mineral tourmaline with good spatial resolution. Such techniques are especially useful for understanding problems related to fluid-rock interactions. The ^{10}B and ^{11}B isotopes were measured on L-3 and H-3 Faraday cups, respectively, in medium mass resolution mode to eliminate isobaric interferences of Ar^{4+} and Ne^{2+} on ^{10}B. External standardization and correction for mass-bias and instrumental drift was done by sample-standard bracketing method. All data reduction was done offline. The analytical protocol was tested by measuring a sequence with the JS-82A-3 tourmaline reference material (Palmer and Slack, 1989) as a bracketing standard and the JS-79N-1 reference tourmaline as unknowns. Instrumental and gas background signals were <1mV for both ^{10}B and ^{11}B. The background subtracted signals for ^{10}B and ^{11}B were used to calculate $^{11}B/^{10}B$. The results ($ä^{11}B$) are expressed as per mil (‰) deviation of the $^{11}B/^{10}B$ from the values recommended for the NIST SRM 951 boric acid standard. All measurements were made under typical instrument operation conditions. The $ä^{11}B$ values obtained for the JS-79N-1 reference tourmaline is -12.76±0.84 per mil (2sd) which matches within error the value (-12.31±0.60 per mil, 2 sigma) reported by Palmer and Slack (1989) measured using thermal ionization mass spectrometer.

Effect of shearing and fluid pathways on myrmekite forming sites

Vedanta Adak, Upama Dutta

Department of Applied Geology, Indian Institute of Technology (Indian School of Mines) Dhanbad

The granitoid bodies present along the North Purulia Shear Zone, India contain myrmekites in three modes. First, they occur along rims of perthite or alkali feldspar porphyroclasts. Secondly, within perthite or alkali feldspar porphyroclasts and lastly, along boundaries of clustered Kfeldspar grains which formed as a reaction rim between plagioclase porphyroclasts and quartz. Reaction modelling suggests that Na^+ and Ca^+ bearing fluid phases were responsible for the formation of myrmekites from K-feldspar which formed by the simple reaction:

$$4.06\ \text{K-Feldspar} + 1.66\ Na^+ + 1.00\ Ca^+ = 3.12\ \text{Plagioclase} + 3.75\ \text{Quartz} + 3.51\ K^+$$

Myrmekites tend to occur mostly along zones parallel to the foliation, which may or may not be mylonitic. The sites along which myrmekites formed were almost always either normal to or at a higher angle with the direction of maximum finite compressive stress and also the direction of maximum compressive stress of the incremental strain axes. Myrmekites were absent along surfaces parallel to the maximum compressive stress suggesting that stress might have acted as a controlling factor in the selection of myrmekite forming sites. In addition, some granitic bodies had foliation at the outcrop and deformation twinning and other deformation microstructures, but lacked any evidence of deformation through shearing both at outcrop and microscopic scales. Such granites lacked myrmekites, indicating that the distribution of stress and strain due to shearing is a factor that affects formation of myrmekites. In less sheared rocks myrmekites occurred either along rims of perthite or alkali feldspar porphyroclasts or along boundaries of clustered K-feldspar grains formed as a reaction rim between large plagioclase and quartz grains. Highly deformed rocks of the area, like mylonites, contained myrmekites either along rims of perthite and alkali feldspar porphyroclasts or within such perthites and porphyroclasts that were altered by some fluid activity through cracks that cut across them. Presence of myrmekites along grain boundaries of Kfeldspar clusters and beside cracks within perthites and porphyroclasts point towards the importance of existing pathways for fluid activity in the selection of myrmekite forming sites. As shearing increases, the percentage of myrmekites within the porphyroclasts relative to the percentage of myrmekites along the rim increases. This observation may imply that as shearing increases, pathways of fluid activity becomes the predominant factor in determining myrmekite forming sites, rather than the distribution of strain

within the rock body. Calculations show that the myrmekite forming reaction is accompanied by a reduction in volume of ~9-10% between the reactants and products. This reduction in volume further facilitates the formation of porosity which in turn act as conduits of fluid activity, thus acting like a positive feedback loop.

The buried paleo-Sutlej river in the NW Indo-Gangetic plain: Sediment provenance, paleoclimate and paleovegetation

Mohd Amir*, Debajyoti Paul, Rajiv Sinha
Department of Earth Sciences, Indian Institute of Technology-Kanpur, Kanpur 208016
**Email: mamir@iitk.ac.in*

The NW Indo-Gangetic Plain is marked by a drainage divide formed by a vast tract of land between the Indus and Ganges river systems, with no major river flowing in between. The presence of a glacial-fed large river (Ghaggar-Hakra) presumably sourced in the Higher Himalaya flowing parallel to the Indus River through this drainage divide, has been inferred. Currently, the Ghaggar River, having its origin in the Sub-Himalaya, occupies one of the proposed Ghaggar-Hakra River valleys. Based on satellite imageries, trace of a paleochannel (paleo-Sutlej) that seems to be connected to the current Sutlej and Ghaggar rivers was identified and Sutlej was suggested as the main source of Ghaggar-Hakra River before switching to its present position (Yashpal et al., 1980). Moreover, no geochemical data from the subsurface sediments of this proposed paleo-Sutlej channel are available to test the hypothesis proposed by Yashpal et al. (1980). Here we analyzed Sr and Nd isotope compositions and stable carbon isotope compositions of sediment organic matter ($ä^{13}C_{SOM}$) in bulk sediment samples from two 45 m long cores raised on the paleo-Sutlej channel in Sirhind, Punjab. Significant temporal variations in $^{87}Sr/^{86}Sr$ and ε_{Nd} are observed suggesting variable contributions from sources i.e., the Higher and Lesser Himalaya. Higher ε_{Nd} (and lower $^{87}Sr/^{86}Sr$) during early MIS1, and MIS3 interglacial periods compared to MIS2 glacial, reflecting increased contribution from the Higher Himalaya (HH), is due to reduced extent of glaciation over the HH and enhanced intensity of summer monsoon precipitation and its migration into the deeper part of the HH during interglacial periods resulting in more erosion of the HH. The $ä^{13}C_{SOM}$ variability suggests dominantly C_3 plants during MIS2 glacial and increasing proportions of C_4 plants since last glacial maximum (LGM) in response to intensifying summer monsoon in the post-LGM period.

Sequence stratigraphic analysis of the Bagh Group of Men river valley, Narmada district, Gujarat

Apurva D. Shitole*, Satish J. Patel, Jaquilin K. Joseph
Department of Geology, M.S. University of Baroda, Vadodara 390002
**Email: apurva77shitole@gmail.com*

The Late Cretaceous beds of the Bagh Group comprise 72 m thick sedimentary sequence exposed in Men river of Narmada district, Gujarat. The sequence consists of siliciclastic, mixed siliciclastic-carbonate and carbonate sediments divided into eight sedimentary facies viz., quartz arenite, ferruginous sandstone, shale, micritic sandstone, sandy micrite, muddy micrite, sandy allochemic limestone, and mudstone. Sediment characteristics (textures, structures and bed geometry) along with palaeontological and ichnological evidences are used to establish the genetic sequence stratigraphic model. It displays two phases of regression (HST-I and HST-II) and two

phases of transgression (TST-I and TST-II); top of the TST-I is marked by the Maximum Flooding Surface. Genetic sequence-I consists of HST-I and TST-I separated by the regressive surface RS-I and Genetic sequence-II comprises HST-II and TST-II separated by the regressive surface RS-II. HST-I comprises eight regressive cycles of 5th order dominated by intercalated cross-bedded micritic sandstone and shale facies of foreshore environment. Aggradations of shale facies marked late HST/early TST-I, followed by cross bedded micritic sandstone and aggraded bioturbated rippled micritic sandstone facies of shoreface environments, and sandy allochemic limestone, shale, mudstone and micritic sandstone facies of offshore environment. Sandy allochemic limestone is highly fossiliferous and bioturbated representing Cruziana ichnofacies (*Thalassinoides, Planolites, Paleophycus, Conostichus* and *Conichnus*,) while rippled micritic sandstone facies is also represented by the Cruziana ichnofacies with distinct trace fossils like *Curvolithus, Phycodes, Oniscoidichnus, and Taenidium.* Top of the mudstone facies marks the maximum flooding surface and is followed by the HST-II comprising micritic sandstone, shale, quartz arenite, and ferrugenious sandstone facies of shoreface environment. TST-II marks the second transgressive phase and comprises muddy micrite and mudstone facies of upper offshore environment. Sequence stratigraphic analysis of the Bagh Group sequence of the Men river indicates the fluctuating sea level in foreshore to offshore environments in slowly transgressive sea during the Late Cretaceous time.

Sr and Nd isotope compositions of alluvial sediments from the Ganga basin and their use as potential proxies for source identification and apportionment

Neeraj Awasthi, Esha Ray*, Debajyoti Paul
Department of Earth Sciences, Indian Institute of Technology Kanpur, Kanpur 208016

The Ganga river system is one of the largest river systems in the world and covers almost 1.06 million km2 basinal area including India, Tibet (China), Nepal and Bangladesh. The Ganga alluvial plain (GAP) supplies weathering products to the Ganga–Brahmaputra River system and the possible contributors of these sediments are majorly Himalaya (Higher and Lesser) and some Penninsular areas (comprising Bundelkhand Craton, Vindhyan Ranges, Deccan Traps and Chota Nagpur Plateau). The interpretation made on identification and characterizations of sources are largely based on use of Sr and Nd isotope geochemistry. However, there are several complexities involved in the use of Sr and Nd isotopes as provenance proxies but this study presents the reliability of using $^{87}Sr/^{86}Sr$ and åNd in characterization of the sources and their apportionment. This study, based on compiled literature data, shows that identification of specific sources of sediments of the Ganga basin (particularly where multiple sources are involved) is difficult due to the large compositional overlapping in isotope data. However, as reflected in our study Nd isotopes are more reliable provenance indicators than Sr isotopes. The $å_{Nd}$ patterns of river sediments clearly demonstrate the influence of various source lithologies (depending on the $å_{Nd}$ compositions) and indicate mixing dominantly from Himalayan sources (Higher and Lesser). Some data gaps have been identified in this study, which are needed to be filled up in order to estimate mixing of sources.

Stable isotope and electron microprobe study on Miocene sediments at ODP -758 in the northeast Indian Ocean

Barnita Banerjee*, E.V.S.S.K. Babu, Syed Masood Ahmad, Waseem Raza, M. Satyanarayana
CSIR- National Geophysical Research Institute, Hyderabad
**Email: barnita.geology@gmail.com*

The middle Miocene transition witnessed rapid changes in oceanographic and climatic system however, very limited studies have been done on Miocene sediments from the Northeast Indian Ocean to identify effects of these events on surface and deep water masses. Here we present the first detailed stable isotope (ä^{13}C and ä^{18}O) records from surface and deep dwelling foraminifera and trace element geochemistry from sediments of ODP site 758 from the Ninetyeast Ridge (Lat. 5°23'N, Long. 90°21'E; water depth 2925 m). Isotopic studies were performed on two species G*lobigerinoides quadrilobatus* (planktonic) and C*ibicides wullerstorffi* (benthic) and trace element study was carried out on bulk sediments. Our data points at various global and local successions of oceanographic and climatic events; (1) Mid Miocene Climatic Optimum (17-15 Ma), (2) Monterary excursion (17-14 Ma), (3) East Antarctica Ice sheet formation (13.8 Ma), (4) Initiation of Indian Summer Monsoon (ISM), waning of Antarctica Ice sheet indicated by (5) High productivity event (12.3-10.4 Ma) indicated by increased Ää^{13}CP-B values and Ba concentrations, (6) Cooling event at 10.2-9.6 Ma due to formation of North Atlantic deep water. The good correlation between South Pacific, Indo Pacific and North East Indian Ocean cores suggests that the strong westerly Ocean current (Miojet) probably linked these Oceans from 14 Ma rearrangement of tectonic plate giving rise to strong Miojet and formation of deep water to modern like oceanographic condition at ~10 Ma.

A detailed microscopic analysis of the sediments helped us identify large quantities of glass shards at ~10.7 Ma indicating a volcanic event in the nearby Indonesian region. The Electron Microprobe analysis (EPMA) of the glass shards revealed a rhyolitic composition, which is somewhat different in composition to lavas from several bathymetric highs in the eastern Indian Ocean that are tholeiitic in nature. The possible source of these glass shards being located in Northeast Indian Ocean might be (1) the Reunion hotspot; (2) the Kerguelen plume; (3) Broken ridge; (4) Indian Ocean Ridge volcanics; (5) Afro-Arabian flood volcanism, or (6) the Taupo volcanic center (New Zealand). But these sources have been ruled out due to their entirely different composition and depositional age. The glass shards have a very different composition than the Toba eruption reported at 8 Ma at our site. The glass shards were large enough to be identified under binocular microscope (size range 250-315 µm,) suggesting that tephra belongs to a volcanically active areas not more than 500 kms away from our region.

Geochemical characteristics of the ultramafic and carbonatite rocks of Sung valley, Shillong plateau, north-east India: Constraints on their petrogenesis

Mrigendra N. Barman, M. Faruque Hussain*, Ajoy Dey
Department of Earth Science, Assam University, Silchar 788011
**Email: mrigenbarman2011@gmail.com*

Carbonatite rocks of Cretaceous age are exposed in the Sung valley within the Shillong plateau in association with ultramafic and alkaline rocks. Major, trace and REE studies are carried out on the ultramafic and carbonatite rock suits of the Sung valley. Petrographically, the ultramafic rocks are predominantly orthopyroxenites and the carbonatites are mostly apatite-carbonatites and silico-

carbonatites. Ultramafic rocks are comprised of moderately high SiO_2 (44.14-53.30 wt. %) and high MgO (9.74-16.44 wt. %) and the carbonatites are comprised of low to moderate SiO_2 (38.64-51.68 wt. %), high CaO (13.28-24.25 wt. %) and low MgO (2.20-12.16 wt. %) contents. Primordial Mantle (PM) normalized multi-elemental patterns for the ultramafic and carbonatite rocks show enrichment compared to PM. Both the LILE and HFSEs are of similar abundances and display roughly flat patterns along with negative anomalies at Ti and Y. The Chondrite normalized REE patterns display fractionated trends with LREE enrichment and HREE depleted suggesting generation of magma from a garnet bearing source in the deeper mantle.

Metamorphic and fluid P-T evolution of high-grade metapelites from Karakorum, Trans-Himalaya, India

Harshit K. Barnwal*, P. Chandra Singh, Aditya Kharya, Himanshu K. Sachan
Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: Hbarnwal90@gmail.com*

The high grade metapelites of Pangong- Tso area in the trans- Himalayan region underwent sillimanite-grade metamorphism during the Cretaceous, associated with the collision of the Kohistan arc and the Indian plate with Asia. The calculated phase equilibria in the Na_2O–CaO–K_2O–FeO–MgO–MnO-Al_2O_3–SiO_2–H_2O (NCKFMMnASHC) system suggest the peak P-T conditions of 12 kbar and 650 ºC for the high-grade metamorphic event. Primary fluid inclusions occur in staurolite and garnet, whereas quartz carries mostly secondary fluid inclusions. The trapped fluids in primary inclusions show melting temperatures in the range of - 56.9 to - 56.6 °C, suggesting a nearly pure CO_2 composition. The secondary fluids are of mixed carbonic-aqueous nature. The re–equilibrated inclusions show annular morphology as well as necking phenomena. The CO_2 isochores for the primary inclusions indicate pressures of 6.1 - 6.7 kbar, suggesting that the CO_2- rich fluids were confined during post-peak exhumation of the rocks, or that synmetamorphic carbonic fluids endured density reversal during isothermal decompression. The secondary CO_2- H_2O fluids must have been trapped during the late exhumation stage, as their isochores define further lower pressures of 4.8 kbar. The morphology of re- equilibrated fluid inclusions and the rapid decrease in pressure are consistent with a near-isothermal decompression trajectory following the peak metamorphism. The carbonic fluids were probably derived locally from decarbonation reactions of the associated carbonate rocks during metamorphism.

Source, transportation and sink of the surface sediments off Hooghly to Pennar River mouths, western Bay of Bengal

Purnima Bejugam*, G.N. Nayak
Department of Marine Sciences, Goa University, Goa 403206
Email: purni_24@rediffmail.com

Spatial distribution and pathways of surface sediments from 27 to 2825 m water depth was investigated along 10 transects off major rivers mouths viz., Hooghly, Mahanadi, Vamsadhara, Godavari, Krishna and Pennar from western Bay of Bengal using sediment components, clay minerals and selected metals to understand source, transportation direction and sink. The study revealed that the overall sediment size decreased with increasing water depth away from the coast and also from off Hooghly to Pennar River mouth regions indicating a sediment transport from coast

to offshore as well as from north to south in the study area. The high energy environment prevailing off Hooghly and off Mahanadi enabled the deposition of coarser material and prevented the accumulation of finer sediments. Illite was the predominant clay mineral in sediments off Hooghly, Mahanadi and Vamsadhara indicating supply from muscovite mica, a dominant mineral in the Himalayas and also from felsic and granitic rocks from the Eastern Ghats. Smectite increased abundantly in sediments off Godavari, Krishna and Pennar which was attributed to the chemical weathering of basic volcanic igneous rocks, namely Deccan basalts, associated black cotton soils and crystalline Archean rocks draining through the peninsular rivers under the prevalent humid tropical climatic conditions. The Al concentration in the samples ranged from 7-9% suggesting limited change in Al accumulation along the transects. Deccan trap basalts are iron and titanium rich mafic rocks and upon weathering produce iron rich clay minerals, Fe-rich oxyhydoxides, unaltered titanium and ferromagnesium minerals and are responsible for higher Fe and Ti concentration off Godavari, Krishna and Pennar. Very high Fe in samples off Godavari may have also been contributed from the leaching of iron rich sediments from 'Red beds', dominant rocks near Vizag coast. The red beds are usually associated with appreciable amounts of kaolinite explaining its higher concentration in the samples near the river mouth. High Ba concentration in the sediments off Mahanadi and Vamsadhara indicate the source of sediments from felsic rocks since Ba is usually hosted in rocks rich in K-feldspars and micas as Ba substitutes K in the lattice structure due to its similar ionic radius. Deccan basalts show restricted mobility of Ba upon weathering explaining low Ba off Godavari, Krishna and Pennar. Higher Ba content noted at deeper water depths in most of the transects must be due to the formation of barites in the water column which takes place well below the photic zone. Illite tends to absorb Pb more readily into its structure due to cation exchange explaining higher Pb enrichment in the sediments where illite was a dominant clay mineral. However, smectite too adsorbs Pb into its lattice because of the negative charge on the surface and its shrink-swell property explaining the appreciable Pb concentration in few surface samples off the southern transects.

Landslide susceptibility zonation using relative effect model in part of Mahad Taluka, Maharashtra, India

Somnath Bera[1]*, Guru Balamurugan[1], Habib Ali Mirdda[2]

[1]Centre for Geoinformatics, Tata Institute of Social Sciences (TISS), Malti and Jal A.D. Naoroji Campus (Annex), Deonar Farm Road, Deonar,Mumbai 400088

[2]Department of Geography, Jamia Millia Islamia University, New Delhi

**Email: bera.somnath2009@gmail.com*

Landslide is one of the major hazards in the Westren Ghat Region, especially in Mahad Taluka. Demarcation of landslide probable area is important to reduce the future damage of property and impact on community. In this regard, the present study is focusing on spatial prediction of landslide susceptibility zonation using one of the statistical methods of Relative Effect Model. In this model, ten controlling parameters, such as lithology, lineament density, lineament proximity, land cover, slope gradient, slope aspect, plan curvature, profile curvature, drainage density, and drainage proximity were determined to estimate susceptibility of landslide. Finally, the landslide susceptibility zones are divided into five classes, such as very high, high, moderate, low and very low and they have occupied 12.31%, 19.83%, 21.08%, 24.50%, and 22.27% of the total study area, respectively. The model was validated using Area under Curve method (AUC), which shows accuracy value of 84.85%. This study is helpful for further risk reduction assessment of the area.

Determining temporal extent of regional superposed deformation events in the Dharwar Craton using anisotropy of magnetic susceptibility data

Sandeep Bhatt*, Virendra Rana, Manish A. Mamtani
Department of Geology & Geophysics, Indian Institute of Technology Kharagpur 721302
**Email: sandeep@gg.iitkgp.ernet.in*

The accretion of East Dharwar Craton (EDC) and West Dharwar Craton (WDC) along the Chitradurga Shear Zone (CSZ) led to the formation of Dharwar Craton at ca. 2.5 Ga. Previous studies in the rocks of the region reveal that the architecture across the craton is controlled by the three deformational events viz. early NE-SW shortening (D1 and D2) and late NW-SE shortening (D3) leading to NW-SE oriented and NE-SW oriented fabric elements, respectively. Generally, syntectonic granitoids preserve emplacement/deformation fabrics related to a particular deformational event, and the subsequent deformation may be recorded as the swerving of the previous fabrics. In this study, we present the case of two such granitoids from Dhawar Craton viz., Koppal Granitoid (KG) and Mulgund Granite (MG) having ~2.5 Ga age. Field, anisotropy of magnetic susceptibility (AMS) and microstructural studies are used to evaluate the fabric development and emplacement mechanism of the KG. AMS reveals NNE-SSW oriented magnetic fabric in KG, which is inferred to be related to regional D3. Variation in the intensity of fabrics and microstructural study of KG exhibits the increase in the intensity of fabrics towards the NW and decline of High-T deformation texture towards the western margin of the granitoid. It is inferred that KG emplaced syntectonically with the D3 deformation event. The initial space was created as the Mode-I crack during the early D3; subsequently, the granitoid ballooned to the upper crustal levels. In contrast to this, previous studies indicate that the MG emplaced and developed fabrics syntectonically with regional D1/D2, which was superposed by D3. Interestingly, the ages of both the granitoids mentioned here are similar. Whilst KG is 2528± 9 Ma, MG is 2555 ± 6 Ma in age. The contrasting fabrics of the two graintoids despite similar ages help to constrain the timing of the superposed deformation events in the region. Taking into account the standard error of the U-Pb zircon ages it is envisaged that D1/D2 is $\geq$ 2549 Ma, while D3 is $\leq$ 2537 Ma. The present study highlights the importance of AMS (a) for deciphering the temporal relationships between fabric development and deformation and, (b) bracketing the temporal extent of the regional superposed deformational events.

Implication of ichnofossil assemblage on paleoenvironment of Permian Barakar sedimentation in the Raniganj Coalfield, India

Joyeeta Bhattacharjee[1]*, Tamanya Roy[1], Sudipto Banerjee[2], Sandip Bandyopadhyay[2], Biplab Bhattacharya[1]
[1]Department of Earth Sciences, Indian Institute of Technology, Roorkee 247667
[2]Department of Geology, Hooghly Mohsin College, Chinsurah, Hooghly 712101
**Email: joyeetageol@gmail.com*

Life activities of various ancient infaunal shallow marine organisms are profoundly preserved in the thick successions of the Permian Barakar Formation in the Raniganj Coalfield, India, in the form of different ichnofossils. Sedimentologically, The Barakar Formation is represented by three main facies associations: the fluval bay head delta facies association, the central estuary basin facies association and the coastal facies association with dominant marine influence in the upper part of the succession. The ichnoforms are present mainly in the sandstone-mudstone heterolithic unit of the wave influenced tide dominated estuarine deposit that constitutes the upper part of the Barakar

succession. The estuarine ichnofabric includes simple shallow tiered, impoverished burrows with low diversity, with somewhat increase in the ichnodiversity and ichnodensity in the upper part of the succession. The burrows are basically fodichnia, domichnia and resting impressions of various marine infaunal organisms like endobenthic annelids, worms, bivalves and small crustaceans. The fluvial dominated lower succession is devoid of any type of ichnoforms. The ichnoforms present in the succession belong to three ichnofacies types namely; mixed Skolithos-Glossifungites, mixed Cruziana-Glossifungites and depauperate Cruziana ichnofacies, showing gradual change over from brackish water to more shallow open marine ichnofacies affiliations.

The overall shallow-tiered ichnofossils, impoverished trace fossil assemblages belonging to mixed ichnofacies types and dominance of feeding burrow made by infaunal organisms over epifaunal varieties suggest that these ichnoforms were formed under certain stressed paleo-environmental conditions which are typical to that of the estuarine conditions. The stressed conditions of an estuary with fluctuating energies of fluvial and tidal currents and waves with the associated varying rate of sediment supply, fluctuating salinity due to influx of fluvial fresh water into the marine waters, fluctuating oxygen availability and intermittent storm waves together work to produce such interaction pattern of organisms along with the sediments in the coal bearing litho-unit of Permian Barakar Formation.

Petrography and geochemistry of Proterozoic Oceanic crust: The Kandra Ophiolite complex, SE India

Munjaji V. Bhosle*, K. Vijaya Kumar
School of Earth Sciences, SRTM University, Nanded 431606, Maharashtra
**Email: bhoslemunjajiv@gmail.com*

The oceanic crust that constitutes the ophiolite protolith is generated by sea-floor spreading at mid-ocean ridges, in suprasubduction-zone environments (island arcs and backarcs), and beneath oceanic plateaus. Based on the site of origin of the protolith oceanic crust, the ophiolites are classified as 1) Ligurian-type formed during the early opening of an ocean basin (Red Sea), 2) Mediterranean-type formed during the interaction of two oceanic plates (Izu-Bonin forearc), 3) Sierran-type represent complex histories of island-arc subduction (Philippines), 4) Chilean-type formed in a continental back-arc spreading zone (Andaman Sea), 5) Macquarie-type formed in the classic mid-ocean ridge setting (Macquarie Island), 6) Franciscan-type are accreted pieces of oceanic crust scraped off the subducted plate onto the upper plate (Japan) and 7) Caribbean-type representing the subducted oceanic plateaus (Java Plateau).

The Kandra Ophiolite Complex (KOC) occurs as an arcuate belt ~19 km long and 3.5-5 km wide in WNW-ESE trend. The KOC shares a discordant relationship with the Nellore Schist Belt, and a thrust contact against granites at the southeastern contact. Although deformed and dismembered, the original zonal arrangement of the KOC has been largely retained. From SW to NE the complex consists of layered + isotropic gabbros, sheeted dolerites and amygdaloidal pillow basalts. Ultramafic units are scattered within the gabbroic rocks, and plagiogranite occurs as veins + patches within dolerite dikes. Metacherty layers cap the complex.

Gabbros show cumulate and poikolitic textures and dikes exhibiting ophitic, subophitic and porphyritic textures with plagioclase phenocrysts. The entire complex underwent epidote-amphibolite facies metamorphism. Unambiguous cumulate gabbros, sheeted dikes and oceanic plagiogranite in the Kandra complex provide robust evidence for Paleoproterozoic sea-floor spreading along the southeastern margin of the Indian subcontinent.

Major element geochemistry of the KOC indicates that the magmas are rich in silica and iron (Fe) and low in potassium (K). The compatible trace elements (Ni, Cr and Co) suggest evolved compositions of the melts. The gabbros show slightly LREE-enriched and almost flat HREE patterns with conspicuous positive Eu anomalies typical of plagioclase-rich cumulates. Some of the gabbros significantly display flat LREE patterns. Plagioclase-rich cumulate rocks with flat LREE are supposedly derived from basaltic melts with LREE depletion characteristic of mid-oceanic ridge (MOR) and back-arc environments. Dolerite dikes and basalts from the KOC show mild LREE enrichment and flat HREE with small negative or no Eu anomalies. Plagiogranites show fractionated REE patterns with characteristic large negative Eu anomalies. The geochemical variation amongst gabbros, dykes, basalts and plagiogranites reflect progressive differentiation by fractional crystallization. The KOC exhibits EMORB geochemistry overprinted by subduction-zone metasomatic signatures similar to the Chilean-type continental back-arc oceanic crust.

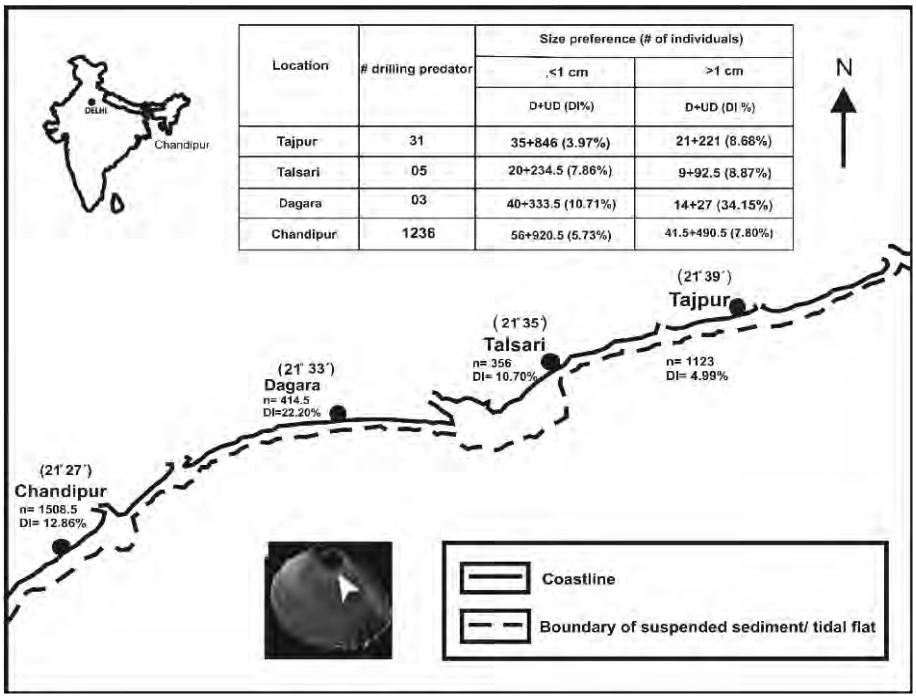
Spatio-environmental variation in gastropod drilling predation on bivalve *Timoclea imbricata* along the eastern coast of Orissa, India

Hindolita Chakraborty[1]*, Subhronil Mondal[1], Debattam Sarkar[2], Pritha Goswami[3], Sandip Saha[4], Ranita Saha[5], Arijit Pahari[6]

[1]Department of Geology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata
[2]GSI training Institute, GSI complex, Bandlaguda, Hyderabad
[3]Department of Geology, Durgapur Government College, Durgapur
[4]Geological Studies Unit, Indian Statistical Institute, 203, Barrackpore Trunk Road, Kolkata
[5]Department of Applied Geology, Indian School of Mines, Dhanbad
[6]CSIR- National Geophysical Research Institute, Uppal Road, Hyderabad
**Email:hindolita@gmail.com*

Traces produced by the gastropod drilling predators on their molluscan prey has attracted attention because of its preservation potential in fossil record and its usefulness in expressing the ecological interaction between these two interacting groups (Kelley & Hansen, 2003). Intensity of this interaction varies from one location to the other mainly due to the variation in local biotic (prey-predator abundance and composition, physical character of the prey like shell thickness, ornamentation, etc.) and abiotic (substrate, temperature, salinity, etc.) factors, although, documentation of this aspect is lacking. To document how and why drilling predation varies spatio-environmentally along the eastern coast of Orissa, India, bulk samples were collected from Tajpur, Talsari, Dagara, and Chandipur, and were analyzed for traces of drilling predation. All locations have identical local environment with nearby vast tidal flats and equitable temperature-salinity conditions (Chaitanya et al., 2015); any variation in predation among these locations, therefore, can only be explained by the biotic factors alone. To nullify the effect of species composition, we have restricted our study on one bivalve -*Timoclea imbricata* - the most abundant species ($\geq$ 50% of all prey). Finally, Drilling predation intensity (DI) was calculated as the ratio between the total number of drilled specimens and the total number of individuals studied.

DI varies from as low as 4.99% (Tajpur) to 22.20% (Dagara), with intermediate values at Talsari (10.70%) and Chandipur (12.86 %). In all locations, ratio of left and right valves is close to 1, suggesting minimum taphonomic overprinting. Furthermore, similar shell thickness (varies from 0.06-0.07 mm) of *T. imbricata* in all locations suggests that variation in DI is independent of the physical characteristics of prey. Moreover, in all locations, the larger-sized individuals (i.e., length>1 cm) are targeted over the smaller-sized individuals, although the smaller size class is always abundant. More surprisingly, DI has no correlation ($p = 0.6$) with the abundance of drilling gastropod predators; although Chandipur has the highest predator abundance, DI is not the highest there. All



Location	# drilling predator	Size preference (# of individuals)	
		≤1 cm	>1 cm
		D+UD (DI%)	D+UD (DI %)
Tajpur	31	35+846 (3.97%)	21+221 (8.68%)
Talsari	05	20+234.5 (7.86%)	9+92.5 (8.87%)
Dagara	03	40+333.5 (10.71%)	14+27 (34.15%)
Chandipur	1236	56+920.5 (5.73%)	41.5+490.5 (7.80%)

Fig. 1. All studied locations along Orissa coast, India along with respective number of individuals (n) and predation intensities (DI). The table in inset shows number of naticid predators at each location along with the number of drilled (D) and undrilled (UD) individuals and corresponding DIs of the two size classes (<1 cm and >1 cm). A drilled *Timoclea imbricata* (drillhole marked by arrow) is also shown.

these factors suggest that DI may vary from one location to the other independent of all these aforementioned variables making it more difficult to study DI in both fossil and modern environments. More studies are required involving all other available biotic and abiotic drivers of this interaction to better understand evolution of this variability through time.

Petrological and geochemical studies of granitoid rocks of Bero-Raghunathpur area of CGGC, eastern India: Implications for palaeo-tectonic setting

Kuhu Chakraborty*, Arijit Ray, Goutam Kr Deb
Department of Geology, Presidency University, Kolkata 700073
**Email: kuhugeol@gmail.com*

The Chhotanagpur Granite Gneissic Complex (CGGC) forms an important part of the eastern Indian Precambrian terrain. The major part of the CGGC is comprised of various types of granitoid rocks. The present study focuses on the granitoid rocks of Bero-Raghunathpur-Purulia area of CGGC. Field studies indicate that CGGC granitoids can be identified as augen gneiss, garnetiferous granite gneiss and pink feldspar granite. The lowlands of the CGGC are covered mostly by the garnetiferous granite gneiss while the hillocks and in some cases the lowlands surrounding the hillocks are covered by the augen gneiss. At few places the garnetiferous granite gneiss grades to migmatites which are present at the quarry faces. The migmatites shows prominent quartz-feldspar rich leucosome and amphibole-biotite rich melanosome. The augen gneiss sometimes got extremely

sheared to form pink granite. Petrographically, they are characterized by laths of alkali feldspar and ribbons of quartz. Plagioclase feldspar is less in amount. Texturally, they are porphyritic in nature. The groundmass is composed of quartz, alkali feldspar, little amount of plagioclase feldspar and sometimes a significant amount of biotite. The foliations, defined by biotite, formed due to deformation, wrap the early grains of quartz, feldspar. Based on modal mineralogy CGGC granitoids have been classified as granite and granodiorite according to IUGS system of classification. Geochemical data indicate that the granitic rocks are basically of two types: high silica and low silica. The high silica (70-77 wt %) granites are Fe-rich, peraluminous and calcic in nature; while the low-silica (64-69 wt %) granites are moderately Mg – rich, peraluminous and alkali calcic to calc – alkali in nature. The peraluminous nature of the granitic gneiss suggests derivation of parent magma from partial melting of semi-pelitic meta-sedimentary rocks. The plot of SiO_2 against major oxides shows a progressive enrichment in silica and a decrease in Al_2O_3, Fe_2O_3, MgO, CaO, TiO_2, P_2O_5 content. The variation diagrams for major elements indicate a magmatic differentiation by fractional crystallization. Chondrite normalized REE diagram typically shows an enriched LREE pattern and a general absence of significant negative Eu anomaly, which is typical of the crustal granitoid rocks and also of calc-alkaline rocks. The A/CNK ratios (ranging from 1.3- 1.5) and A/NK ratios (ranging from 1.4- 2.3) provide evidences for the peraluminous, S-type nature of the CGGC granitoids. The peraluminous, S-type character is further supported by geochemical parameters such as Fe* and MALI (modified alkali lime index). Normative corundum >1.0 wt.% is also suggestive of the S-type nature of CGGC granitoids. Geochemical tectonic discrimination diagram may suggest a syn-orogenic environment for the granitoid rocks of Bero-Raghunathpur-Purulia area in a continent-continent collisional setting.

Constraining the timing of the Main Central Thrust activity in Sikkim Himalaya, eastern India

Sayantan Chakraborty*, George Mathew, Malay Mukul, Kanchan Pande
Department of Earth Sciences, Indian Institute of Technology Bombay, Mumbai 400076
**Email: sayantanc@iitb.ac.in*

The recognition of major thrusts and constraining their timing of activity forms a fundamental part in understanding the evolution of the fold thrust belts which they characterize. The Main Central Thrust (MCT) is a major thrust in the Himalaya, originally defined as a sharp contact between Greater Himalayan (GHS) gneisses and Lesser Himalayan (LHS) schists. The lack of a prominent structural break associated with the MCT and similar grade of rocks in its immediate hanging-wall and footwall, resulted in its multiple definitions. We have mapped the MCT in the Sikkim Himalaya based on a ductile shear zone model in combination with protolith ages and geochemical signatures along a ~40 km transport direction. Our study showed that the geometry of the MCT shear zone is anastomosing, with its width varying from ~1 km in the frontal-most exposure to ~2.5 km in its intermediate exposure to ~1.12 km in its hinterland-most exposure. The $^{40}Ar/^{39}Ar$ step heating from the neo-crystallized muscovites and biotites from the mylonites in the MCT shear zone yielded ages of ~14.5 Ma for the biotites in the frontal exposure, ~9.2 Ma for muscovites and ~8.9 Ma for biotites in the intermediate exposure and in the hinterland-most exposure the muscovites and the biotites yielded ~7.2 Ma and ~18.2 Ma respectively. This ~7 Ma time window between the frontal-most and hinterland-most exposures of the MCT shear zone indicate its thrusting period in the Sikkim Himalaya. The new data suggests that the initiation of MCT activity in Sikkim was much later than ~27 Ma as suggested by previous workers. The minimum age of MCT activity is also later than ~12-13 Ma as earlier inferred in Sikkim. The apatite fission track dates (<1 Ma) from the same

samples do not show any prominent break across the MCT, indicating that the MCT and MT sheets were exhumed above the 120°C isotherm at the same time following passive uplift by the Lesser Himalayan Duplex.

Trace and major element analysis of tourmalines from granitic and schist rocks of the Gangpur Schist Belt and its implication for magmatic-hydrothermal fluid evolution

Tuhin Chakraborty, Anwesa Banerjee, Dewashish Upadhyay

Department of Geology and Geophysics, Indian Institute of Technology-Kharagpur, Kharagpur 721302
**Email: tuhinearth@gg.iitkgp.ernet.in*

The Gangpur Schist Belt (GSB), sandwiched between Chottanagpur Gneiss Complex (CGC) in the north and Singhbhum Craton (SC) in the south, comprises group of rocks metamorphosed to lower amphibolite facies condition. The schist belt is intruded by several S-type granitoid bodies. Tourmaline is present in all the rock types of the schist belt. Tourmalines in the GSB are broadly of schorl-dravite composition irrespective of the rock types. However, there is significant variation in major and trace element composition of the mineral in different rock types. Tourmaline in the granites and pegmatites are coarse-grained with millimetre- to centimetre- sized grains, whereas in the schists the grain size is 50-100 microns. Tourmaline in the granites and granitic pegmatites show zoning in thin section comprising an outermost olive green rim usually followed by a blue inner mantle surrounding a light green core. Grains with hour-glass pattern sector zoning are also present in the granitic pegmatites of the Gangpur Group. In general the blue tourmalines have lower concentrations of Na, Mg but higher Al and X-site vacancy compared to the green tourmalines. In terms of trace element concentrations, the blue tourmalines have lower Sc, Sn whereas higher Zn and Pb as compared to the green tourmalines. The substitution vector operational during the transition from green to blue coloured tourmaline growth is $Al(NaR)_{-1}$. It is observed that green tourmaline cores have resorbed boundaries with blue tourmaline rims. This suggests that the green tourmalines had become unstable and partially reacted to maintain chemical equilibrium with a fresh batch of boron rich fluid. Tourmaline compositions of the Gangpur granites follow a trend parallel to the substitution vector $Fe^{3+}(Mg(OH))_{-1}$ whereas the pegmatites follow the $MgFe^{2+}_{-1}$ trend. This indicates that the pegmatites have formed under more oxidizing conditions. Tourmalines, in schistose rocks, occur along with the minerals muscovite and biotite, which define the penetrative foliation in the rock, and also within garnet porphyroblasts as inclusions. Tourmalines in the schists are optically zoned from core to rim and display compositional variations. The rims are enriched in heavy rare earth elements (HREE), Ti, Ca and Na as compared to the cores. This indicates that fluids with different compositions were present during the growth of the cores and rims. However, the Ti-rich rims can also be attributed to the co-existence of biotite with the tourmalines, which may have grown together. The tourmaline inclusions in the garnet are compositionally different from those in the matrix. The tourmalines that occur in the matrix become more Mg-rich as we approach the CGC-GSB contact in the north. This could be correlated with the increasing pressure-temperature condition towards the contact with the CGC. The tourmaline composition implies that different fluids were operational during the evolution of the schist belt, however boron isotopic studies of the tourmalines are necessary for a more comprehensive understanding of the processes involved.

Shape analysis of extinct Amphibian skulls using the software

S. Chakravorti[1]*, D.P.Sengupta[1]
Indian Statistical Institute, 203, Barrackpore Trunk Road, Kolkata 70010
**Email: chirpymoni2009@gmail.com*

Genetic data being unavailable in palaeontology, all palaeospecies are morpho-species. Thus, morphological comparison of sizes and shapes is of utmost important in palaeontology. Traditional vertebrate palaeontology was largely centralised on the anatomical description of fossils. The future trends of palaeontology largely pivot around the newer concepts of morphometry. One of the most important concepts in modern morphometry is the concept of morphospace. It is a multivariate space defined by morphological parametres describing and relating organismal phenotypes. The present work deals with a new method of outline shape analysis involving the study of morpho-space alongwith elliptical fourier analysis and principle component analysis. All of these statistical data analysis and comparison of shapes were done with the R language. R is GNU's freely available software for statistical computing and graphics and is one of the strongest shape prospecting softwares. Here, the Indian Triassic temnospondyl amphibians are used for pilot study. The temnospondyl skull being flat, triangular and bilaterally symmetrical, most of it could be viewed in two dimensions itself. Thus, it was considered as one of the ideal shapes to be constructed and analyzed in a two dimensional morphospace. The order Temnospondyli are amphibians of the extinct Subclass Labyrinthodontia. There are several Triassic temnospondyl taxa known from various Gondwana basins of India. They pose an important status in the history of vertebrate palaeontology in India. Metoposaurids within Temnospondyli ranged from Carnian to Norian with worldwide distribution including India. Their taxonomy remains to be an enigma because within the order Temnospondyli, families are distinguishable, but within family, genera are similar; within genus, species are more similar but within species individuals are different. Their morphospaces were constructed based on shapes of the skulls, lacrimals and parietals. It was discovered that Indian forms occupy a distinct position within the morphospace when a combination of lacrimal and parietal shape was considered. This combination of characters was chosen to distinguish the Indian metoposaurid population as a new genus and species. Thus, this new method of shape analysis can be used to sort taxonomic problems. The Metoposaurids though long headed had their orbits anteriorly placed and were equally short faced. Thus, they were grouped with other short faced temnospondyl forms like brachyopids, plagiosaurids and chigutisaurids. Morphospace of skull outlines of all these short faced forms were constructed and convex hull was superimposed on them. Results depict sharp contrast between their morphospace and functional space. Metoposaurids were widely separated from the other groups showing no overlap whereas the others had substantial overlap within themselves. The limitation of available organismal design helps to analyse the functional trait variation within these groups. Thus, though short faced in their organismal designs they show sharp functional dissimilarity with others. Hence, they are more aptly grouped within the long snouted temnospondyl amphibians. However, to conclude morphospace does not account for the evolutionary fitness of the considered morphotraits. Adaptive landscapes are used in addition for visualising the evolution in terms of geometry of spatial relationship between the selected morphospace and their adaptivity through time and space.

Dasycladaceae algae from the Pin (=Takche) Formation, Spiti Himalaya

Ravi S. Chaubey[1]*, Olev Vinn[2], Birendra P. Singh[1], O.N. Bhargava[3], S.K. Prasad[1], Naval Kishore[1]

[1]Center of Advanced Study in Geology (CAS), Panjab University, Chandigarh 160014, India
[2]Department of Geology, University of Tartu, Ravila 14A, 50411 Tartu, Estonia
[3]INSA Honorary Scientist, 103, Sector-7, Panchkula, India
**Email: ravischaubey@hotmail.com*

The Caradocian (Ordovician)-Wenlock (Silurian) Pin (=Takche) Formation of the Spiti region, northwest Himalaya is a highly fossiliferous lithounit. It has yielded bryozoa, corals-reefs, conodont, algae, ostracods and trilobites. The presently described specimens of dasycladaceae algae Cyclocrinitids *Cyclocrinites* are recovered from the Pin Formation exposed at the Gechang locality in the Parahio Valley where they occur abundantly in the lower part of the Pin Formation and particularly in the calcareous siltstone and sandstone units (=Farakha Muth). The Cyclocrinitids (middle Ordovician to early Silurian) are a small group of macrofossils usually regarded as an extinct tribe of dasycladaceaen algae. The tribe cyclocriniteae includes the *Cyclocrinites* Eichwald, *Mastopora* Eichwald, *Coelosphaeridium* Roemer and *Apidium* Stolley. Cyclocrinites are problematic algae related to receptaculitids. The Cyclocrinitids are warm-water algae and their extinction at the end of Ordovician is related with the cooling and glaciations. Ordovician Cyclocrinitids occurs at several localities in central and southern Asia, including eastern Kazakhstan and western China. Cyclocrinitids preserved in the Pin Formation are flattened thallus and show high degree of compaction. The decline and end of these warm-water algae in Ordovician may reflect the simultaneously cooling and glaciations. Cyclocrinitids occur in normal marine water to highly-saline restricted water setting. Paleogeographic reconstruction shows that most and perhaps all Cyclocritinits lived within 30 degree of the palaeoequator. Cyclocritnitds probably so colonized in soft substrate by attaching themselves to small solid objects, living dasycladacens are often found on soft bottoms attached to pebbles, shells and coral fragments. Cyclocrinitis thalli were relatively, fragile, they were largely restricted to quiet-water environments, either below wave-base of in protected lagoons. Large accumulation of Cyclocirinites in Pin Formation may be attributed to the formed by rare storm generated currents, which penetrated into normally quiet water and swept thalli together.

Sedimentology and depositional environment of Jurassic sequence of Chorar Island, eastern Kachchh, Gujarat

Jehova L. Darngawn*, Satish J. Patel

Department of Geology, The Maharaja Sayajirao University of Baroda, Vadodara 390002
**Email: jjfaiheng@gmail.com*

Chorar Island is the eastern most part of Kachchh basin and comprises ~74.18 m thick, condense sequence of middle Jurassic (Bathonian-Callovian) which is divided in to Khadir (Hadibhadang Shale and Hadibhadang Sandstone Members) and Gadhada (Ratanpur Sandstone Member) formations, demarcated by coralline limestone which is at the top of Hadibhadang Sandstone member. It consists mainly of shales, mixed siliciclastic-carbonate and ferruginous sandstone with thin mudstone bed. The Lower part of the sequence is shale dominated, middle part consist mainly of mixed siliciclastic-carbonate sediments while the upper part is chiefly ferruginous sandstone. The mixed siliciclastic-carbonate sediments display various physical (ripples marks and cross bedding) and biogenic sedimentary structures and are highly fossiliferous in nature comprising

abundant bivalves, corals and echinoid spines. They also display variations in proportions of clastic, allochems and micrite; clastic grains are very fine to coarse in nature while allochems are chiefly made up of fossil fragments, pellets and isolated oolites. The sequence is analyzed for sedimentary facies and divided into eight genetically related sedimentary facies which include Ferruginous Sandstone, Micritic Sandstone, Sandy Allochemic Limestone, Allochemic Limestone, Sandy Micrite, Coralline Limestone, Mudstone and Shale. Clastic and nonclastic sediments show various stages of diagenesis; the boundaries of quartz grains are corroded and later replaced by micrite, micritization of allochems, such as shell fragments, neomorphism to microspar, sparite as well as well developed calcite crystals and dolomitization.

Sediment characteristics (texture, structures and mineral composition) and fossil evidences indicate middle shoreface to offshore environment of deposition. Hadibhadang Shale Member of the Khadir Formation is characterized by shale with thin bands of fine to medium grained micritic sandstone with cross bedding indicating lower shoreface environment. The lower part of the Hadibhadang Sandstone Member shows increases in intensity of allochems envisaged to be deposited in middle shoreface environment. The upper part of the Hadibhadang Sandstone Member consisting of large sized corals coinciding with global rise in the sea level during late Bathonian is envisaged to indicate offshore condition. The intensity of allochem as well as biogenic activities increases towards the upper part of the formation. The shale dominated lower part of the Ratanpur Sandstone Member of the Gadhada Formation was deposited in lower shoreface environment. The upper part grades into friable thickly bedded sandstone followed by coarse grained, cross bedded sandstone and thick ferruginous sandstone with bivalve and, gastropod shells and fossil wood marking the progressive shifting of environment to middle shore face condition.

Laboratory experiments on the role of mechanically weak layer on sequential thrusting in orogenic wedges

Animesh Das*, Santanu Bose, Subhajit Ghosh
Department of Geology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata 700019
**Email: dasanimesh187@gmail.com*

Orogenic wedge is a complex geological structure which usually evolves on a long time scale in a convergent system. Although a large number of experimental and theoretical studies have been carried out to understand the evolution of thrust wedges, majority of them focused on the influence of frictional resistance at the basal decollement (mb) and the geometrical configuration of basal layers on a homogeneous rock sequence. However, layered stratigraphic sequence of varying strength is commonly observed in almost all fold-and-thrust belts. In recent times, some numerical and analogue experiments showed the influence of evaporate layers in the thrust architecture of Zagros mountain.In the present study, we used sandbox experiments systematically to understand the role of mechanically weak layers in a stratigraphic sequence in foreland-ward thrust propagation. Non-cohesive sand and mica powder were used as analogue materials for simulating the strong and weak layers respectively. Our experiments show that foreland vergent imbricate thrusts do not always emerge from the basal decollement. The implication of this finding is immense as it is a common practice to reconstruct a structural section across the orogenic belts, based on the popular assumption that thrust always emerges from the basal decollement. Our results suggest that such simple assumption may lead to significant error in the interpretation of amount of displacement along imbricate thrusts in response to crustal shortening. Our results further demonstrate that presence of mechanically weak horizon can shift the basal decollement surface vertically upward, resulting in ramping of the basal decollement similar to what we observe in the case of Main Himalayan Thrust

(MHT) from INDEPTH seismic profiles. Such ramps eventually perturb the frontal thrust progression by deforming the shallow crustal part above the weak layer by closely spaced thrusts, keeping the layered sequence below it virtually undeformed. Our experiments also showed variations in the amount of displacement along thrust that emerged from the basal decollement, when it traversed through mechanically weak layer. The amount of displacement is large in the segment above the weak layer and it decreases with increasing depth. This has resulted because thrust initially emerged from the upper weak layer, but with progressive shortening it propagates downward to the basal detachment. At this stage, some out-of-sequence thrusts also develop from the basal detachment towards the hinterland and they are likely to have formed by releasing accommodated strain within layers below the weak horizon.

Metamorphism and tectonics of the gneisses from Askot Klippe, Kumaun, Lesser Himalaya

Mallickarjun Joshi, Biraja Prasad Das*
Centre of Advanced Study in Geology, Institute of Science, Banaras Hindu University, Varanasi 221005
**Email: birajageology@gmail.com*

Grade of metamorphism within the Askot Klippe varies from the greenschist to the upper amphibolite - granulite facies transition. Geochemical behaviour of gneisses from the Askot Klippe shows some variation. The biotites in the Askot Crystalline gneisses are enriched in Al_2O_3 and FeO but depleted in SiO_2 and MgO. Fe^t/Fe^t+Mg in biotites of gneisses vary from 0.52 to 0.84 wt%. The MgO content of biotite in the rock shows large variation from 3.15 wt% to 9.29 wt%, whereas Al_2O_3 content varies from 16.3 to 19.77 wt% and FeO content varies from 19.85 to 26.9 wt%. The average FeO^t/MgO ratio in biotite is 4.98. Based on Fe^t/Fe^t+Mg vs. Al^{iv} and FeO/MgO ratio, the biotite in the rocks is mainly siderophyllitic in composition and peraluminous (S-type) in character. In ternary plot of FeO-MgO-Al_2O_3, the Askot gneisses have an affinity towards the per-aluminous (S-type) suite. From the thermobarometry, the average temperature and pressure exceeded 771° C and 6.5 kbar, respectively. The boundary between garnet and biotite is invariably corroded in the thin sections suggesting that the reaction garnet + biotite = orthopyroxene + K-feldspar+ cordierite + melt is likely to have occurred. Thus, this is perhaps the first evidence of the metamorphics of the Askot Klippe touching granulite facies conditions. The pelitic rocks of the Almora Group showing onset of the granulite facies metamorphism are located close to the central parts of the Klippe while the peripheral parts largely comprise mylonitized granite gneisses of the Ramgarh Group with a thrust contact in between.

Based on the field observations and the petrographic observations made on asymmetric shear sense indicators in the oriented thin sections the sense of movements in the Klippe were deduced to be top-to- the south. The folding is pre-kinematic with respect to the thrusting as evidenced by the shear zones cutting across the folds. However, some later syn-shear folds have also developed. The Askot Klippe was formed as a consequence of the southward thrusting of the rocks of the Almora Group and those of the Ramgarh Group from the Higher Himalayan Crystallines (HHC) along the Main Central Thrust (MCT). The Metamorphic Field Gradient (MFG) indicates that the temperatures exceeded 771°C and it is likely that the rocks may have reached the maximum temperature of > 800°C and then returned back along the regressive arm of the P-T path during the tectonic uplift. This is evidenced by the presence of later generation of fresh reaction contacts of muscovite-biotite, muscovite-quartz and biotite-quartz. This would have been possible only if there was little or no fluid loss.

A study on intertidal foraminifera from the coastal region of Chandipur, India

Ishita Das[1,2]*, Meghna Das[1], Gargi Bag[1], Anupam Ghosh[2]
[1]*Department of Geology, University of Calcutta, Ballygunge Science Colleg, Kolkata 700019*
[2]*Department of Geological Sciences, Jadavpur University, Kolkata 700032*
**Email: ishita.mishtu@gmail.com*

A scientific study was carried out in Chandipur region lying on the eastern coast of India to analyse the surficial and infaunal foraminiferal content. Foraminifera are a group of single celled micro-organisms which are extremely sensitive towards subtle changes in environmental conditions. Their ability to detect and record little changes in ambient environmental conditions in their hard external coverings make them very good proxies for monitoring environmental conditions. Coastal conditions often experience a high contamination rate caused mainly by anthropogenic causes. Benthic foraminifera are an effective, low cost indicator to detect the recent changes going on in these coastal systems.

The studied coastal region of Chandipur (21°30'N, 86°54'E) is an endless tidal flat with marshy characteristics in certain areas. The beach has some fresh water influence towards its northern side as Buribalam River meets the Bay of Bengal at Chandipur. Two types of samplings were done, surface sampling (10 x 10 x 1 cm) with the help of a simple trowel and core sampling up to 20 cm of the sediment with the help of a short core tube. The main sampling locations considered for surface sampling were the estuary mouth region, tidal creek region, tidal flat region, bar swamp region and tidal channel region. As they represent a wide variety of environmental conditions, the foraminiferal signatures are also expected to vary. The core sampling was done near the estuary mouth to observe the change in foraminiferal signatures from the top of the sediment surface up to 20 cm into the sediment.

A total of thirteen species of foraminifera have been observed from the intertidal area. The assemblages are characterized by both calcareous and agglutinated foraminifera. The different genera are *A. beccarii, Ammonia tepida, Asterorotalia trispinosa, Discorbis* sp., *Elphidium excavatum, Haplophragmoides wilberti, Haynesina germanica, H. depressula, Nonionella labradorica, Nonionella* sp., *Quinqueloculum akeriana, Trochammina inflata, Trochammina* sp. Agglutinated forms such as *Haplophragmoides* sp. and *Trochammina* spp. designate the marsh zones because absence of continuous supply of marine water causes the organisms to form an agglutinated test whereas calcareous forms such as *Elphidium excavatum*, *Haynesina* spp., *Ammonia* spp., *Nonionella* spp. and *Asterorotalia trispinosa* represent the intertidal zones of the Chandipur coast.

As we go down the core, the total foraminiferal count shows a characteristic variation. We get a good count of foraminifera of above 150 individuals per cm of the sediment till the depth of 12 cm. beyond that, the total foraminiferal number shows a drop till 16 cm of the sediment. After that, the total foraminiferal count increases again. The drop in count of total foraminiferal number in the sediments ranging from 12 cm to 16 cm could be due to some local anomalies. Two consistent foraminifera found throughout the core are *Ammonia* spp. and *Asterorotalia trispinosa*. *Asterorotalia trispinosa* is a typical foraminifera characterised by three prominent slender spines that is perhaps an adaptation to avoid burial in high sedimentation areas. This suggests the distinct preference for substrates with relatively higher mud content and relatively high sedimentation rate of this area.

Accretion of the eastern Ghats with peninsular India: Records from the Rengali orogenic belt and Domain-4 of the eastern Ghats

Sudeb Chandra Das[1]*, Lopamudra Saha[1]
[1]Department of Earth Sciences, Indian Institute of Technology-Roorkee, Roorkee
**Email: sudebju@gmail.com*

WNW trending Rengali Orogenic Belt in eastern India defines the framework of accretionary orogen between the northern margin of the Domain-4 of the Eastern Ghats and peninsular India. This belt, which is sandwiched between the southern margin of the Singhbhum Craton and the northern margin of Domain-4 of the Eastern Ghats consists of amphibolite facies metasedimentary sequences (garnet-staurolite mica schists and quartzites) interleaved with amphibolites. These supracrustal units warp around the migmatitic pelitic and charnockitic gneisses, which yield U-Pb zircon ages of ~2.7-2.5 Ga. These gneisses possibly represent a part of the Bastar Craton (occurring west of the Domain-4). On the contrary, the metasedimentary schists of the Rengali Orogenic Belt ubiquitously preserve metamorphic monazites of ~550 Ma. In our present study along several NNE-SSW transects of the Domain-4 of the Eastern Ghats (extending from south of Rengali Belt to the Mahanadi Shear Zone in the south), we have observed that the main lithology is the garnet-sillimanite-orthopyroxene-biotite bearing khondalites (with well-preserved migmatitic bands), which develop hook-shaped co-axial folds and are intruded by the charnockites and blasto-porphyritic granitoids. Multiple generations of melt layers are also noted in the charnockites. Rare occurrences of folded calc-silicates are also noted. Peak P-T conditions of ~750°C, 7-8 kbar have been recorded from the garnet-sillimanite-orthopyroxene bearing assemblages of the khondalites. EPMA monazite ages from the khondalites yielded broadly ~1.0 Ga from northern parts of transects and ~1.0 Ga, 780 Ma from the southern margin of Domain -4 along the Mahanadi Shear Zone. ~780 Ma age represents exhumation of the terrane post to ~1.0 Ga granulite facies event. Few monazite rims have yielded ~550 Ma ages. The study thus establishes poly-metamorphic evolutions of Domain-4 of the Eastern Ghats with a major mid-crustal granulite facies event at ~1.0 Ga during Rodinia formation and then ~550 Ma during collision of the Indian peninsular when Gondwana supercontinent was formed.

Syngenetic development of carbonates in the late Triassic fluvial deposit of a central Indian rift basin: example from the Maleri formation

Sanghita Dasgupta
Geological Studies Unit, Indian Statistical Institute, Baranagar, Kolkata 700108
Email: sangu.dg@gmail.com

The occurrence and origin of carbonates as grainstones and marls, intimately associated with fluvial mudrocks and sandstones of a Late Triassic fluvial succession (Maleri Formation) deposited within an intra-cratonic rift basin (Pranhita-Godavari) of India, are discussed here. Two main types of freshwater carbonates are associated with this formation: a) Laminated Marls, b) Carbonate Grainstones. The carbonates represent a minor component (5-8%) of this siliciclastic dominated succession, yet are ubiquitous at every stratigraphic level. The grainstones mostly occur as 10-30 cm thick, lensoid or sheet-like bodies either encased within thick, massive, red mudstones or at the base of the stratified mudrock unit; or constitute the basal part of the storeys within multistoreyed sheet-sandstone bodies deposited by ephemeral sheet-floods. They contain fragments of freshwater bivalve shells, ostracods and bones of land vertebrates. The laminated marls usually occur as 5-8 cm thick, discontinuous sheets encased within massive red mudstones, extending for a few tens of

meters. Under microscope they show thin alternating lamination of micrite, microspar and clay. Spar-filled root channels or burrows cross-cut the lamina-set. The micritic lamina contain small articulated ostracod shells and are associated with calcified stems of macrophytes. Framework of the carbonate grainstones constitutes medium sand to granule-sized, internally massive, micritic peloids and coated (oncoids) carbonate grains admixed with variations of subordinate to angular, fine to medium sand-sized siliciclastic grains, bioclasts, and mud-aggregates. Multiple generations of poikilotopic calcite, at places barite occur as cement in inter-granular spaces. Small needle-like manganese and iron rich carbonates also line the wall of these cavities. The oncoids are constituted of nucleus and surrounding layered cortex with varying composition and types. They indicate limited and infrequent rolling of grains in sluggish channels or ponds and formation of microbialite. The peloids resemble fragments of subaerially modified carbonate mud in palustrine environment. The intervening micrite were possibly formed due to bacterial decomposition. Identification of features similar to palustrine carbonate and freshwater oncoliths within these grains as well as their association with the aquatic invertebrates and microbes suggests the existence of contemporary carbonate depositing environments, as evident from the sporadic occurrence of the marls. The occurrence of fossilized remains of amphibians and fishes within the Maleri sediments lends credence to the existence of such environments. The mean $ä^{13}C$ and $ä^{18}O$ values for the carbonate grains are ~ -7.69‰ VPDB and -5.38‰ VPDB, respectively. A distinctly negative isotopic ratio for both carbon and oxygen clearly indicates a freshwater origin. The mean isotopic values for the calcified stems and the marls are similar to the carbonate grains, suggesting a genetic similarity between these two types of carbonates and corroborate the influence of microbial activity. The carbonate grains of the Maleri grainstones were likely to have formed in ponds and sluggish channels that bordered the rift basin margin and fed with Ca^{++} and HCO^{3-} rich spring water draining thick Proterozoic limestones at the rift shoulder. The episodic erosion of the carbonates deposited in those peripheral areas possibly introduced the carbonate grains to the central part of the rift, where the deposition of siliciclastics prevailed.

Analysis of superimposed deformation in the supracrustal rocks near Kesari, Sindhudurg district, Maharashtra: A macro-meso-micro synthesis

A.S. Dashputre[1]*, P.B. Jadhav[2], T. Marathe[1]

[1]Department of Geology, 411004. Fergusson College, Pune

[2]Department of Petroleum Engineering, Maharashtra Institute of Technology, Pune 411038,

**Email: dashputreamey@gmail.com*

The area under present investigation is the northwestern extension of a highly deformed and evolved Dharwar Craton of southern India. Geographically it lies in the Sindhudurg district of Maharashtra and is covered in the Survey of India Toposheet No. 48 E/13. The lithology is dominated by a sequence of metapellites and amphibolites which have been intruded by granitoids with a sporadic presence of quartzites and the BIF. Remote sensing and rigorous field studies have ascertained three deformational events in the study area. All three events have predominantly led to ductile deformation evidenced from the regional scale folds. Three regional fold closures and several small closures have been identified in the study area towards south, west and northeast of the village Kesari. On mesoscopic scale, the folds formed during these deformational events have resulted into formation of interference patterns of diverse shapes; the scale of these interference patterns ranges from inches to metres and even kilometers on a regional scale. The inconsistency amidst the angle between the axial planes and the fold axes of the early folds, attitudinal variation with respect to the angularity of the fold systems, and the altitudinal variation in the tightness of the later folds on the earlier folds can be attributed to the diverse shapes generated by the Ramsay's type III interference pattern in the region.

The present work deals with the analysis and interpretation of about 3500 measurements of the planar and linear structures in the supracrustal rocks. The equal area plots of the measurements across five structurally homogenous domains warrant the aforesaid description of the regional folds. A sharp deviation can be seen in the trend of the F1 fold axes from southwest to east and finally northeast and F2 fold axes from southwest to west across the domains whereas the F3 fold axes have a uniform trend towards northeast. A study of about 500 thin sections of metapellites, amphibolites, granitoids, quartzites and the BIF elucidates the relationship between deformation and metamorphism. The stable mineral assemblages are indicative of greenschist to epidote-amphibolite facies of metamorphism for the metapellites and greenschist to lower amphibolite facies for amphibolites. The evolution of biotite and garnet in the metapellites can be attributed to all the three deformational events (D1, D2, and D3) whereas amphiboles have evolved in the second (D2) and third (D3) deformational events. Inter-tectonic, syn-tectonic to post-tectonic garnets have evolved from biotite in all three successive deformation episodes by progressive metamorphism. The earliest formed garnets during D1 deformation were rotated during D2 deformation wherein they show strain shadows while the new garnets were syntectonic. Shearing during D2 deformation is evident 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. A strong structural overprint and a complex deformation history is revealed by the analysis and synthesis of Macro-, Meso- and Micro- scale observations of the supracrustal rocks in the study area.

Interpretation of strain pattern across Main Boundary Thrust (MBT) in the Darjeeling-Sikkim Himalaya: Insights from microstructural study

Sayan Datta*, Santanu Bose, Subhajit Ghosh
Department of Geology, University of Calcutta, Kolkata 700019
**Email: sayandatta23@gmail.com*

Himalayan fold--thrust belts represent a natural laboratory for understanding thrust tectonics. Three major E-W striking continental scale thrusts are predicted to have splayed from basal Main Himalayan Thrust (MHT) from north to south: Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Main Frontal Thrust (MFT). They are marked primarily by the juxtaposition of lithological units of varying grades of metamorphism and are characterized by distinct zone deformational features. This study focuses on the MBT zone that separates the Tertiary Siwalik rocks in the south from Paleozoic Gondwana sequence in the north in the frontal mountain belt of Darjeeling Himalaya. We carried out detailed field work along the Tista and Mahanadi river sections across the MBT zone. Field observations revealed that the deformation localization is much stronger within the coal bearing Gondwana rocks and shows characteristics of shear localization along this zone. However, we preferentially collected sandstone samples from both hanging (Gondwana) and footwall (Siwalik) rocks for microstructural study to investigate the imprints of mesoscopic deformation observed in the field. We used Normalized Fry method and Rf-Ö method to quantify the strain in quartz grains within sandstone. This analysis calculates the strain magnitude and/or orientation of distortion of strain axis in rocks to estimate the status of strain along the MBT. Our analysis shows that the X/Z axial ratio (Rs) varies from 1.559 to 2.095 for Fry method and 1.432 to 1.725 for Rf-Ö method. The value of Rs (shape parameter) is much higher for samples located near the southern margin of the Gondwana rocks. The maximum value of Rs obtained from both Fry (Rs=2.095) and Rf-Ö (Rs=1.725) methods are recorded from the Gondwana rocks in the hanging wall implies localization of large strain, that might have led to MBT localization in the frontal mountain belts of Darjeeling Himalaya. Both microstructural and field observation suggest evidence of weak deformation in the Siwalik rocks in the farther south.

Terrigenous minerals in the sediments of western Arabian Sea: Evaluation of hinterland

Vikas Dev
Department of Earth & Planetary Sciences, University of Allahabad, Allahabad
Email: glyvikas@gmail.com

Heavy minerals along with acid insoluble residue, biogenic carbonate, and organic carbon isotopes of G. Sacculifer were studied from a gravity core of leg 117 site 722B (Lat. 16°37.312'N, Long. 59°47.755'E; Water depth 2027.8m) in the north western Arabian Sea near Oman margin to identify provenance of sediments and paleo-monsoon changes for the past 554 kyrs. The dominant non-opaque heavy minerals which are available in samples of ODP site 722B are zircon, tourmaline, fluorite, epidote, rutile and staurolite which shows low ZTR index indicating their derivation from mixed sources to the source region. The heavy minerals indicate their derivation from mixed source of acid igneous, basic igneous, gneisses/granites, low to high grade metamorphic rock and reworked sediment occurring in the north- western part of Arabian peninsula (mainly from Oman region) and Indus river (Indus fan). The dominant presence of subangular to angular sand sized heavy minerals indicates a short distance of sediment transport. This implies that sediments at this site are contributed mainly from the nearby Arabian Peninsula (Oman Region). More roundness of finer grains during glacial stages suggests that they are dominantly transported by wind from Arabian Peninsula. Finer grains also show roundness during interglacial stages indicating infer the influence of Indus river. Roundness of coarser grains during interglacial stages which suggest the influence of Indus river and that they are transported by alluvial system (mainly Indus river), but a good amount of rounded coarser grains during glacial period shows the influence of north-western wind from Arabian Peninsula region. These evidences indicate that there is mixed type of environment (eolian and fluvial) with glacial and interglacial stages at particular site 722B. The provenance studies suggest that the heavy minerals are largely derived from the adjoining Arabian sea by north-westerly winds and long transportation by Indus River from Himalaya. It appears that cold and dry periods during the glacial times were responsible for higher amount of terrigenous matter and heavy mineral.

Sediment accumulation rate and bathymetry of Renuka Lake, Himachal Pradesh, India

Pranaya Diwate[1], N.K. Meena[1]*, Ravi Bhushan[2], K.R. Chandana, Sundeep K. Pandita[3]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Physical Research Laboratory, Navrangpura, Ahmedabad 380009
[3]Department of Geology, University of Jammu, Jammu 180006
**Email: naren@wihg.res.in*

The Himalayan lakes are very important as they provide water for drinking, irrigation and other activities. However, these lakes are facing many problems due to higher siltation and pollutant. The present study aimed at understanding the sedimentation rate & bathymetry profile of the Renuka Lake of Himachal Pradesh, India**.** Sedimentation is controlled by both natural and anthropogenic activities in Renuka Lake. The sedimentation rate was measured in top 126 cm core from the surface using ^{210}Pb and ^{137}Cs isotope technique. The current study reveals that Renuka Lake experiences two different sedimentation patterns, from 0-19 cm it shows 0.51cm/year whereas 19-37cm exhibits 0.78cm/year. The average sedimentation rate of Renuka Lake was calculated 0.72cm/year during last 175 year. The Renuka Lake shows reduction in sedimentation rate during *ca* 1974 to 1950 AD possibly due to lake management (The ministry of environmental and forest government of India).

The sedimentation rate of Renuka Lake is well comparable with other North-western Himalayan lake except Rewalsar Lake which shows a very rapid sedimentation rate.

The bathymetry survey also carried out and bathymetry map was prepared in order to understand the bathymetric profile of the lake. The study shows that the maximum depth in Renuka Lake measures 11.89 meters at the centre of Renuka Lake. It has been observed that the Renuka Lake has been deeper toward centre and shallow toward the margin. The Western side of the lake is much shallower with average depth <1 m compare to Eastern part of the wetland shows depth in the range of 1-2 m.

Trace element geochemistry and diatoms of Pulicat Lake, Tamil Nadu, India: Environmental implications

Shubhangi T. Fulmali[1], S.M. Hussain[1]*, D. Sunitha[1], S.K. Humane[2], S.S. Humane[2], Rayees Ahmad Shah[3]

[1]Department of Geology, University of Madras
[2]P.G.Department of Geology, RTM Nagpur University
[3]Department of Geology, Anna University
**Email: smhussain7@hotmail.com*

Inflow of eroded materials and other contaminants from the lake catchments have accelerated the rate of sedimentation and the eutrophication processes. Hence, the assessment of Pulicat lake is necessary. For the purpose, a short core with a length of 1 m is retrieved from the lake which is sub sampled into 35 subsamples with an interval of 3 cm each. All the samples are subjected to standard microplaeontological techniques to the study. The study area consists of 35 species belonging to 35 genera, 25 families, 3 suborder, 2 subclasses and 2 classes have been identified throughout the core. *Grammatophora oceanica Cocconies heteroidea, Opephora swartzii, Mastogloia baldjikiana, Petroneis marina* and *Tryblionella hungarica* were the abundant species and *Nitzschia palea* as well as *Nitzschia sigma* are least present in the entire core. On the basis of textural analysis, a litholog is prepared and divided into three zones i.e., Zone I, Zone II and Zone III from bottom to top. Zone I and Zone III are dominated by sand which indicates the higher energy condition and Zone II shows the calm environment. Zone II showing the dominance of clayey sand, may be due the distribution of mangrove during this period of deposition of sediments. Organic matter is relatively less, it may be because of higher accumulation of sand particle which are carried out by the river in to the lagoon. Deposition of sand in the lagoon favours the significant growth of diatom. The higher concentration of the trace elements may be due to fishing boats and surface runoff of the fertilizer remains of the lake.

Mantle source control on the primitive magma geochemistry: Evidences from four distinct mafic dykes

Sachin S. Ghodke, K. Rathna, K. Vijaya Kumar
School of Earth Sciences, SRTM University, Nanded 431606, Maharashtra
Email: sachinghodke555@gmail.com

Geochemistry of the mantle-derived primitive mafic magmas are controlled by the characteristics of the mantle reservoirs as well as melting mechanisms. Continental rifts are one of the important tectonic settings where geochemical heterogeneities in the mantle reservoirs are reflected by variegated mafic magmas. In the present study, we evaluate the role of mantle source on

the mafic magma geochemistry citing examples from Proterozoic SE India. The Prakasam Alkaline Province in SE India, considered as a Meso-Proterozoic continental rift, hosts at least four distinct mafic magmas represented by alkali basaltic, lamprophyric, shonkinitic and gabbroic dykes. The geochemistries of these four cospatial and coeval primitive magmas require contrasting mantle reservoirs.

The alkali basaltic dykes display ocean island basalt-type characteristics whereas gabbroic magmas exhibit geochemical signatures akin to the subduction-related mafic melts however formed in a continental rift environment. The lamprophyres possibly represent products of mantle-vein melting. The shonkinites are similar to lamprophyres in some of the geochemical characteristics but not all. Lamprophyre-gabbroic melts reflect progressive vein +wall-rock melting process within the continental lithosphere. The alkali basaltic, lamprophyric, shonkinitic and gabbroic dykes from the Meso-Proterozoic Prakasam rift exemplify plume/asthenosphere-lithosphere interactions. The compositional timeline of erupted magmas in the SE India reflect changing deep-seated mantle reservoirs and aid us in the geochemical mapping of the past plate- and plume-tectonics.

Petrography of skarn rocks at Belka Pahar, Sirohi district, Rajasthan

Ghosh Urmi[1]*, Upadhyay Dewashish[1]
[1]Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur
**Email: ughosh17@gmail.com*

Skarn deposits, generally found adjacent to plutons, can form during regional or contact metamorphism by a variety of metasomatic processes involving fluids. The fluids can be of magmatic, metamorphic, meteoric or marine origin. The skarn rocks are zoned and usually associated with economic mineralization. The paragenetic stages common to many calcic skarn are intrusion of a pluton into relatively cool host rocks and hydrothermal fluid infiltration into the surrounding country rocks. Study of skarn rocks is thus useful in understanding fluid-rock interaction processes associated with mineralized zones. The calc-silicate rocks at Belka Pahar in the Sirohi district of Rajasthan belong to the Delhi Super Group and have been intruded by medium-grained leuco-granite. Rb-Sr whole rock isotopic data for the intrusive granite gives an age of 860 ± 25 Ma. A coarse grained wollastonite-rich skarn rock has developed at the contact zone. The skarn mineralogy depends on both the granite and the host rock composition. The Belka Pahar rocks have abundant and ubiquitous wollastonite with garnet, pyroxene, calcite, quartz, epidote, amphibole and chlorite. Individual skarn minerals like garnet or pyroxene display systematic color or compositional variations within the larger zonation pattern. The comparative study of the intruding granite and the skarn rocks is important to find the interaction between them. The calc-silicate rocks are not exposed in the study area. Fine-grained granite, garnet, epidote bearing rocks and biotite granite are present in adjacent areas. Pegmatite veins intrude into the granite bodies. Graphic texture is observed in the pegmatite and mafic enclaves are found within the granitoid body. The deposit is a calcic exoskarn as suggested by the mineralogy. Fluid inclusions in skarn minerals reflect the physiochemical nature of the solutions present during the skarn-forming process; the Na, K and Cl proportions reflect the nature of the associated pluton. Fluid inclusions can provide direct evidence for the content of CO_2, CH_4, N_2, H_2S and other gases in hydrothermal fluids. It also provides direct evidence for the temperature and salinity shift in most skarn systems. Detailed petrographic study of the skarn rocks will tell the prograde and retrograde reactions between the different associated minerals. The peak *P–T* conditions of contact metamorphism can be estimated from mineral equilibria. Presently, Wolkem Private Limited is mining Wollastonite from Belka Pahar. A large amount of calcite is also being produced from this region at present. The present study is based on samples collected from this region. The aim

of this study is the determination of petrographic features, geology and alteration style of the skarn mineral assemblage and the detailed geochemistry of the rocks and fluid so that the processes of formation of the skarn rocks become clearer.

Landform evolution in the marginal Ganga foreland basin during late Pleistocene, India

Rupa Ghosh[1]*, Pradeep Srivastava[1], U.K. Shukla[2], R.K. Sehgal[1]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Dept of Geology, Banaras Hindu University, Varanasi 221005
Email: 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 Geomorphic surfaces of these plain ad their antiquity with respect to climate and tectonics is broadly understood . 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. The present study area occupy the Marginal plain upland surface which is considered to be equivalent to the T_2 surface. 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 lithoclats. 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. 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.

A Jurassic freshwater wetland: Evidences from the Kota limestone, Pranhita-Godavari Gondwana basin

Suparna Goswami[1]*, Parthasarathi Ghosh[2]
[1]Indian Statistical Institute, 203, Barrackpore Trunk Road, Kolkata 700108
[2]India Statistical Institute, 203, Barrackpore Trunk Road, Kolkata 700108
**Email: suparna.goswami5@gmail.com*

Continental carbonates are rich repositories of palaeoclimatic, palaeo-environmental and palaeontological information. The Lower Jurassic Kota limestone is such a continental carbonate deposit which is a part of the sedimentary infill of the Pranhita-Godavari rift basin, India. The three -

four km thick continental sediments (Late Paleozoic to Cretaceous in age) preserved within the P-G basin are known as the Pranhita-Godavari Gondwana succession. These sediments are mostly fluvial in origin. In the Early Jurassic time the fluvial systems gradually transformed into a shallow carbonate depositing lake. Repetitive occurrence of very well laminated calcareous shales, lignitic at places and seven different limestone facies (a variety of laminites, massive, nodular limestones, etc.) comprise the 20-30 m thick Kota limestone. These carbonates show typical features of very shallow lake and palustrine environments. Evidences of microbially mediated precipitation of carbonates are well preserved in these sediments. Based on carbonate facies and their vertical juxtaposition as documented in a number of sedimentological logs we demonstrate here that the deposition of this limestone is characterized by rapid and repetitive fluctuations in water level in a swarm of coeval very shallow, flat bottomed water bodies that constituted a Jurassic wetland. The well-known dinosaur community of India thrived in this wetland environment.

Detrital zircon geochronology of quartzites from southern Madurai Block, India: new insights for Gondwana reconstruction

G. Indu*, Binoj Kumar RB, E. Shaji
Department of Geology, University of Kerala, Kariyavattom Campus, Trivandrum 695581
**Email: indoos209@gmail.com*

The Southern Granulite Terrane (SGT) in the southern part of the Peninsular India preserves Precambrian rock records suggesting a prolonged geological and tectonic history from Paleoarchean to latest Neoproterozoic – Cambrian. It is composed of a number of crustal blocks with protolith ages ranging from Paleoarchean to Neoproterozoic, and dissected by crust-scale shear/suture zones. Among the various crustal blocks in the SGT, the Madurai Block is the largest and is bound by the Palghat-Cauvery Shear Zone to the north and the Achankovil Shear Zone to the south.

Detrital zircons are important proxies for crustal provenance and have been widely used in tracing source characteristics and continental reconstructions. Previous studies considered the Madurai Block as a single crustal block, but recent investigations, particularly those based on high precision zircon geochronology have identified that this block is composed of at least three distinct segments: a Neoarchean segment in the northwest, a Paleoproterozoic segment in the centre and a Meso-Neoproterozoic segment in the southwest. In this study, a detailed investigation is carried out in the southwestern segment of the Madurai Block which is dominated by Meso- and Neoproterozoic lithologies. Here we investigate detrital zircon grains from a suite of quartzites accreted along the southern part of the Madurai Block. The LA-MC-ICPMS, U-Pb dating reveals multiple populations of magmatic zircons, among which the oldest group ranges in age from Mesoarchean to Paleoproterozoic (ca. 2980-1670 Ma, with peaks at 2900-2800 Ma, 2700-2600 Ma, 2500-2300 Ma, 2100-2000 Ma, Shan). Zircons in two samples show magmatic character with dominantly Neoproterozoic (950-550 Ma) ages. The metamorphic zircons from the quartzites define ages in the range of 580-500 Ma, correlating with the timing of metamorphism reported from the adjacent Trivandrum Block as well as from other adjacent crustal fragments within the Gondwana assembly. The zircon trace element data displays prominent REE fractionation, mostly characterized by LREE depletion and HREE enrichment, positive Ce, Sm anomalies and negative Eu, Pr, Nd anomalies. An exception is one sample that shows slight REE variation and can be divided into two groups: one group showing positive Pr, Eu anomalies, negative Nd, Sm anomalies and the second showing positive Ce, Sm anomalies, and negative Nd, Eu anomalies.

The Mesoarchean to Neoproterozoic age range and the contrasting petrogenetic features as indicated by zircon chemistry suggest that the detritus were sourced from multiple provenances involving a range of lithologies of varying ages. Since the exposed basement of the southern Madurai Block is largely composed of Neoproterozoic orthogneisses, the data presented in the study suggests derivation of the detritus from distal source regions implying an open ocean environment. The data suggests that a branch of the Mozambique ocean might have separated the Paleoproterozoic basement rocks in central Madurai Block to the north and the Trivandrum and Nagercoil Blocks to the south, the closure of which occurred during the collisional amalgamation of Gondwana supercontinent during the latest Neoproterozoic-Cambrian.

Benthic foraminifera and geochemical assessment of Puravadaiyanar estuary, Karaikal, south east coast of India

P. Jeshma*, M. Suresh Gandhi

Department of Geology, University of Madras, School of Earth and Atmospheric Sciences, Chennai
**Email: jeshma111@gmail.com*

Foraminifera are unicellular marine micro-organisms classified within the phylum Protista. Foraminifers, being sensitive to minute changes, either undergo morphological changes or even disappear from the area completely due to pollution or unfavorable conditions. The characteristics of foraminifers to incorporate the signature of presence of pollutants are considered an effective tool for temporal pollution monitoring studies. A total of 12 estuarine samples (both sediment and water) were taken along the Puravadaiyanar estuary for distribution of foraminifera and pollution studies. Apart from foraminiferal studies, geochemical studies of the sediments collected are also undertaken to correlate and substantiate the findings. Distribution and multivariate statistical methods, such as correlation and factor analysis were used as predictive and effective tools. The Enrichment Factor, Contamination Factor and Igeo indexes are calculated and used to infer the degree of pollution.

In the water samples, major elements are found to be in the order of Cl>Na>Mg>K>Ca. Trace element studies carried out in water samples show high percentage of Pb, Co and Cu followed by Ni, Zn, Fe, Mn and Cr. The contamination factor of trace elements of sediment sample from the Puravadaiyanar estuary is found to be in the order: Co>Pb>Cu>Zn>Ni>Fe>Mn>Cr. The water samples shows influence of sea water into the estuarine environment. The results also indicate that this region is more contaminated with Pb, Co and Cu but less contaminated by Fe, Zn, Ni, Mn, and Cr than other regions on the south- east coast of India. The Enrichment Factor, Contamination Factor and Igeo indexes indicate the presence of pollution in the study area. Statistical analysis also confirms the presence of pollution. In view of the rapid urbanization and industrialization in nearby area, uncontrolled input of sewage, garbage and industrial effluents into the estuarine region, the elevated concentrations are not surprising. The sedimentological studies reveal the organic matter and calcium carbonate content of the samples, and the bottom water measurements reveal the temperature, salinity and dissolved oxygen of sample locations. These are used to determine whether the conditions prevailing could sustain life. The ratio of living to dead species is also determined and correlated with sedimentological and geochemical parameters. Pollution studies have given way to identify morphological abnormalities in the species, but we could not find many effects among the faunal assemblages because of the nature of the sediments found in that area.

T-R sequence of Wagad highland (Jurassic) of eastern Kachchh, India

Jaquilin K. Joseph*, Satish J. Patel
Department of Geology, Maharaja Sayajirao University of Baroda, Vadodara 390002
**Email: jaquilinjoseph@gmail.com*

Wagad Highland, occurring as an isolated and detached group of outcrop from the Mainland Kachchh, comprises Callovian to Kimmeridgian (Jurassic) sediments. Washtawa dome and Adhoi anticline represents ~341.9 m thick sequence of Washtawa and Wagad Sandstone formations comprising sandstone, limestone and mixed siliciclastic-carbonate, often intercalated with shale, These are divided into eight sedimentary facies, namely quartz arenite, subarkosic arenite, pelloidal wackestone, micritic sandstone, allochemic sandstone, sandy allochem limestone, sandy micrite, and claystone/shale. The quartz arenite and sandy allochem limestone facies shows low to moderate bioturbation in Kharol, Nara shale and Kanthkote members; while the quartz arenite and pelloidal wackestone facies shows high bioturbation in Gamdau and Kharol members, respectively. *Astarte* rich bands of Kanthkote member are represented as sandy allochem limestone facies. The lower band shows the presence of abundant convex-up oriented shells of *Astarte*, along with few *Alectryonia* and *Belemnites*; while the upper band shows the presence of abundant convex-up, down oriented disarticulated *Astarte* shells with feeding and resting traces. The ichnological analysis shows presence the of *Arenicolites*, *Diplocraterion*, *Gyrochortes*, *Gyrolithes*, *Laevicyclus*, *Ophiomorpha*, *Palaeophycus*, *Planolites*, *Protovirgularia*, *Rhizocorallium*, and *Skolithos*, representing Skolithos and Cruziana ichnofacies. Integration of sedimentological and paleontological data reveals two 4th order transgressive-regressive cycles, (TRC-I & TRC-II) consisting of two transgressive system tract (TST-I and TST-II) and two regressive system tracts (RST-I and RST-II). Two flooding surfaces (FS-I and FS-II), three regressive surfaces (RS-I, RS-II, RS-III/MRS), and one sequence boundary (SB-I) marked by RS-I are also identified. The transgressive-regressive cycle-I represents TST-I comprising 98.8 m thick retrogradational middle to lower shoreface deposits and RST-I comprising 54.7 m thick progradational and aggradational deposits of middle shoreface and upper shoreface/foreshore. TRC-II represents TST-II showing 47.3 m thick retrogradational middle to lower shoreface, and RST-II comprising 141.1 m thick progradational distal to proximal delta-front deposits. T-R sequence analysis of the western Wagad region shows that the sediments of Washtawa Formation representing a lower shoreface to foreshore environment was later overlain by tide-dominated delta-front deposits of the Wagad Sandstone Formation, and represents an overall 3rd order regression during Callovian to Kimmeridgian age.

Microgranular enclave hosted in Cambrian Mylliem granitoids: Globules of mafic to hybrid enclave magmas undercooled in plutonic setting

Hansa Joshi, Santosh Kumar
Department of Geology, Kumaun University, Nainital 263002
**Email: skyadavan@yahoo.com*

The Meghalaya Plateau is an extension of Precambrian Indian Shield separated by a large scale Garo-Rajmahal depression. Pan- African orogeny-related Cambro-Ordovician granitoid plutons intrude the Shillong Group and Proterozoic basement gneissic complex. Granitoids exposed in the region referred as Mylliem granitoids intrude the Shillong Group quartzite. Rounded to ellipsoidal, mafic to hybrid mesocratic to melanocratic, fine to median grain microgranular enclaves are hosted in the Mylliem granitoids. Size of enclaves varies from a few cm to 30 cm (0.5 m) across, showing sharp to crenulated margins with the host Mylliem granitoids. Mylliem granitoids are

medium to coarse grained with equigranular to porphyritic texture and contain megacrysts of k-feldspar embedded in a medium to coarse grained igneous matrix. The mineral assemblage of the Mylliem granitoids (bt-hbl-pl-kfs-qtz-mag-spn-ap-zrn) is similar to that noted in the microgranular enclave but differs in modal proportion. The microgranular enclaves contain k-feldspar megacrysts similar to those noted in the host granitoids but they are partially dissolved. Irregular crenulated enclave–host contact with sharp margin without any reaction signature is indicative of undercooling of mafic to hybrid enclave magmas against cooler host magma in a plutonic environment. Magnetic susceptibility (MS) of granitoids can be used to evaluate the granitoid series (ilmenite vs. magnetite series). In the Mylliem pluton magnetite series granitoids predominate over the ilmenite series granitoids; 73% of granitoids record the MS values (7 to 23×10^{-3} SI) typical to magnetite series granitoids that are akin to oxidizing environment intrinsic to source regions and partly to modal abundance of mafic minerals. On the other hand 27% of granitoids record very low MS values (0.25-0.35×10^{-3}SI), typical to ilmenite series reduced type granitoids. The Mylliem pluton records highest MS value (23×10^{-3} SI unit) in the eastern margins, because oxidizing environment in the open chamber was achieved during the magma-mixed and mingled conditions as evident by the presence of ubiquitous enclaves.

Assessment of active tectonics in the zone of Main Central Thrust (MCT), Garhwal Himalaya, India with climate-tectonic implications in lake formation

Lalit M. Joshi, Anoop K. Singh*, Bahadur S. Kotlia
Centre of Advances Study in Geology, Kumaun University, Nainital 263002
**Email: anoop1818@gmail.com*

The present investigation focused on climate/tectonic perturbation along a major tributary in the catchment of Mandakini river, Garhwal Himalaya, India. We are delineating a NW-SW trending active fault (hereafter, named it Gethina-Badanital Fault (GBF) across the Lastar Gad (stream) watershed in the zone of Main Central Thrust (Jutogh/Munsiari thrust/ MCT II). The active fault movement is recognized by various geomorphic features viz., fluvial-lacustrine deposits, water fall, two levels of river terraces, small ponds, stabilized and active landslide fans, fault scarps, higher slope, offsetting of drainage pattern, etc. Additionally, the computing of morphometric data with low value of Valley floor width to valley height (V_f), Asymmetry factor (Af), basin shape (B_s), higher bifurcation ratio (R_b) and sinuosity parameters reflect accelerated erosion, incision, elongation and tilting of drainage basin under strong structural control along the GBF. Further, the ^{14}C AMS radiocarbon chronology of the present day Badanital lake and its counterpart as Badanital paleolake profile (BTP) and Gethina-Jagtoli paleolake profile (GJP) in the zone of GBF/MCTII, documented a lacustrine phase between ca. 12—2 ka BP and even till today. The landslide dammed lake has almost disappeared and shrank to a small pond due to a tectonic upheaval along the GBF/MCT II and intensification of monsoon around ca. 2 ka BP, as characterized by rapid uplift and erosion, sparse Quaternary deposits and debris material throughout the valley carved.

Morphometric analysis of the Khurar river, textural characteristics of its bed-load sediments and weathering environment in the river catchment, central India

S. Kanhaiya*, B.P. Singh, S. Singh, Preeti Mittal
CAS in Geology, Institute of Science, Banaras Hindu University, Varanasi 221005
**Email: sksgly@gmail.com*

The present study is an attempt to investigate the regional topography and, drainage dynamics of the Khurar River, a tributary of Ken River, in central India along with the textural, mineralogical and geochemical behaviour of its bed-load sediments. For the above purpose, a detailed morphometric analysis of the river along with textural, mineralogical and geochemical analysis of its bed-load sediments was carried out. Morphometric analysis was done using SRTM data with the help of ArcGIS 10 software. The area of the basin is 309.57 km^2 with its perimeter 83.24 km and maximum length 32.06 km . Drainage patterns are dendritic to sub-dendritic with stream orders ranging from first to third. Drainage density is 0.34 per km^2, while the bifurcation ratio is 4.5 for the river. The textual analysis indicates that the samples are bimodal to polymodal in nature ranging from very coarse to coarse grained and poorly to moderately well sorted in all the geomorphic units with a few exceptions. The skewness values are coarse to fine-skewed, while kurtosis values are platykurtic to very leptokurtic. The quartz, microcline, muscovite, albite, orthoclase, and oligoclase are abundant minerals in all the sapmles with neglegible variation from source to confluence of the river. The major oxide geochemistry of sedimets indicates that the dominant oxide was SiO_2 followed by Al_2O_3 and other oxides which shows felsic character of river sediments. The Chemical Index of alteration (CIA), Plagioclase Index of Alteration (PIA), Chemical Index of Weathering (CIW), Weathering Index of Parker (WIP), Vogt's Residual lndex (V), Rtrxton Ratio (R), Silica- Titania Index (STI) and Resistant index of maturity (R_M) reflect moderate weathering condition and immaturity of sediments in the basin. The moderate weathering of granites was possible in a sub-humid climatic condition in the river catchment.

Geochemical investigations in sediments from lower Krishna river: Implications to source rock weathering

Archana B. Kaotekwar*, S. Masood Ahmad, M. Satyanarayanan, A. Keshav Krishna
CSIR-National Geophysical research Institute, Uppal Road, Hyderabad–500 007
**Email: archana.ngri@gmail.com*

Detailed geochemical investigations were carried out in sediments and their clay fractions from lower reaches of the Krishna River to investigate provenance of sediments and weathering processes. Major, trace and rare earth elements geochemistry of sediments suggests evidence of sedimentary sorting during transportation and deposition. The geochemical characteristics indicate their origin from weathering of Deccan basalts and Precambrian rocks of southern India. There is a strong negative relationship of SiO_2 with Al_2O_3, Fe_2O_3, K_2O, Na_2O, CaO and MgO and a strong positive relationship of Al_2O_3 with K_2O, MgO and Fe_2O_3. High values of Chemical Index of Alteration (CIA) (61-72) are suggestive of moderate to strong chemical weathering environment. The chondrite - normalized and shale- normalized REE patterns are characteristic of sediments derived by the weathering of mafic minerals. The sediments contain significantly low concentrations of Ba, Sr, La, Ce and Nd and moderately low concentrations of V, Zr, Rb, Zn, Ni and Cr relative to upper continental crust (UCC). Most of the other trace and rare earth elements are almost similar to UCC

values. The strong relationships between ÓREE and TiO_2 and ÓREE with Zr in sediments suggests that REEs are controlled mainly by heavy minerals, such as titanite and zircon.

Lithostratigraphic, geochronological and depositional framework of the Morli – Khiwandi metasediments of Sirohi and Pali districts of Rajasthan

Harish Kapasya*, Yogesh Manat
Department of Geology, M.L.S. University, Udaipur 313001
**Email: harish.geo1606@gmail.com*

The Sirohi Group is the youngest of the three Precambrian orogenic metasedimentary/ metavolcanic sequences in northwestern India, which along with granitoids and granite gneisses constitutes the southwestern part of the Aravalli Mountain belt. The Neoproterozoic Sirohi orogeny (850 Ma) marks the closure of compressional tectonic regime in the Aravalli craton. The beginning of Neoproterozoic marks one of the most dynamic periods in the history of the earth. The Morli-Khiwandi study area is situated in the NW part of Sirohi town and eastern and northern part of Sumerpur town. These form a linear outcrop south-west of the Aravalli Mountain Belt. The Morli-Khwandi metasediments are part of Sirohi Group and dominantly comprise shale sandstone-carbonate-carbon shale metasediments. Some of these metamorphic rocks were subjected to mylonitization and contact metamorphism. They are form outcrops in the Erinpura granitoid terrane. The metasediments are phyllite, quartzite, calc-silicate and carbon phyllite. Geological evidence suggests evolution of the Sirohi basin developed subsequent to cratonization of the underlying Delhi Supergroup rocks at ca 1450 Ma. The Neoproterozoic age of the Sirohi Group is based on reports of younger tectono-thermal events between 1200 and 950 Ma from the region surrounding the Sirohi. A middle to late Neoproterozoic age for the Sirohi Group is also inferred from the field association of these rocks with ca. 850 Ma old granitoids and from several isotopic ages in the range of ~780-680 Ma for the Malani volcanics and plutonic felsic activity. The magma resulted in thermal resetting of older granitoids and other Sirohi rocks. This hypothesis is confirmed from lithostratigraphic and structural evidences. The Sirohi basin opening occurred later than ca. 920 Ma. He also reported the single zircon age of sample collected from the Jawai Bandh region, near Sumerpur, 822.8±0.8 Ma and interpreted youngest age for the Sirohi Group on the ground that the granite body shows features indicating its synkinematic feldspar growth in relation to deformation of the Sirohi rocks. Our study further indicate northwest drifting and an enechelon distribution pattern and last phase of geodynamic resetting in the region.

C - O isotope and REE geochemical studies of auriferous quartz-carbonate veins in granite hosted orogenic gold Deposit at Jonnagiri, Neoarchean Dharwar Craton, Southern India: Implication to the source of gold mineralising fluids

Manisha Kesarwani[1]*, S.K. Swain[1], S. Sarangi[1], A. Sarkar[2], R. Srinivasan[3]
[1]Department of Applied Geology, Indian School of Mines, Dhanbad
[2]Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur
[3]INSA Senior Scientist, IISC, Bangalore
**Email: kesarwanimanisha5@gmail.com*

Archean lode gold deposits belong to the class of orogenic gold deposits. In greenstone terrains, they are hosted in supracrustal rocks of greenstone belts as well as in granitoids. Tracing the

source of mineralising fluids hosted by suprcrustal rocks of greenstone belts (metamorphosed volcanic and sedimentary rocks) have received greater attention relative to those hosted by granitoids, as world class deposits have been known mainly from greenstone belts. In Neoarchean Dharwar craton also, greenstone belt hosted gold deposits have been studied more intensively earlier. C, O, S isotopic studies of greenstone belt gold deposits had indicated juvenile origin of mineralising fluids. We verify in this work whether the same origin holds good for the granitoid hosted gold deposits in the Dharwar craton using C and O isotopic composition of auriferous quartz carbonate veins occurring in shear zones in granitoids. The study area is in the Jonnagiri gold prospect in Andhra Pradesh, southern India.

In the Jonnagiri gold prospect, the ~2650 Ma old greenstone belt consisting of metabasalts and rhyolites are invaded by two granitoid bodies designated as Pagadarayi and (Chennampalli) Gooty granites. Along the eastern margin of the Jonnagiri greenstone belt, a crustal scale shear zone has affected the greenstone belt rocks as well as the Pagadarayi granite. The sheared Pagadarayi granodiorite hosts the gold deposit in this belt. Auriferous quartz-carbonate veins (QCVs) are emplaced in this shear zone within Pagadarayi granitoid. The carbonates of these QCVs were analysed for C and O isotope compositions to constrain the source of auriferous ore fluids.

ä^{13}C values of carbonates of the QCVs fall in the range 4.1‰ to 7.3‰ VPDB and the ä^{18}O values range from 5.4‰ to 20.7‰ VSMOW. C-isotope values are consistent with fluids of magmatic (-5±2‰) and/or mantle (-6±2‰) origin. Although some of the ä$^{18}O_{SMOW}$ values are consistent with fluids of such origin (8±2‰), others are enriched in heavier isotopes which we consider are result of post emplacement interaction with low temperature meteoric/groundwater. On the basis of C isotopic data and unaltered O isotopic data, we suggest a mantle or juvenile magmatic source for the mineralizing fluids. Chondrite normalised REE patterns for a majority of QCVs show convex upward and LREE enriched pattern. Most samples show positive Eu anomalies. These evidences also support juvenile magmatic origin of hydrothermal fluids that gave rise to auriferous QCVs. On the basis of C and O isotopic and REE geochemical data while we propose juvenile magmatic origin for the auriferous fluids, we refute metamorphic origin for the fluids.

Our earlier studies on supracrustal rock (BIF at Ajjanahalli and greenschist facies metamorphosed greywacke in Gadag) hosted gold deposits in the Dharwar craton had provided evidence for juvenile magmatic source for gold deposits in the greenstone belts of the Dharwar craton. The present study provides evidence for similar source for granitoid hosted deposits also. In the Neoarchean Dharwar granite greenstone province, gold deposits seem to have been formed from juvenile hydrothermal solutions irrespective of whether they are emplaced in greenstone belts or in granitoids.

Palaeoclimatic reconstructions during early stage of Himalayan orogeny from the study of middle Eocene foreland basin sediments of Subathu sub-basin, NW Himalaya, India

Yuvika Khanna[1], Seema Singh[1], Santanu Banerjee[2]

[1]Centre of Advanced Study in Geology, Panjab University Chandigarh 160014

[2]Department of Earth Sciences, Indian Institute of Technology Bombay, Powai, Mumbai 400076

The continent-continent collision between the Indian plate and the Eurasian plate in the Lower Eocene resulted in the emergence of World's youngest, highest and most dynamic orogenic belt known as the Himalaya. Subsequently, a foreland basin was created to its south which is filled by sediments generated due to the denudation of uplifted Himalayan rocks. Foreland basin sediments

are widely studied and their studies are critical because they preserve climate, tectonic and sedimentary process records. In general, it has been shown by researchers that fine-grained sediments commonly comprise the early orogenic foreland basin deposits. The early Himalayan Foreland Basin (HFB) sediments are named as Subathu and Dagshai formations in the Shimla hills of Subathu sub-basin of the NW Himalaya, India. The contact between Subathu and Dagshai formations is represented by a combination of variegated purple siltstone-shale alternations, described as 'passage beds'. Several outcrops of passage beds occur in and around Shimla hills in the HFB. Here we report geochemical studies carried out in such a passage bed exposure along the Koshaliya River in the Parwanoo district of Himachal Pradesh state of India. These sediments are pedogenically modified and show conspicuous change in colour from the older greenish-grey to dark greyish-brown to the youngest dark reddish-brown pedons. Several geochemical transfer functions are used to interpret the ancient mean annual precipitation (MAP) and mean annual temperature (MAT) values from major oxide concentrations of sediments. Palaeoclimatic reconstructions of that time have been done on the basis of major oxide values in these passage bed sediments. The major oxide concentrations have been determined using ICPAES. In general, MAT remained ~14C throughout the deposition of these passage beds except two significant peaks of ~11C and ~16C in the lower and upper beds, respectively. Similarly, MAP remained on an average ~1000 mm/yr with two distinct peaks of decreased precipitation of ~750 mm/yr and ~350 mm/yr during deposition of lower part of passage beds. Preservation of such finer scale climatic signals in these pedons paves way for detailed studies at various other such regional outcrops for a holistic understanding of tectono-climatic conditions during deposition of these sediments in the early stage of Himalayan orogeny.

Emplacement velocities of hydrous alkaline mafic magmas

Gaurav J. Kokandakar*, K. Rathna, Sachin S. Ghodke, K. Vijaya Kumar
School of Earth Sciences, SRTM University, Nanded 431606, Maharashtra
**Email: kgjgeology@gmail.com*

Magma velocities are a function of chemical composition and physical properties viz., viscosity and density. However, the presence of fluids in the magmas greatly influences the emplacement velocities. In the present study, we have calculated magma densities, viscosities and velocities for three distinct varieties of hydrous alkaline mafic magmas based on their chemical composition. The three mafic alkaline magmas are represented by the dykes of shonkinite, lamprophyre and alkali basalt. The dykes belong to the Meso-Proterozoic continent-rift related magmatism within the Prakasam Alkaline Province (PAP), SE India.

The shonkinite and lamprophyre dykes are emplaced into alkaline plutons composed of nepheline syenite and alkali basaltic dykes are emplaced into mafic-ultramafic complexes. Width of the dykes range from 15-68 cm, 21–77 cm and 45-76 cm for shonkinite, lamprophyre and alkali basalt dykes, respectively. We have estimated the viscosities and densities of the magmas at different temperatures. The calculated viscosities between 700°C and 1300°C for shonkinite are in the range of 10^{7}-$10^{1.5}$ Pa S, lamprophyres are in the range of 10^{7}-$10^{0.3}$ Pa S and alkali basalt are in the range of 10^{8}-$10^{0.4}$ Pa S. The average estimated velocities of shonkinite, lamprophyre and alkali basalt dykes are 833, 892 and 1,529 cm/sec, respectively when considered phenocryst-free, whereas with 30% of phenocrysts, the velocities reduce to 215, 230 and 395 cm/sec, respectively. It is found that, velocity negatively correlated with increasing percentage of phenocrysts and decreased by up to 75% for all the three types dykes.

The emplacement velocities of the hydrous alkaline magmas are negatively correlated with viscosity but positively correlated with dyke width, temperature and density. We found that the

calculated velocities are positively correlated with FeO content in the dykes suggesting that iron content of mafic hydrous alkaline magmas may be an indirect indicator of their emplacement velocities.

Tectonic framework of the Aravalli-Delhi Fold belts in northwestern India

Ambik Kumar*, Lopamudra Saha
Department of Earth Sciences, Indian Institute of Technology-Roorkee, Roorkee
*Email: kumarambik@gmail.com

NE-SW trending Aravalli-Delhi Fold Belt in north-western India forms a polymetamorphic terrane that records imprints of two major orogenies: (i) Palaeoproterozoic Aravalli Orogeny and the (ii) Grenvillian Delhi Orogeny. This polymetamorphic terrane includes the granulites of the Sandmata and Mangalwar Complexes. East of these granulite belts are the vast expanses of migmatites in the north and the NE-SW trending amphibolite facies schist belts of the Rajpura-Dariba and Pur-Banera areas in the south together form the Aravalli Supergroup. The polymetamorphic granulite belts of the Mangalwar and Sandmata Complexes record a Palaeoproterozoic granulite facies anatexis at ~8 kbar, 750°C and a Grenvillian high pressure anatexis at ~10-14 kbar, 800°C. On the contrary, a Grenvillian (EPMA monazite ages) anatexis at ~8 kbar, 725°C are recorded from the garnet-sillimanite-biotite-mullite bearing migmatites occurring at the north-western margin of the Aravalli Supergroup, that are separated from the high-pressure granulites of the Mangalwar Complex. Similar P-T conditions for Grenvillian anatexis have also been obtained in the present study from granite gneiss occurring at the north-eastern margin of the Aravalli Supergroup at the contacts of North Delhi Fold Belt. In contrast, Grenvillian metamorphism recorded from the Rajpura-Dariba and Pur-Banera Schist belts indicates mid-crustal amphibolite facies subsolidus conditions (8 kbar, 600°C; unpublished data, present study). The migmatites of the central part of the Aravalli Supergroup were formed during a single phase of crustal anatexis at ~7-8 kbar, 750°C at ~1.7 Ga (monazite ages). These migmatites do not show any Grenvillian overprint. The study thus reveals that different sections of Aravalli Supergroup evolved in different time-frames (~1.7 Ga or ~1.0 Ga) and have undergone metamorphism under different P-T conditions. A future comprehensive study in the terrane is proposed for detailed characterisations of different metamorphic terranes in the Aravalli Supergroup especially to establish the extent of impact of Grenvillian Delhi Orogeny along several units. Such a study will help to establish the framework of north-western part of peninsular India during formations and break-ups of Columbia and Rodinia supercontinents.

A-Type granites from the Nigana Ring Complex, Bhiwani (Haryana), India : Petrological, geochemical and tectonic approaches

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

The present research activity is focused on petrological, geochemical and tectonic studies of A-Type granites from the Nigana Ring Complex. On the basis of detailed field and petrographical observations, 10 granite samples were selected for geochemical analysis and analyzed by using XRF and ICP-MS from the Wadia Institute of Himalayan Geology, Dehradun. Nigana Ring Complex (NRC) which is a part of Neoproterozoic Malani Igneous Suite (MIS) consists of different varieties

and shades of acid plutonic rocks, viz., light grey granite, dark grey granite, light pink granite and dark pink granite. Xenoliths, sharp contacts between rock types, vertical columns, joints, fractures, small sized veins with copper enrichment (upto 1578 ppm), and spheroidal weathering are the distinctive features of these granites. Petrographically, granites show hypidiomorphic, granophyric and microgranophyric textures. They are essentially composed of k-feldspar, quartz, amphibole, plagioclase and biotite as essential minerals and hematite, zircon, annite, monazite and rutile as accessory minerals. Geochemically, the granites of NRC are characterized by high SiO_2, Na_2O+K_2O, Fe/Mg, Al_2O_3, ASI, HP, HGU and low CaO, MgO, Nb. Primitive mantle normalized spider diagrams show that the Nigana granites are enriched in Rb, Zr and Ba and depleted in Sr, Ti, P, Y and show negative Eu anomaly, which explains the role of crustal contamination in mantle derived magma. Negative Ti and Sr anomalies can be interpreted as reflecting ilmenite fractionation and attributed to low-pressure feldspar fractionation, respectively, during rock formation. The high A/CNK (>1) ratio values suggests that these rocks are of peraluminous nature. They owe their high A/CNK (>1) ratio to a combination of source, magmatic and fluid effects. Overall, they have much higher values of HP (10.23 ì Wm^{-3}) and HGU (24.35) 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. Trace element discrimination diagrams, i.e., Rb vs Y+Nb diagram, R1-R2 diagram (after Batchelor and Bowden, 1985) showing the "Within Plate Granite" (WPG) and Anorogenic characteristics of the Nigana granites. Field observations and petrographical and geochemical data indicates that A-Type granites from Nigana area having Peraluminous nature is related to within plate granite tectonic setting and in future can be used to expand the understanding regarding mineralization potential and tectonic aspects of the MIS.

Inconsistent variation of sediment load and discharge in Chenab and Sutlej Rivers: the effect of snowfall and glacier melting in abnormal years

Prem Kumar[1]*, C.S. Dubey[1], R.P. Singh[2]
[1]Department of Geology, University of Delhi, Delhi 110007
[2]DEPS, University of Allahabad, Allahabad 211002
**Email: prem.dugeology@gmail.com*

Discharge and suspended sediment load of rivers in the northwest Himalayan region is mainly result of rainfall, snow, glacial melt, landslides, erosion and snow avalanche. The area lies in very difficult terrain of Himalaya which provides very less number of metrological stations. Rivers in this region supply agricultural and, drinking water to a large community and also used for hydropower generation. Here we analyzed discharge and sediment load data at different stations for two catchments i.e. Chenab and Sutlej rivers of the northwest Himalaya. Suspended sediment load and discharge data were calculated for 36 years (1974-2009) in the Chenab basin and for 5 years (2004-2008) in the Sutlej basin which shows increasing trend from upstream to the downstream stations. The seasonal variation of the discharge and suspended sediment load data shows high value in the monsoon period followed by pre-monsoon and post-monsoon. The TRMM 3B42 precipitation data of 10 years (2001-2010) is analyzed which shows high rainfall in the orographic windward side due to the effect of summer monsoon.

An analysis of daily sediment load and discharge data for the Sutlej rivers and Spiti River (latter is a tributary of Sutlej both meet at Khab) shows a significant increase in discharge and sediment load in year 2004 and 2005 which shows that they are the abnormal periods. Average seasonal discharge and sediment load for Pre-monsoon, Monsoon and Post-Monsoon shows increase in discharge with increase in sediment load for Sutlej and Spiti River. However decrease in sediment

load with increase in discharge is observed for Post-monsoon of 2004-05 for both the rivers which can be attributed to melting of snow/glaciers. Interestingly, it can be seen that these anomalies are noticeable for year 2004 and 2005 at Khab, which suggests that these two years could be anomalous or years of extreme events. The reason for this anomaly could be anything from extreme precipitation, high glacier melt, cloud burst and heat anomaly to presence of thrust/ faults, etc.

The upstream part of the catchment of both the rivers lies in the leeward side of the orographic barrier. The westerlies carry moisture in this leeward side of this area and precipitates in the form of snowfall also known as winter monsoon. Due to the higher elevation of this area summer monsoon is not able to carry moisture to this part and high rainfall is observed only in the downstream part of the catchment basin. The high discharge in the upstream stations is a result of glacial and snow melting due to increasing temperature. In the month of February 2004 and 2005 high snowfall is reported in the leeward side which is mentioned in SAC report. Glaciers in this area of Himalaya are retreating rapidly and out of 337 glaciers mapped in the Spiti catchment, 50% are retreating while 113 out of 116 glaciers of Chandra basin and 108 glaciers out of 111 glaciers in Bhaga basin are retreating. The high sediment load and discharge in the leeward side of the area is the combined effect of snow, glacier melting, erosion, landslides and snow avalanche.

Isotopic characterization of snow in the upper catchment of Ganga river

Rajvardhan Kumar, Ramotar Singh, Abhayanand Singh Maurya
Department of Earth Sciences, Indian Institute of Technology,Roorkee 247667

Himalaya is the third largest cryospheric system outside the polar region and is popularly known as water tower of Asia because it stores a huge amount of fresh water resources in the form of seasonal snow and high altitude glaciers. Fresh to a few days old snow was collected by pitting method from the various locations of upper catchment of Ganga Basin, which lies between 2300 m to 3500 m altitude during January and March 2015. The isotopic ($ä^{18}O$ and äD) results of winter snow were compared with summer precipitation data of equivalent altitude. The $ä^{18}O$ and äD regression shows that the LMSL (Local Meteoric Snow Line) lies above the LMWL (Local Meteoric Water Line) and GMWL (Global Meteoric Water Line). The average $ä^{18}O$ and äD of both precipitation and snow are comparable to each other whereas the d-excess of winter snow (~25‰) much higher than precipitation (11‰). The higher d-excess in snow can enhance by notable four mechanisms like precipitation from locally re-evaporated vapor or due to secondary isotopic effect in snowpack and the precipitation from Mediterranean vapor and fourth factor is condensation of moisture in open system. The literature and theoretical calculation suggests that such a huge snow fall won't be possible from locally re-evaporated component as there are no such big reservoirs which can generate huge amount of vapor to sustain Himalyan winter snowfall and secondly, the secondary effects can enhance only some ‰ of d-excess due to melting and re-freezing. Possibly the enhanced d-excess which is observed in winter snow of upper catchment of the Ganga River may be the source of moisture located in Mediterranean region and transported to Himalayan region through Western disturbance or the moistures from various sources condensed in open system.

Time averaging – an enigma for the palaeontologists: An example from the Turonian (Late Cretaceous) of central India

S. Kumar
Centre of Advanced Studies, Department of Geology, Banaras Hindu University, Varanasi 221005
Email: skumarpetro09@gmail.com

The geological records are considered ideal when they incorporate the infinite resolution, completeness, perfect chronological order and global isochroneity. In reality, these are affected by direct or indirect factors. Such imperfections are classified as incompleteness, stratigraphic disorder and time averaging. Time averaging is one of the preservational events through which shells from different time intervals are preserved together. This brings the events that occurred at different times appear to be synchronous in the geological record. In the present contribution author collected the bivalve specimens from the Nodular Limestone Formation of the Bagh Group. It comprises a thick pile of siliciclastic and calcareous sediments exposed in several localities of the western Narmada Basin, Central India which deposited during the Late Cretaceous. It is unconformably overlain and underlain respectively by crystalline rocks and the Deccan Traps. An attempt has been made to use the concept of time averaging to explain the occurrence of bivalve fossils of different ages in a single horizon. The three divisions (Early, Middle and Late) of Turonian exhibit conformable stratigraphic succession. The Middle Turonian bivalves *Modiolus typicus* Forbes, *Grammatodon* cf. *japeticum, Mytiloides duplex* (Chiplonkar & Badve), *Inoceramus apicalis* (Woods), and *Paraesa faba* (Sowerby) occur mixed with the Early Turonian taxa, such as *Spathites* (*Jeanrogericeras*) *revelieranus* (Courtiller), and *Mytiloides labiatus* (Sclotheim). Similarly, the Late Turonian bivalves (*Flaventia deserti* Douville, *Liopistha protexta* Conard, *Pachymya* (*Arcomya*) sp., *Flaventia brongniartina* Leymerie) occur with the Middle Turonian ammonoid species *Collignoniceras* cf. *carolinum* d'Obrbigny and inoceramid species *Inoceramus hobetsensis* Nagao and Matsumoto. The present contribution suggest that the time averaging in the Turonian of Bagh is a biostratigraphically condensed assemblage. This time averaging in the studied area spans about 4.1Ma, which is a long geological duration for such cases.

Isotopic evolution of earth's silicate reservoirs using open systemgeochemical models

Seema Kumari*, Debajyoti Paul
Department of Earth Sciences, Indian Institute of Technology-Kanpur, Kanpur 208016
**Email: seemak@iitk.ac.in*

An open system geochemical model for the Earth, comprising bulk continental crust (CC), depleted upper mantle (UM)–source of mid–ocean ridge basalts (MORB), a lower non-chondritic mantle (LM)–source of ocean island basalts (OIB), and an isolated reservoir (IR), is solved numerically at 1 Ma time step for 4.55 Ga, simulating the evolution of key radioactive isotope systems (Rb–Sr, Sm–Nd, and U–Th–Pb) through Earth's history. The most plausible model derived solution is the one that produces the present–day concentrations as well as isotopic ratios in terrestrial reservoirs constrained from published data. Various crustal growth scenarios (continuous versus episodic and early versus late) and their effect on the evolution of isotope systematics in the silicate reservoirs have been evaluated. Modeling results suggest that a whole mantle that is compositionally similar to the present–day MORB source is not consistent with observational constraints. However, a heterogeneous mantle model, in which the present–day UM is ~60% of the total mantle mass and a lower non–chondritic mantle, reproduces the estimated isotopic ratios and abundances in Earth's

silicate reservoirs. Our results show that mode of crustal growth strongly affects the isotopic evolution of silicate Earth; only an exponential crustal growth pattern satisfactorily explains the chemical and isotopic evolution of the crust–mantle system. One notable feature of successful models is the early depletion of highly incompatible elements (and a rapid decrease in Th/U ratio, ê, in the UM) by the initial 500 Ma, as a result of early formation of continental crust. Results show that it is possible to resolve the Pb paradox in an evolutionary model that also matches mass balance constraints. We find that the ê conundrum (as well as Pb isotopic ratios in the UM) is a natural outcome of an open system evolution in which crustal recycling, specifically preferential recycling of U for the past 2 Ga, plays a dominant role. It favours a young Earth (4.45 Ga) and highlights the importance of U recycling in the Pb isotopic evolution of the Earth. Our model simulations favour preservation of compositionally distinct mantle reservoirs over billion year time periods and a present?day non?chondritic lower mantle.

Sediment core textural analysis to verify Quaternary deposit abnormality

Abhijith P. Kurian*, Rajendran S.
Kerala University of Fisheries and Ocean Studies, Panangad, Kochi 682506, Kerala
**Email: abhijithpkurian@gmail.com*

The study of a sediment core (VC-03) collected from Kochi offshore has brought out the down core variation in the textural parameters of the sediments. Study of grain size parameters and bivariate plots has revealed the various details and nature of the sand, silty sand, ferruginous sand. On the whole, there is an increase in silt content and decrease in sand content towards the core bottom. There is an overall fining of sediments towards core bottom. Sorting values for all the sediments show poor to very poor sorting reflecting variation in rate and energy of the depositing agent. Similarly, all the sediments are finely skewed indicating excess tail of fine sediments and a low energy depositional environment. All sand samples fall in leptokurtic to very leptokurtic field in nature reflecting unimodal distribution and silty sand shows bimodal distribution reflecting mixing of environments. The C-M diagram Tanner's plot all types of sediments are deposited in beach environment and are transported both by suspension and traction loads. Sediments studied show dominance of fluvial process with slight influence from storm activity. In the coarse fraction, sediments are mainly terrigenous quartz (>90%). In the sand and silty sand fraction below 100 cm, quartz grains are yellow in colour due to staining by iron oxide suggesting that oxidation took place due to sub-aerial exposure in the geological past. Biogenic matter contains shells, shell fragments and foraminifera. In beach environment, finer sediments are deposited progressively towards sea. The presence of coarser sediments in deeper offshore areas in an overall regime of finer sediments is anomalous. This sand occurrence, beyond 77m, is a product of high energy littoral environment, and possibly represents the last still stand of the sea. So, this relict or palimpsest sediments (Emery, 1968) represents sea level fluctuations during the Late Quaternary Period after the Last Glacial Maximum from radiometric dating.

Geological investigation of rockfall in Aizawl, Mizoram

H. Lalhlimpuia[1]*, Shiva Kumar[1], Laldinpuia[2]
[1]Department of Geology, Mizoram University, Aizawl, 796 004, Mizoram
[2]Department of Geology, Pachhunga University College, Aizawl 796001, Mizoram
**Email: ahlimahauhnar@gmail.com*

Mizoram situated in the north-eastern part of India is a rugged terrain and forms a part of Patkai-Naga-Lushai-ArakanYoma Hill ranges. Rockfall is one of the common hazards along the highways in the terrain of Mizoram. Rock-fall is the detachment of blocks from a steep slope along a surface on which little or no shear displacement takes place. It happens repeatedly during dry and monsoon season. These are one of the common hazards along the highways in the terrain of Mizoram. Rock-fall is the detachment of blocks from a steep cuts scarpment rarely along a surface on which little or no frictional force takes place. Material falling down ranges from fine (1-2 mm) to boulder size. The most prominent one is Ngaizel rockfall that occurred on 17th August 2010 and 22nd May 2011. These two rock-falls affected settlement, motor workshop, road and vehicles. Therefore, a need of geotechnical analysis of the study area is important with an objective of studying the behaviour of rock-fall. Various field work and instrumental (Schmidt Hammer's instrument for in-situ compressive strength) measurements reveal the nature of rock-fall in the study area which can be helpful in developing the rockfall hazard rating system for geotechnical investigation.

Stratigraphy and structure evolution of Revder area and adjacent region, Sirohi district, Rajasthan

Yogesh Manat
Department of Geology, M.L.S. University, Udaipur, 313001, Rajasthan
Email: manatyogesh@yahoo.com

A younger volcano-sedimentary phase representing the Sindreth Group overlies the Sirohi Group. The Sirohi metasediments have been intruded by younger Erinpura Granite. The Sirohi Group comprises phyllite, chlorite-biotite schist and para-gneisses belonging to the Jiyapura Formation and mica-schist (quartz-chlorite schist), calc-silicate rock and marble belonging to the Revdar Formation. The phyllites are exposed on the western fringe of Mount Abu Massif with a tectonic contact, They are light green to dark brown in colour and at places, show extreme ferruginisation, and are composed mainly of quartz, chlorite and sericite. In some unmappable bands they occur as siliceous phyllites dark brown to grey in colour. Schistose rocks (biotite schist, mica schist and para-gneisses) occur to the west of this phyllite. The main constituents of schistose rocks are biotite, chlorite and quartz with subordinate garnet, muscovite, sericite, magnetite, epidote and zircon. These have been feldspathised at a number of places along their contact with the granite and as a result to the north and west of tokra these schist occur as para-gneisses. The schistose rocks are intercalated with a minor band of calc silicate rocks, and marble bands near Hara Magra area and south of Anadra.

Erinpura Granite occurs as an intrusive body (porphyritic granites-pink and grey variants) in the area. It is composed essentially of quartz, k-feldspar (orthoclase and / microcline), plagioclase (albite, a little oligoclase), biotite hornblende and chlorite with minor apatite, zirocon and magnetite. Graphic, perthitic, antiperthitic and myrmekitic intergrowth textures are present in thin sections of this granite. Along the contact with phyllite this granite is sheared and occurs as foliated granite. Mylonitic foliation and a strong down-dip stretching lineation defined by thin streaks of muscovite are developed in this granite.

Conditions of crystallization and genesis of mica-amphibole bearing granitic pegmatites of Nagamalai area, Madurai district, Tamil Nadu, India

R. Manu Raj*, S.N. Kumar
Department of Geology, University of Kerala, Palayam, Thiruvananthapuram 695034, Kerala
**Email: manuraj1331@gmail.com*

The Southern Granulite Terrain (SGT) has different types of gneisses, charnockites and intrusives. The Nagamalai area in the Madurai Block, located in South Tamil Nadu, forms a part of the SGT, where the gneisses and charnockites are pierced by Late Proterozoic A-type granites and granitic pegmatites. The pegmatites of Nagamalai area are of two types-gray and pink. Both variants of pegmatites are composed of varying proportions of k-feldspar+ quartz+ plagioclase+ biotite+ hornblende+ titanite+ magnetite+ apatite and zircon. Biotite and amphibole, the dominant ferromagnesian minerals of pegmatites, have been subjected to electron microprobe analysis. The $Mg^{\neq}$ [Mg/ (Mg+Fe^{2+})] of biotites in gray (av. 0.697) and pink pegmatites (av. 0.680) indicate their Mg-rich nature. The Ti content in the biotites of gray pegmatite (av. 0.298) is higher than that of pink pegmatites (av.0.192). The content of Al^{IV} in biotites of both gray (av. 0.212) and pink pegmatites (av. 0.161) is low. The average Fe^{3+}/ (Fe^{3+} + Fe^{2+}) value of biotites in both pegmatites is 0.046. Biotite in the granitic pegmatites belongs to the reequilibrated type pointing to the alteration from magmatic hornblende /biotite. It also indicates that Mg-Fe substitution has played a significant role in the crystallization of biotite. The chemical signatures of biotite show its crystallization from a reduced magma with an alkaline affinity; and temperature of formation between 600 and 650°C. The amphiboles in the pegmatite have low $Mg^{\neq}$ (av. 2.85 for gray and 0.275 for pink pegmatites) and high Fe^{3+}/ (Fe^{3+} + Fe^{2+}) (av. 0.819 for gray and av. 0.830 for pink pegmatites) values. The structural formula and end member composition of amphiboles represent the hastingsite type calcic amphibole in these granitic pegmatites. The crystallization pressure of amphiboles in these pegmatites was estimated using the Al^{tot} content. The calculated geobarometry for gray and pink pegmatites is 4.5 and 5.5 kb respectively (av. 5 kb). Based on amphibole-plagioclase thermometer ($HB_2$94) the magmatic temperature is deduced for gray and pink pegmatites as 763°C (av.) and 743°C (av.) respectively. Biotite and amphibole in both pegmatites represent low oxygen fugacity condition of crystallization and show the pink pegmatites to have formed from the latest magmatic fraction.

Provenance, petrofacies, tectonic setting and diagenesis of Sawa Sandstones Formation, lower Vindhyan in and around Rithola village, Chittaurgarh, southeastern Rajasthan, India

Jyoti Mathur*, Abdullah Khan and Meradul Islam
Department of geology, Aligarh Muslim University, Aligarh 202002
**Email: mathurjyoti52@gmail.com*

The Meso-Neoproterozoic Vindhyan Basin is considered as one of the largest and thickest Proterozoic sedimentary basins of the World. Sawa Sandstones Formation (~60m) representing clastic assemblage of Lower Vindhyan Supergroup of southeastern Rajasthan overlies The Bhagwanpura Limestone Formation with a sharp, non-depositional contact and crops out as narrow linear ridges of sandstone trending north-south along the regional strike with regional dip towards east. The Sawa Sandstones in and around Rithola village, southwest of Chittaurgarh were studied in order to understand provenance, tectonic setting and diagenetic history. The Sawa Sandstones consist of various types of quartz, feldspar, rock fragments and micas which are medium to coarse grained, subangular to subrounded, moderately well sorted to well sorted and quartzarenite in nature, derived

mainly from Banded Gneissic Complex and preceding Vindhyan Succession located to the west of study area. Petrofacies study reveals that the Sawa sediments were derived mainly from craton interior and continental block orogen provenance. The chemically precipitated cements include silica, iron oxide, calcite in order of abundance.

Sr–Nd isotopic and elemental compositions of Neo-Proterozoic sedimentary succession from the upper Vindhyan basin, Madhya Pradesh India: Implications for provenance evolution

Deepak Singh Maurya[1]*, S.K. Rai[2], Uday Bhan[1], D.K. Gupta[1]
[1]University of Petroleum and Energy Studies, Dehradun 248007
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: dsmaurya11@gmail.com*

The major, trace element and Sr–Nd isotopic compositions of Neo-Proterozoic sedimentary rocks from the Bhander Group, Sirbu Shale Formation, Upper Vindhyan Basin, Madhya Pradesh, have provided evidence for provenance evolution and associated paleo-geographic renovation. Compared to the average composition of post-Archean Australian shales (PAAS), the Neo-Proterozoic sedimentary rocks of Bhander Group and the Rewa Group have similar SiO_2, Al_2O_3 contents, lower K_2O, Na_2O contents, relatively lower contents of V, Cr, Co, Ni, Nb, Ta, Y, Rb, and Cs, and higher contents of Sr, Ba, Zr and Hf. The Sr–Nd isotopic compositions of the Neo-Proterozoic sedimentary rocks are different from those of the Meso-Proterozoic sedimentary rocks which generally have higher $^{87}Sr/^{86}Sr$ and lower $^{143}Nd/^{144}Nd$. In respect of geochemical discrimination (e.g., La/Th–Hf, La–Th–Sc, and Th–Hf–Co), the studied samples suggest that the source rocks are composed mainly of post-Archean igneous rocks and recycled sedimentary rocks. This is also supported by inter element ratios such as La/Co, La/Th, Th/Co, and Th/Cr. The Sr–Nd isotopic variation from the Neo-Proterozoic to Meso-Proterozoic sedimentary rocks further suggests a change in provenance, during which simultaneous volcanic rock fragments supplied some clasts with higher $^{143}Nd/^{144}Nd$ and lower $^{87}Sr/^{86}Sr$ ratios for deposition of Neo-Proterozoic sedimentary rocks, whereas the influence of volcanic detritus became much less during the Meso-Proterozoic time. The geochemistry of sedimentary rocks from the Sirbu Shale, seem to indicate that the Proterozoic sedimentary rocks covering the Bundelkhand Granitic basement rocks may not be totally denuded at the surrounding enriches and highs during the Neo-Proterozoic time. Further analytical results are underway to provide better insight on the issue of provenance identification of these sediments.

Holocene fault slip rates along the frontal thrust of the eastern Himalaya, India: Evidence for the decrease of geological convergence across the eastern Himalaya

Rajeeb Lochan Mishra[1,2], R. Jayangondaperumal[1]*, Arjun Pandey[1], Ishwar Singh[1], Pradeep Srivastava[1]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Department of Geology, Utkal University, Bhubaneswar, Odisha
**Email: ramperu.jayan@gmail.com*

The geological fault slip along the frontal thrust is used to assess the average convergence velocity over time, as it is concerned with several earthquake cycles. Studies on geological fault slip rates so far conducted along the frontal thrust of the Himalaya inferred geological convergence rates

of 21 ± 1.5 mm/yr across the Nepalese Main Frontal Thrust, 23 ± 6.2 mm/yr across the Sub-Himalayan zone with ~5 mm/yr across the Nameri Thrust, 20.8 ± 8.8 mm/yr and 27 ± 9.6 mm/yr along the Himalayan Frontal Thrust zone. However, GPS estimates provide much lesser values of convergence rates (i.e., 16 ± 0.5 mm/yr between the northeastern Himalaya to the north of the Shillong and the Tibetan Plateaus) which are inconsistent with the inferred geological fault slip rates. A re-analysis of the previous studies hitherto conducted along the Nameri Thrust (i.e., Himalayan Frontal Thrust) traversing the Kameng River exit in the Arunachal Sub-Himalayan zone of the eastern India, along with luminescence dating of optical sediments obtained from deformed strath terraces of ~3 m height preserved along the Kameng River provide significant estimates of fault slip rates along the frontal Nameri Thrust. Considering the maximum and minimum OSL ages of the terrace abandonment to be 10.6 ± 2.6 and 3.2 ± 0.4 ka respectively, long-term minimum and maximum vertical uplift rates of ~0.28 and ~0.93 mm/yr were obtained. This suggests that the incision rate by the Kameng River could not be less than ~0.28 mm/yr. Considering dip angle of the frontal thrust between 25 ± 5°, the height of the lowest uplifted strath terrace *T1*, and two OSL ages of 10.6 ± 2.6 and 3.2 ± 0.4 ka, maximum and minimum Holocene fault slip rates of 2.3 ± 0.4 and 0.69 ± 0.1 mm/yr were inferred. This may be otherwise interpreted that the slip across the Nameri Thrust could not be lesser than 0.69 ± 0.1 mm/yr. Both the slip rate values of 2.3 ± 0.4 and 0.69 ± 0.1 mm/yr across the Nameri Thrust are lesser than that inferred by previous studies in the area. A significant contribution of the present study is that the inferred values of geological shortening are in close harmony with the GPS convergence rates in the area.

Compositional variation in amphibole and pyroxene in granites of the Malani Igneous suite, Rajasthan

Mondal Suman*, Upadhyay Dewashish
Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721302
**Email: sumanmgeo@gmail.com*

The Malani Igneous Suite in Rajasthan comprises volcanic as well as plutonic rocks. The plutonic rocks are represented by the Siwana and Jalore granites. The Siwana granites are peralkaline, A-type with high Na_2O+K_2O, Fe/Mg, Ga/Al , Ga, Zr, Nb, Y+REE, Zn and low Al_2O_3, CaO, and Sr. They are enriched in incompatible elements like Zr, Nb Y, Rare Earth Elements (REE), and display negative Ti, Sr and Ba anomalies. The Jalore granite comprises two petrological varieties, viz., biotite granite and hornblende granite. The biotite granites are peraluminous and characterized by relatively high SiO_2, Al_2O_3, Rb, and low REE, Zr, Nb whereas the hornblende granites are metaluminous to mildly peralkaline, moderately enriched in REE, Zr, Nb but depleted in Sr .

The contrasting composition of amphibole and pyroxene in the Jalore and Siwana granites indicate different parental magma compositions. In the Jalore granite the amphiboles are ferro-pargasite, hastingsite, ferro-hornblende to ferro-edenite whereas the pyroxenes range in composition from diopside to hedenbergite. Amphiboles in the Siwana granites are ferrorichterite, riebeckite and arfvedsonite in composition whereas the pyroxenes are hedenbergite to aegirine. A core to rim compositional variation is seen in the pyroxene with Ca and Fe^{2+} gradually decreasing and Na and Fe^{3+} increasing from the core to the rims. The amphibole and pyroxene in the Jalore granite define compositional trends with #Mg decreasing with increasing differentiation. Their Al and Mg contents are higher than pyroxene and amphibole from the Siwana granites. This reflects the peraluminous and peralkaline nature of the two granitoids and indicates different parental magmas for the two suites. The constant #Mg of pyroxenes and amphiboles in the Siwana granites are suggestive of

limited fractional crystallization. The $Ca+Al^{iv}$ vs Si+Na+K and Ca^{B} vs Si diagram of amphibole and pyroxene show different trends in the Jalore and Siwana granites which demonstrates that the Jalore granites are more primitive compared to the Siwana granite. Furthermore, aegirine in the Siwana granites is mostly formed through deuteric/hydrothermal process and occurs as replacement rims on the existing amphibole or alkali feldspar. These hydrothermal aegirines are characterized by high Ti and Al^{iv} in their structure and are highly porous and turbid. The La/Sm vs Gd/Yb diagram shows high value for Gd/Yb in the primary pyroxene and low value for the deuteric/hydrothermal aegirine. Both the primary and deuteric/hydrothermal aegirine show negative Eu anomaly but primary pyroxene shows flat REE pattern whereas deuteric/hydrothermal aegirine are enriched in HREE.

Multiple mantle sources for mafic Continental Large Igneous Provinces (C-LIPs): Insights from the Panjal, Rajmahal and Deccan Basalts, India

Laxman B. More*, K. Vijaya Kumar
School of Earth Sciences, SRTM University, Nanded 431606, Maharashtra
Email: morelaxman70@gmail.com

The Continental large igneous provinces (C-LIPs) provide us natural laboratories to evaluate the geochemical diversity of basaltic melts and their mantle sources. In this study, we try to assess the geochemical diversity and relative contribution of distinct mantle reservoirs in building three spatially and temporally distinct C-LIPs of the Indian sub-continent including Panjal (~289 Ma), Rajmahal (~117 Ma) and Deccan (~65 Ma). Our analysis is based on geochemical data compiled from *GEOROC* data bank and published papers.

We have categorized the Panjal, Rajmahal and Deccan basalts as type I and type II based on Zr/Nb and La/Nb, Th/Nb and Th/Yb ratios and distinct Nd isotopic composition. The age corrected $åNd_i$ values are higher in type I basalts ($åNd_i$ = +8 to -3) than in the type II ($åNd_i$ = -3 to -20). We suggest that the type I basalts with Th/Nb ratios <0.15 are derived from sub-lithospheric mantle sources (OIB- and EMORB-type) and type II basalts with Th/Nb ratios >0.4 are derived from sub-continental lithospheric sources. The Lithosphere-Asthenosphere/plume interaction is exhibit by the three provinces. We estimate that lithosphere and sub-lithosphere (plume and/or EMORB patches within asthenosphere) have respectively contributed approximately 67% and 33% to the Panjal Continental-LIP, 52% and 48% to Rajmahal, and 28% and 72% to Deccan basalts. Considering all the three provinces, we estimate that the lithosphere and sub-lithosphere mantle sources, respectively, contributed 38% and 62% in the generation of the Indian Phanerozoic Continental-LIP magmatism. Highly heterogeneous sub-continental lithospheric mantle (SCLM) and its differential partial melting may have contributed substantially to the geochemical diversity in the C-LIPs as recorded in the Phanerozoic C-LIPs of India. Extensive presence of lithosphere-derived basalts in the Phanerozoic Continental-LIPs suggests significant thermo-chemical erosion of the Indian sub-continental lithosphere. Fertility of the Indian sub-continental lithosphere may have increased with decreasing age related to the break-up of Gondwana.

Fractal analysis of *In Situ* host rock Nepheline Syenite xenoliths in a shonkinite dyke from the Elchuru alkaline complex, SE India

B. Nagaraju, Sachin S. Ghodke, K. Rathna, K. Vijaya Kumar
School of Earth Sciences, SRTM University, Nanded 431606, Maharashtra
Email: nagaraju.ign@gmail.com

Fractal distribution of fragments, i.e., scale-independent size distribution by brittle fracturing was recorded in many physical processes including breaking of sea ice, rock fragmentation in nuclear explosions and projectiles, and asteroids. The scale-invariance in geological processes at continental scale to micro-scale including river order, fracture and fault dimensions, magmatic enclaves, and hydraulic conductivity in porous rocks is also well documented. Formation and preservation of the xenolith fragments of the wall-rock during dyking is one of the important manifestations of instantaneous magmatic events. This process is well documented at shallower depths of Earth's crust but processes of fragmentation at deeper levels are not fully understood.

In this paper, we describe *in situ* xenoliths of host rock nepheline syenite with in a shonkinite dyke emplaced at mid-crustal depths and apply the fractal theory to evaluate origin of the nepheline syenite fragmentation. The nepheline syenite xenoliths are angular to oval shaped and sub-millimetre to ~50 cm long. The xenoliths are matrix supported with clasts and matrix being in equal proportions. The *in situ* nature of the xenoliths allowed us to model fragmentation processes solely due to dyke emplacement. We have also tested for post-fragmentation processes which may result in scale-variance in the shapes and sizes of xenoliths. We have carried out the fractal analytical techniques including clast size distribution, boundary roughness fractal dimension and clast circularity. The fractal data suggests that hydraulic (tensile) fracturing is the main process of host rock brecciation. However, the clast size and shape are further modified by post-fragmentation processes including the interplaying effects caused by shearing and thermal fracturing, and chemical erosion. The study demonstrates that dyking (magmatic emplacements) in an isotropic medium produces fractal size distributions of host rock xenoliths; however, post-fragmentation processes modify original fractal size distributions.

Classification of landslides between Badethi-Uttarkashi, Uttarkashi district, Uttarakhand, India

Aravind S Nair, S.K. Singh
Department of Geology, University of Delhi, Delhi 110007

Badethi–Uttarkashi NH-135 and 108 and its adjoining areas have experienced many landslides in the past. The present study area is situated between latitudes of 30°36'13.9"N and 30°44'2.16"N and longitudes 78°18'30.1"E and 78°26'52.6"E along the Bhagirathi river catchment in the Garhwal Himalaya. The area is transacted by a National Highway corridor connecting Uttarkashi and Gangotri via Bhatwari in Uttarakashi. An attempt has been made to document the different landslides in this 34 km stretch and its adjoining areas which fall under SOI topographical map No: 53 J/6. Uttarkashi region has been experiencing 400 mm to 800 mm rainfall on an average since 2008. It has been found that the maximum and minimum rainfalls in the last 100 years are 800.8 mm in August 1963 and 36.8 mm in June 1987, respectively. It may be noted that in 2013 the district received about 529.9 mm rainfall in June. The same stretch also experienced an incessant heavy spell of rain and was the highest for the 2013 monsoon season, causing several landslides in many areas

including the Badethi – Uttarkashi NH-135 and 108 and its adjoining areas. These landslides created severe damage to a large number of livestock, surface water storages, human settlements, communication networks, power transmission lines and, agricultural and forest land. It is also true that huge loss of properties worth millions of rupees has been recorded in the district. Further scrutiny of the available data sets on rainfall reveals that the most important factors responsible for the landslides in this sector were heavy rainfall. During the field investigations of March 2016, as many as 27 landslides have been found activated either due to rainfall or due to blasting for road construction and mining of rocks for building materials along NH-135 and 108 (Badethi to Uttarkashi). These 27 landslides in this sector may be classified into four main categories namely; rock fall, debris slide, rock-cum debris slide, and rock blasting. The villages adjoining these landslides are Badethi, Dharasu Bend, Singoti, Ratauri Sera, Bandarkot, Badhethi Chungi and Uttarkashi. Of these, 11.11% are rock fall, 29.63% are debris slide, 51.85% are rock cum debris slide and 7.41% are due to rock blasting. The mass movement during landslides has been caused due to toe cutting, saturation of slope-forming materials and road cuttings. Encroachment in the river/canal bank and unplanned development along with urbanization has aggravated the hazard and damaged these villages. Geotechnical assessment of landslides along NH-108 (a stretch between Dharasu Bend and Gangotri) and NH-134 (Chinyalisaur to Yamnotri) and assessment of disaster affected villages in the district ascertained the probable causes and accordingly remedial measures are proposed.

Benthic foraminifera from the littoral zone between Thiruvanmiyur and Mahabalipuram, Tamilnadu, south-east coast of India

P.M. Nimmy[1]*, N. Rajeshwara Rao[1], M. Sathish Kumar[1], N. Yuvaraj[1]
Department of Applied Geology, University of Madras, Guindy Campus, Chennai 600025
**Email: nimmypmukundan@gmail.com*

Foraminifera have been successful inhabitants of every aquatic environment from deep oceans to brackish water lagoons, estuaries and even rarely in freshwater streams, lakes, etc. Beach sands yield foraminifera (majority of them benthic) mainly from the intertidal or littoral zone. Although several studies have been carried out on foraminifera from beach sands, there have been very few such studies in the last couple of decades. A systematic study of benthic foraminifera has, therefore, been carried out on 18 sediment samples collected manually between Thiruvanmiyur in the north and Mahabalipuram in the south, Tamil Nadu, India. A total of 28 foraminiferal species belonging to 19 genera, 10 families, 9 superfamilies and 3 suborders are identified. Among these, 12 are calcareous, imperforate, porcelaneous forms (suborder miliolina), one is a calcareous, planktic species (suborder globigerinina*)*, and 15 are calcareous, perforate taxa (suborder rotaliina). Laboratory work has been carried out on water samples to determine dissolved oxygen and salinity. From the sediment samples, ecological parameters, such as organic matter, sand-silt-clay and calcium carbonate ($CaCO_3$) percentages were also determined using established procedures. Spatial variations in the living and total populations of benthic foraminifera are discussed. Correlation between the distribution and diversity of foraminifera and the water and sediment parameters has been attempted.

Boudinage characterization: A combined approach of structural geology and fluid inclusion study

Arun K. Ojha[1]*, Rajesh Sharma[2], Deepak C. Srivastava[1], Gordon S. Lister[3]
[1]Indian Institute of Technology Roorkee, Roorkee 247667, India
[2]Wadia Intitute of Himalayan Geology, Dehradun 247667, India
[3]Australian National University, Canberra, Australia
**Email: ojhaarun323@gmail.com*

Structural analysis along Khairna – Almora section of the Kumaun Lesser Himalaya reveals a wide variety of structural features which requires logical explanations. Among these, boudins are the most common and intriguing. A variety of boudins are found such as, Pinch-and-swell, Barrel and Fish mouth. Several workers have already mentioned their findings of boudins in the Almora area, but the complexity, condition of formation and their relation to the South Alomora Thrust (SAT) is not yet known. We use Fluid inclusions in the veins as a proxy to characterize the structure and to derive the evolutionary history of the area.

This study reports a new variety of boudin;``Self-organised boudin``(Fig. 1). This new kind is completely different from the classical varieties, because of the following characteristics; (i) Combination of Pinch-and-swell and Fish mouth structure and (ii) pinching of one layer lies adjacent to the swelling of another neighbour layer.

Fig. 1. Field photograph of the 'Self organised boudin' found in layers of interbedded quartzite and schist.

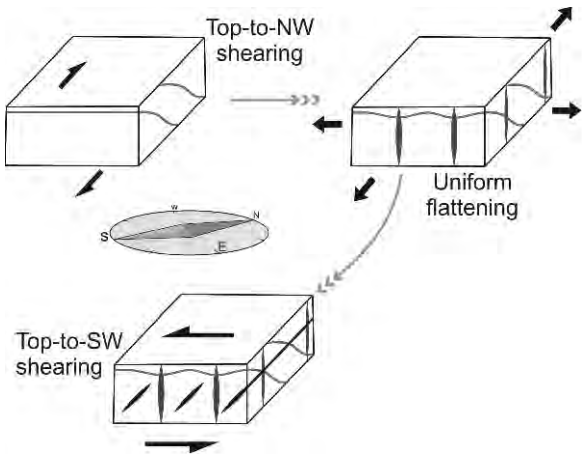


Fig. 2. Different stages of deformation with their recognizable veining events.

Multi stages of deformation with distinct veining events, marked each episode, is revealed by the analysis (Fig. 2). Three distinct deformation events with two shearing events and a uniform flattening event are well observed. The flattening event is marked by the presence of chocolate boudin.

Udiripikonda shoshonitic lamprophyre, eastern Dharwar craton: melts from slab window?

Ashutosh Pandey*, Dinesh Pandit, N.V. Chalapathi Rao, Praveer Pankaj, Rohit Pandey, Alok Kumar, Samarendra Sahoo
Department of Geology, Centre of Advanced Study, Banaras Hindu University, Varanasi 221005
**Email: ashutoshpandey2111@gmail.com*

The mineralogical and petrological studies on Udiripikonda lamprophyre, Eastern Dharwar Craton are presented. The lamprophyre occurs as ~1 km long and 1.2 m wide NW trending dyke intruding the Dharwar Batholith and is located in the Wajrakarur kimberlite field (WKF) towards the western margin of the Cuddapah Basin. The dyke is melanocratic and characterized by the presence of clinopyroxene megacrysts of cognate origin. The rock exhibits porphyritic-panidiomorphic texture with phenocrysts of clinopyroxene and olivine. Biotite, spinels and feldspar are confined to the groundmass. EPMA studies reveal that olivine is forsteritic in nature ($Fo_{86.66-77.36}$) and clinopyroxene is diopsidic showing reverse zoning with Fe and Na rich cores and Mg rich rims. Both clinopyroxene and biotites are enriched in Ti. The mineralogy of the lamprophyre classifies it as alkaline lamprophyre in general and as camptonite in particular. Using TiO_2 partitioning between melt and biotite, its temperature of crystallization has been calculated to be 1021-1091°C. Based on intracrystalline equilibrium between Fe^{2+} and Mg^{2+} at M1 and M2 octahedral sites in pyroxenes, the temperature of crystallization of core has been found to be 926-972°C whereas those for rim ranges between 913-950°C.

Excess of K_2O over Na_2O in the bulk rock suggests ultrapotassic to shoshonitic nature of these lamprophyres. Chondrite normalized REE patterns reveal melt derivation from an enriched garnet bearing mantle source. Nb/La ratio of less than 1 again suggests their derivation from the lithosphere-asthenosphere interaction. Trace element modelling reveals melt generation from less than 1% melting of the source that subsequently underwent fractional crystallization. On the basis of trace element geochemistry, we suggest involvement of asthenospheric upwelling in a subduction modified sub-continental lithospheric mantle in the mantle source region of the Udiripikonda lamprophyre.

Dispersed organic matter analysis of Subathu formation in Dogadda area of Pauri Garhwal district, Uttarakhand

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

The present paper deals with the palynofacies analysis of the Subathu Formation of Dogadda area, District Pauri Garhwal, Uttarakhand. Samples for the present study were collected from Umreila - Aeta road and were processed with standard technique with HCl followed by HF to recover dispersed organic matter for quantitative and qualitative examination of palynofacies. The recorded

palynofacies data reveal predominance of amorphous organic matter with modest contribution of non-opaque non-biostructured phytoclasts followed by opaque phytoclasts. Freshwater microplankton are rare and marine microplankton are represented by some acritarchs. Abundance of amorphous organic matter represents high marine productivity which indicates reducing environment. A majority of phyoclasts, especially non-opaque non-biostructured phytoclasts with dark brown color, are deprived of botanical structures, indicating proximal source of organic matter. The decrease in phytoclasts accompanied by amorphous organic matter enrichment indicates change in depositional environment, i.e, partial oxidizing to reducing environment which is further supported by marine microplankton, i.e, acritarchs assemblage pointing to marine influence in area. Considerable amount of fungal hyphae and fungal spores show warm and humid environment during depositional episode in the study area.

Geochronological and structural constraints of the fold thrust belt and forland basin of Mandi region, Himachal Pradesh, NW- Himalaya

R.C. Patel, Man Mohan*, Reena Karnwal, Prerna Gahlaut
Department of Geophysics, Kurukshetra University, Kurukshetra 136119
**Email: manmohan.81587@gmail.com*

Tectonically the Himachal foreland basin is divided into six major thrust boundaries. From north to south across the foreland basin. These are Main Boundary Thrust (MBT), Galma thrust, Joginder Nagar thrust and Palampur thrust in arcuate shape lying in NE margin, and Jawalamukhi thrust, Barsar thrust and Himalyan frontal thrust (HFT) having linear boundaries and NW – SE trend.In the Central part a big syncline is present having trend of NW- SE, which occupies conglomerate of Upper Siwalik and two major anticlines; Paror anticline and Sarkaghat anticline having axial plane trend of NW-SE. Some small thrusts have also present like Pali thrust, a subsidiary of the MBT and Bamla thrust. To understand the timing, pattern and potential control on the Cenozoic shortening of the Fold thrust belt and Forland basin in Mandi region a study of low temperature thermochronometry is required across the major thrust sheets. A review study of the area suggests: a) Sub-Himalayan zone (SHZ) of NW India is a foreland fold and thrust belt that is detached from the pre-Tertiary basement along a shallow dipping decollement b) Magnetostratigraphic data have been used to determine the timing of structural events and to constrain estimates of the long-term slip rate c) The SHZ between the HFT and the MBT is characterized by the Late Quaternary–Holocene rock deformation. Bulk of active deformation is concentrated on the Himalayan front which includes the HFT and the hanging wall frontal anticlines. However, faults between the MBT and the HFT have been reactivated during Late Quaternary and probably Holocene times. d) Along the Subathu transect cross section in the frontal part, the structures owing to widely spaced ramps; in the central sector, the structural geometry as seen at the surface is controlled by a buried thrust system that can be approximated as a hinterland-dipping duplex; further north, the structural geometry is extremely complex with a large number of stacked.

Assessment of geomorphometric indices and landform evolution of the Zanskar Valley, Ladakh Himalaya

Poonam[1]*, Anil Kumar[2], Pankaj Sharma[2], Y.P. Sundriyal[1], Pradeep Srivastava[2]
[1]Department of Geology, HNB Garhwal University, Srinagar Garhwal, Uttrakhand
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: poonam.hnbgu02@gmail.com*

Zanskar Ranges lie between the Tethyan sediments in the south and Ladakh Batholith in the north. Sedimentary sequences of Zanskar ranges are largely of continental origin, which were uplifted and deformed via several north verging thrusts, where Choksti and Indus thrusts are an important thrust zone. In the headwater of Zanskar River, there are two major tributaries: Tsrapchu and Doda, which flow along the strike of the South Tibetan Detachment System (STDS), an east-west trending regional fault. Earlier work indicates that deformed sedimentary succession of Indus Molasse have been thrust northwards on to the Ladakh Batholith and there is at least 36 km of crustal shortening in the Zanskar section that continued from Middle Miocene to the late Pleistocene. This shortening is accommodated mainly by north or north-east directed back-thrusts of Zanskar ranges. The present study incorporate field sedimentology, geomorphology and chronology of landform associated with Zanskar valley. The upper Zanskar flows in a wide valley, where alluvial fan, valley fill and strath terraces made the major landform. The alluvial fans exhibit higher fan to catchment area ratio and sporadic palaeolakes indicating neo-tectonically controlled landscape. The lower Zanskar flows through a deep V-shaped gorge. With the help of geomorphometric indices an attempt is made to understand neo-tectonic deformation and landform evolution of these ranges. Geomorphometry is a mathematical analysis for landform evolution which quantifies the morphological, hydrological and other aspect of land surface. For the geometric description of drainage basin and its stream channel network, it is required to measure Linear, Areal and Relief aspect of the basin. Different morphometric indices: stream order, stream number, bifurcation ratio, circulatory ratio, basin hypsometry, valley floor width-valley height ratio, mountain front sinuosity, stream length gradient index, longitudinal river profile and normalized steepness index are to be determined with the help of SRTM 30m DEM in the ArcGIS 10.3. The longitudinal profile of the Zanskar River shows several local convexities marking knick point zone. Further, hypsometric curve for the third order basins is convex upwards implying tectonic control on drainage.

Provenance, palaeoweathering and tectonics of the Gondwana sediments of Palar Basin, south India, Tamil Nadu-Evidence from sandstone petrography, heavy minerals and clay mineralogy

R. Subin Prakash*, S. Ramasamy
Department of Geology, University of Madras, Chennai 600025
Email: suban5geo@gmail.com

Palar Basin is considered as one of the pericratonic rift basins of East Coast of India. Integrated petrography, clay mineralogy and heavy mineral studies of sandstone and shale from the Palar Basin have been carried out to decipher their provenance, palaeo-weathering and tectonic setting. These rocks are composed of quartz, feldspar, rock fragments with minor amounts of chlorite, glauconite, zircon, garnet and opaque. The rocks are texturally mature, well sorted grains, which are rounded to subrounded. The well rounded and rounded quartz, monocrystalline quartz with uniform or straight extinction, inclusions of sillimanite, rutile and zircon needles, polycrystalline grains with 5 crystals of straight to slightly curved inter crystalline boundaries, low

content of plagioclase and k-feldspar, euhedral, angular and subrounded grains of zircon and high and moderate ZTR, RuZi and GZi values suggest that the Palar Basin are likely dominated by various grades of metamorphic, intermediate acidic and metasedimentary rocks. Because the Palar Basin sediment source can be constrain the group of Archaean metamorphic and igneous rocks of the Eastern Ghat rocks comprising of charnockites, quartzites, granitic gneisses and schists. The frame work petrography exhibits predominance of quartz and monocrystalline grains, feldspar affinity, paucity of rock fragments and low F/R ratio suggesting that the sediment deposited in a passive continental margin tectonic settings. The rock derived clay (illite, chlorite) is predominant than soil derived (kaolinite, smectite) clay minerals. The high content of illite, low to high illite chemical index and illite crystallinity which indicates the source of the clay minerals from pre-existing rocks (granite and gneisses), subjected to physical weathering over chemical weathering in a temperate climate (Hot/ Humid) with moderate hydrolysis.

Geochemistry of the siliceous high-Mg basalts (SHMB) from the Neo-Archean Sonakhan greenstone belt, Bastar craton, central India- Implications for an Island-Arc tectonic setting

M.P. Manu Prasanth*, K.R. Hari
School of Studies in Geology and Water Resource Management,
Pt. Ravishankar Shukla University, Raipur, 492010
**Email: manuprasanthmp@gmail.com*

The Neo-Archean Sonakhan Greenstone Belt (SGB), located in the north-eastern fringes of Bastar craton, Central India, is dominated by basalt, andesite, dacite and rhyolite (BADR) association. Chromite mineralization is present in the siliceous high magnesium basalts (SHMB) of the SGB. The SHMB rocks are characterized by very high MgO (33.4%), enriched LREE and LILE relative to the HFSE. Negative Nb-Ta-Ti anomalies in the primitive mantle normalized multi-element diagram indicate a subduction-related magmatism. The plottings of samples in the Th/Yb versus Nb/Yb discrimination diagram point towards a fore-arc tectonic setting. General conclusion drawn on the genesis of SGB includes initial subduction of an intra-oceanic lithosphere followed by an eruption of the lava in an oceanic environment. Further, subduction of the oceanic lithosphere continued with slab-rollback resulting in the generation of SHMB.

A study on Ostracoda distribution and ecology from the continental shelf sediments of Gulf of Mannar, India

A. Rajkumar*, S.M. Hussain, N. Mohammed Nishath
Department of Geology, University of Madras, Guindy Campus, Chennai 600025
**Email: vivegaraj@gmail.com*

The present work has been carried out to study the ostracoda distribution and ecology in the sub-surface sediments of the Gulf of Mannar, India. Two short core sediment samples along with bottom waters have been collected through a multi-corer, in an NIO Cruise – ORV Sindhu Sadhana (SSD-004) which range in the water depth of 58 m and 215 m, respectively. Water parameters such as salinity, temperature and dissolved oxygen were measured onboard from the collected water samples. The core samples with a length of 26 cm and 45 cm were recovered and sub-sampled with an interval of 3 cm, through which a total of 24 sub-samples were obtained and subjected to standard micropaleontological techniques. The classification proposed by Moore *et al*., (1961), Van

Morkhoven (1963) and Hartmann and Puri (1974) has been followed for Ostracods identification. More than 3500 ostracod specimens belonging to various genera were recovered from the sub-samples. Carapace and open valve ratio have also been taken into consideration as it, helps to determine the relative rate of sedimentation. The sedimentological parameters such as $CaCO_3$, organic matter and sand-silt -clay ratio were estimated using the standard procedures. Silty sand and silty substrate are present in the study area. Water and sediment parameters are correlated with the distribution of the Ostracoda to interpret the ecological conditions in the study area.

Petrography, heavy minerals, and geochemical analysis of Barail sandstones, Jotsoma upper, Kohima district, Nagaland, India

A. Ramamoorthy*, S. Ramasamy, Ramesh Chandra Patel
Department of Geology, School of Earth and Atmospheric Sciences, University of Madras, Chennai 25
Department of Geophysics, Kurukshetra University, Kurukshetra 136119
Email: ramgeo.in07@gmail.com

The present study is based on the petrographic and heavy mineral analysis of the Barail sandstones, Jotsoma village, Kohima district, Nagaland, India. The study reveals that the percentage occurrences of different constituents of the Barail sandstones range as Quartz 39.85**%** to 64.10**%**, Feldspar 5.27**%**, Rock fragments 4.53% to 14.25%. The sandstones are mainly Quartz arenite. Triangular diagram indicates that the constituents of the sandstone under study were derived from middle, upper, as well as low rank metamorphic sources. QFL triangular plot infers the derivation of the sandstones from recycled orogenic sources. QmFRt triangular plot shows that the provenance of these Barail sandstones are mainly of mixed and dissected arc types. However, a few of them also show their derivation from quartz arenite recycled origin. Heavy mineral study reveals that the Barail sandstones under study have both opaque and non–opaque minerals. The non-opaque minerals include Zircon, Tourmaline, Rutile, Sillimanite, Kyanite, Staurolite. ZTR maturity indexes varies from 82.059**%** to 96.082**%** with an average 88.538**%.** ZTR triangular diagram indicates the predominance of tourmaline and zircon which infers the derivation of the Barail Sandstones from both metamorphic and igneous sources.The low values of Cr, Co and Ni suggest that the sediments were derived from felsic igneous source. Also the low value of Cu/Zn and Ni/Co ratio support that the Barail shale and sandstone were deposited in well-oxidizing conditions

Petrography of the lower Siwalik Nahan Formation in the type area Nahan, northwestern Himalaya

Rajesh Ranga*, Yoginder Singh
Department of Geology, Kurukshetra University, Kurukshetra, 136119
**Email: rajeshranga333@gmail.com*

The petrography of the Middle Miocene Nahan Formation of the type area, northwestern Himalaya, India has been analyzed to understand the paleoclimatic and paleotectonic conditions in the frontal Himalayan terrain. two hundred and fifty thin sections of rocks collected from the Lower Siwalik Nahan Formation exposed in selected and measured three sections (Shambhuwala – Nahan section, Renuka – Nahan section and Sataun – Rajban section) of the northwestern Himalaya. These were subjected to petrographical and mineralogical investigations. Various petrological units distinguished in the Lower Siwalik Formation include lithic arenite ferruginous cement, quartz wacke, lithic arenite siliceous cement, quartz arenite, siltstone/clays/shales. The detrital grains are

angular to subangular and have moderate sorting. A significant proportion of the quartz grains shows undulatory extinction. Some of the quartz grains bear dark inclusions and incipient development of minute flakes of micaceous minerals is another diagenetic feature. Some of the flakes show parallel linear arrangements. In some sections mica flakes are seen bent along non-flaky constituents. The rock fragments makeup 30 to 35 percent of the modal composition and represent such parent rocks as sandstones, siltstone/clays, muscovite schists and biotite schists. Presence of fragments of polycrystalline quartz is rather significant. The more important mineralogical components having a bearing on the petrogenisis of the sediments include garnet, staurolite, epidote , chloritoid/chlorite, biotite and muscovite.

In-situ U-Pb dating of zircon using LA-ICPMS: data acquisition and processing protocols and results of dating zircon reference materials

Sameer Ranjan*, Dewashish Upadhyay
Department of Geology and Geophysics, Indian Institute of Technology- Kharagpur, Kharagpur
**Email: sameerranjan.18@gmail.com*

Zircon is a common accessory mineral in many felsic igneous and sedimentary rocks. U-Pb dating of zircon with high spatial resolution using LA-ICPMS has become an important tool in geochronological studies. The preferential incorporation of U, Th and nearly complete exclusion of Pb in zircon structure during crystallization makes the mineral ideal for dating using U-Th-Pb isotope system. A robust method for data acquisition and processing was established using Thermo Fisher Scientific iCAP-Q Quadrupole ICPMS coupled with a NWR (ESI) 193nm ArF Excimer laser ablation system. The laser-induced time-dependent fractionation is corrected by calculating zero ablation time intercepts of least-squares linear regression lines fitted to the time-resolved isotopic ratio data, whereas instrumental drift, and mass-bias are corrected by sample-standard external bracketing method using the matrix matched reference zircon GJ-1. The analyses are performed in time-resolved mode with 30 second measurement of gas background with the laser turned off and a 50 second window for sample signal acquisition with the laser firing on.

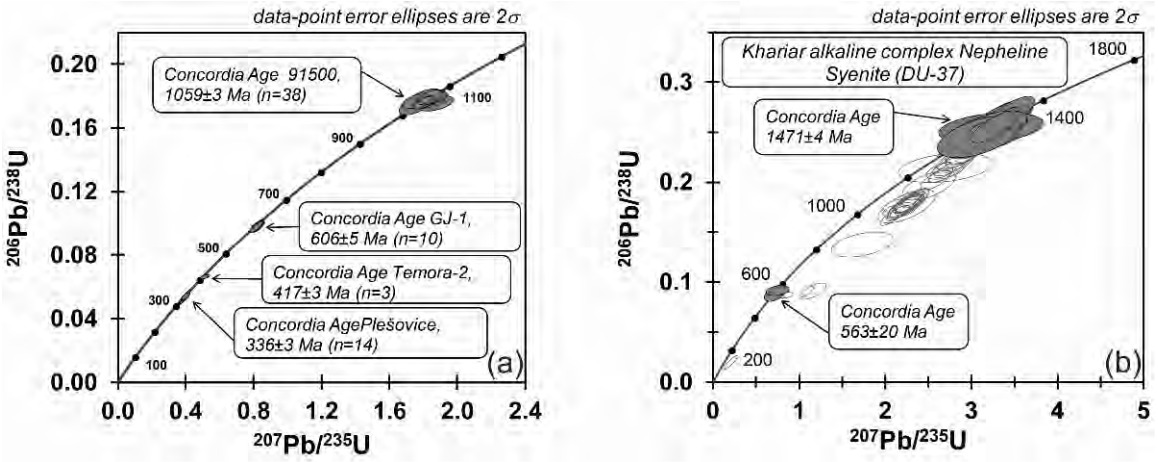


Fig.1. Concordia plot for the analyzed reference zircon standards (a) also shown the Concordia plot (b) for the zircon analyzed from Khariar alkaline complex rock type Nepheline Syenite dated earlier (1480±17 Ma, 2ó) Upadhyay et al. (2006).

To assess the accuracy and reproducibility of the analytical protocol, several well characterized reference zircons ranging in age from Mesoproterozoic to Middle Mississippian were analyzed. The $^{206}Pb/^{238}U$ and $^{207}Pb/^{206}Pb$ ratios of the standards and their Concordia ages with 2ó uncertainties (0.1780±0.0048, 0.0747±0.0016, 1059±3Ma), (0.0984±0.0028, 0.0602±0.0010, 606±5Ma), (0.6671±0.009, 0.0560±0.0018, 417±3Ma), (0.0534±0.0031, 0.0534±.0008, 336±3Ma); They are 91500 [1065 Ma], GJ1 [608±1.5 Ma], Temora 2 [418±7.1 Ma], and Plešovice, [337±.37 Ma]. The results show that our analytical protocol is capable of dating zircons of a wide range of ages and isotopic ratios.

Biogeochemistry of carbon in the western ghats coastal rivers, India

Kiran Kumar Reddy*, Harish Gupta
Department of Applied Geochemistry, Osmania University, Hyderabad 500007
Email: skiran2888@gmail.com

Issues related to recent global warming remain one of the widely discussed topics in realm of Earth and Environmental Science. Carbon transport and transformations in the Biosphere have received growing research interest because of their mediation in global warming. Thus, understanding the present day carbon cycle has become a matter of societal urgency because of concerns about the effects of human activities on atmospheric chemistry and its link to global climate. Carbon in the biosphere is unevenly distributed among three major reservoirs: terrestrial, oceanic and atmospheric. Simplified depiction of the global carbon cycles generally consisted of two biologically active boxes (oceans and land) connected through gas exchanges with a third box, the atmosphere. This approach led to identification of major knowledge gap and also to understand and evaluate the response of these reservoirs to global change issues. Rivers and other inland water systems represent distinct ecosystems, geomorphological agents, sites of biogeochemical storage and transformation conduits for material transport (such as carbon and nutrients) across continents and to the ocean. The importance of rivers is well recognized for modulating the transfer of terrestrial weathering and biological materials from the land to coastal. More than 100 small mountainous rivers originate through Western Ghats region and debouch into the Arabian Sea. These coastal rivers are characterized by relatively small length (50-300 km) and high channel gradients. Western Ghats region covers only 4% of Indian land mass yet count for 14% fresh water discharge. This region has distinction of being one of the global Biodiversity Hotspots. At global scale the number of small rivers far exceeds the number of large rivers in this region collectively, these smaller rivers are responsible for a much larger amount of sediment delivery to the global ocean than one might intuitively imagine. However, once we turn to coastal rivers, owing to their smaller catchment/ length and high channel gradient, large amount of carbon and weathering products are delivered to coastal seas without much alterations. Therefore, small rivers have gained more attention in recent years due to their significant role in transporting riverine flux. Through this study we calculated the annual flux of carbon species in dissolved and particulate forms and their sources. We also looked into the factors regulating transport of carbon and other elements at catchment level as well as regional scale, i.e. Western Ghats. Here we will present the analysed data of monsoon season (July-2016) of these rivers by comparing with the published data of other major rivers.

Tale of four plutons: Pressure, temperature and oxygen fugacity conditions of calc-alkaline granitoids of Chhotanagpur Gneissic Complex, eastern India

P. Roy, B. Goswami*
Department of Geology, University of Calcutta, Kolkata 700019
**Email: bapigoswami69@gmail.com*

Petrography and mineralogy of four calc-alkaline granitoid plutons of Agarpur, Sindurpur, Raghunathpur and Sarpahari of the northern Purulia of Chhotanagpur Gneissic Complex, eastern India are investigated. These plutons are spatially associated with the east-west trending North Purulia Shear Zone (NPSZ). The plutons as a whole are composed of varying proportions of quartz + plagioclase +potash feldspar + biotite + hornblende ± pyroxene + sphene + magnetite + apatite and zircon ± epidote. Hornblende-plagioclase thermometry, aluminum-in-hornblende barometry and the assemblage sphene–magnetite–quartz were used to determine the P, T and fO_2 during the crystallization of the parent magmas in the different plutons. The plutons crystallized under varying pressures (7.2–2.6 kbar) and wide range of temperature (896°C –718°C) from highly oxidized magmas (log fO_2 -11.2 to -15.4). The depths of emplacement of these plutons seem to increase from west to east. Petrologic compositions of these granitoids continuously change from enderbite (opx-tonalite: Sarpahari) in the east to monzogranite (Raghunathpur) to syenogranite (Sindurpur) to alkali feldspar granite (Agarpur) in the west. Water contents of the parental magmas of different plutons also increase systematically from east to west. No substantial difference in the depth of emplacement is found in plutons lying south and north of the NPSZ suggesting the strike-slip nature of the shear zone.

Folding in viscous wedge: Implication on long term deformation in an orogenic belt

Sreetama Roy*, Santanu Bose
Experimental Tectonics Laboratory, Department of Geology, University of Calcutta, Kolkata 700019
**Email: littlepie.roy@gmail.com*

Orogenic belts are generally characterised by multi-order folds and sequence of thrusts. Commonly folds represent a deformation that occurs at greater depth in a ductile manner at high P-T conditions. However, all convergent orogens in the world from the Himalaya to the Caledonides and Variscides are characterised by the presence of folds of diverse orientations and morphology, even at a shallow crustal horizon. It is likely that folds of multiple orders in convergent systems develop at low strain rate condition, where rock has the ability to flow in a viscous way. In the present study, we used a viscous experimental model to understand the development of folds in a convergent system. Newtonian viscous material PDMS (polydimethylsiloxane, produced as an intermediate product by Dow Corning, UK) and elastic layers are used as analogue materials to address this issue. Elastic layer was embedded at different depths within the PDMS matrix in the initial model, which was deformed at varying strain rates ranging from 10^{-3} to 10^{-5} s^{-1}. The objective of this study is to understand the mechanics of folding by long term tectonic forces and subsequent modification of fold morphology in orogenic belts by gravitational collapse when deformation either slows down or completely ceases. Our experimental results show that location of fold initiation and its forelandward propagation is controlled by a complex interaction between convergence rate and frictional strength at the basal decollement. At low basal friction and low convergent rate, wedge develops with a very low surface slope implying that the amount of shortening was accommodated largely by foreland ward propagation of deformation than the vertical growth of the wedge. This has eventually led to faster nucleation of cylindrical folds in the entire elastic layer from hinterland to foreland. With progressive shortening cylindricity of folds towards the hinterland was

replaced by tight plunging folds, however towards the foreland folds remained cylindrical under experimental condition after 50% shortening. On the other hand, at high convergent rate the width of deformed wedge became narrow, leading to high surface slope of the wedge. In this condition, rate of fold propagation towards the front was significantly low. At high basal friction, wedge geometry developed with narrow width and steep surface slope irrespective of convergent rate. The style of fold propagation, however, is consistent with strain rate as observed at low basal friction. However, initial upright cylindrical folds are rotated to inclined and recumbent folds with progressive shortening. Our results suggest that the zone of recumbent folds separates the intensely deformed hinterland from relatively less deformed frontal part of the model wedge. Our experiments thus reveal that unidirectional shortening can develop folds with varying geometry from open upright to inclined and recumbent folds with progressive deformation. Our results, therefore, suggest that diversely oriented fold pattern in the Himalayan belts can also be explained by single progressive deformation during Indo-Asia collision.

Distribution of Ostracoda in the core sediments of Pulicat Lagoon, Tamil Nadu

Merin Sackaria, Nandhakumar, S.M. Hussain*
Department of Geology, University of Madras, Chennai 600025
Email: smhussain7@hotmail.com

In order to study the distribution of Ostracoda in the core sediments of Pulicat Lagoon, Tamil Nadu South-East coast of India, a core sample was collected from Sunnambukulam (90 cm in length) in Pulicat Lagoon. The core sample was sub sampled at an interval of 3 cm and thus, a total of 30 samples were obtained and subjected to standard micropaleontological and sedimentological analysis. The core sample yielded good abundance of ostracods, but diversity is poor. In the present work, the classification proposed by Hartmann and Puri (1974) has been followed for the ostracod taxonomic studies through which 4 ostracod taxa belonging to 4 genera of 4 families of the order Podocopida have been identified. Among these 3 genera belong to lagoonal environment and one genus is a marine form. Sedimentological parameters, such as $CaCO_3$, Organic matter and sand-silt-clay ratios were estimated and their down core distribution is discussed. An attempt has been made to evaluate the favourable substrate for the ostracod population abundance in the present area of study. From the overall down core distribution of Ostracoda, it is observed that clayey sand and silty sand are more accommodative substrate for the population of Ostracoda. The ratio between the carapaces and open valves of Ostracoda has been taken into consideration for determining the rate of sedimentation in the study area.

Report of the oldest Naticid Gastropod drilling predation on Corbulidae (Bivalvia) from the upper Jurassic of Kachchh, Gujarat

Ranita Saha[1]*, Shiladri S. Das[2], Sumanta Mallick[3], Subhendu Bardhan[4], Shubhabrata Paul[1], Sandip Saha[2]
[1]Department of Applied Geology, Indian Institute of Technology (Indian School of Mines), Dhanbad
[2]Geological Studies Unit, Indian Statistical Institute, Kolkata
[3]Department of Geology, Triveni Devi Bhalotia College, Raniganj
[4]Department of Geological Sciences, Jadavpur University, Kolkata
**Email: ranitasahakolkata@gmail.com*

The family Corbulidae of Bivalvia appeared arguably during the Early Jurassic. In India, corbulid bivalves have been reported since the Jurassic. We here report the dynamics of naticid

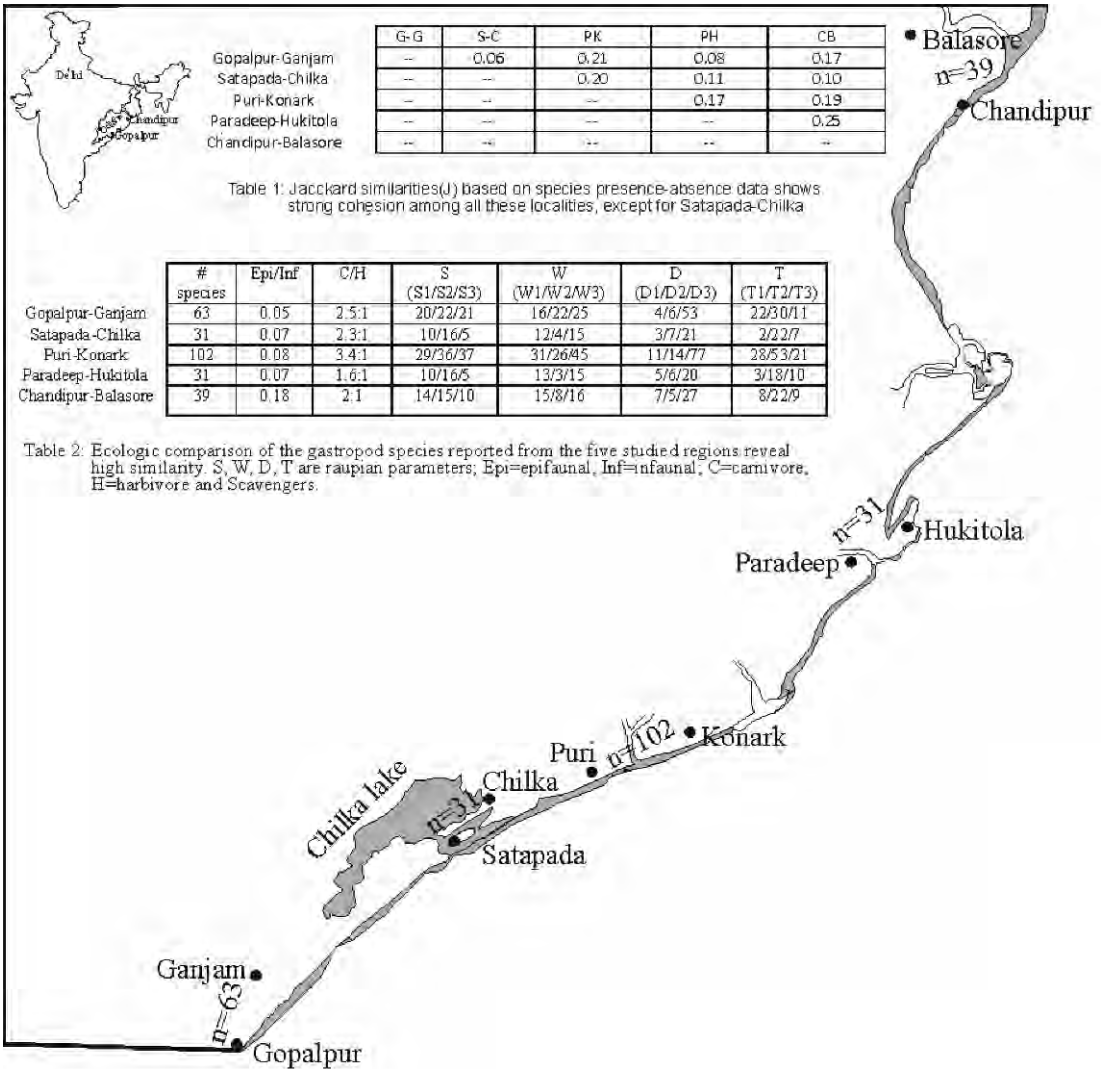
predation on corbulid bivalves from the Upper Jurassic (Oxfordian) of Kuchchh. The prey-predator interaction, especially between the naticid predator and their prey, has evolutionary consequences (i.e. coevolution and escalation). Corbulid bivalves are shallow infaunas and are easily targeted by predatory gastropods, especially the naticids, which make characteristic drillholes (*Oichnus paraboloides*) on their prey shells. In the present study, we have analysed several aspects of this prey – predator interaction. Drilling frequency, estimated as the ratio between successful drillholes and total no. of individuals, is low (DF 4.95%, N = 504.5) in comparison to all the Cretaceous and Cenozoic values. PE, prey effectiveness which is estimated from incomplete drilling frequency (IDF, which is proportion between incomplete drillholes and total no. of shells examined). IDF and multiple drilling frequency (MULT, is ratio between total no. of drill holes in multiply drilled valves and total no of attempted holes) are 0.19% and 28.12%, respectively. Drillholes are randomly distributed and lack site selectivity. Size selectivity is weakly developed as the relation between outer borehole diameter (OBD; which is a proxy for predator size) and maximum length of the prey shell shows poor correlation. Previously, the oldest records of naticid drillholes on corbulid bivalves were reported from the Early Cretaceous which was considered as the time of origination of the carnivorous naticid gastropods. In the present study, we present evidences of naticid predation on corbulid from the Upper Jurassic, along with naticid body fossils recovered from the same locality and stratigraphic horizons. We, therefore, argue that naticid predation was initiated at least in the Late Jurassic, much earlier than previous records and naticid predators were inexperienced in handling corbulid prey in their early evolutionary stage as evident from low drilling frequency, low prey effectiveness and lack of behavioural stereotypy.

Spatio-environmental variation in modern marine gastropod shell forms along the coastal regions of Odisha, India

Sandip Saha[1]*, Sayantan Sinha[2], Sahana Dey[2], Hindolita Chakraborty[2], Subhronil Mondal[2], Shiladri S. Das[1]

[1]Geological Studies Unit, Indian Statistical Institute, 203, Barrackpore Trunk Road, Kolkata
[2]Department of Geology, University of Calcutta, 35, Ballygunge Circular Road, Kolkata
**Email: sandipsaha.ju@gmail.com*

Gastropod shell morphology has been a subject of interest for many decades and has been used to study many ecological and evolutionary aspects both spatially and temporally. Spatio-environmentally, shell morphology can vary from one location to the other due to interplay of many biotic (predation and competition) and abiotic (temperature, salinity, substrate, etc.) factors (known as 'ecomorphologic' variation). The present study documents spatio-environmental variation of shell morphology of modern marine gastropods along the Odisha coast. For this, the following ecological and morphological parameters of 160 gastropod species were studied – (1) live habitat (i.e., epifaunal and infaunal); (2) feeding habit (carnivore and herbivore+scavengers); and (3) Raupian parameters, i.e., shape of generating curve (S), whorl expansion rate (W), distance of the generating curve from the coiling axis (D), and degree of whorl translation (T). Feeding and tiering data were collected from the NMITA database (http://nmita.geology.uiowa.edu/). W, D, and T of each species were qualitatively assigned three values – 1 for low value, 2 for intermediate, and 3 for high. For example, T1 indicates low translation rate, and W3 indicates high whorl expansion rate. S1, S2, and S3 stand for circular, elliptical and slit-like apertures, respectively. All species were binned within five spatial bins from north to south–Chandipur-Balasore, Paradeep-Hukitola, Puri-Konark, Satapada-Chilka, and Gopalpur-Ganjam and ecologic variables were compared among these areas. These locations are proximal to a vast tidal flat, with smiliar salinity-temperature conditions. Finally, Jacckard correlation coefficient was used to compare taxonomic



	G-G	S-C	PK	PH	CB
Gopalpur-Ganjam	--	0.06	0.21	0.08	0.17
Satapada-Chilka	--	--	0.20	0.11	0.10
Puri-Konark	--	--	--	0.17	0.19
Paradeep-Hukitola	--	--	--	--	0.25
Chandipur-Balasore	--	--	--	--	--

Table 1: Jacckard similarities(J) based on species presence-absence data shows strong cohesion among all these localities, except for Satapada-Chilka

	# species	Epi/Inf	C/H	S (S1/S2/S3)	W (W1/W2/W3)	D (D1/D2/D3)	T (T1/T2/T3)
Gopalpur-Ganjam	63	0.05	2.5:1	20/22/21	16/22/25	4/6/53	22/30/11
Satapada-Chilka	31	0.07	2.3:1	10/16/5	12/4/15	3/7/21	2/22/7
Puri-Konark	102	0.08	3.4:1	29/36/37	31/26/45	11/14/77	28/53/21
Paradeep-Hukitola	31	0.07	1.6:1	10/16/5	13/3/15	5/6/20	3/18/10
Chandipur-Balasore	39	0.18	2:1	14/15/10	15/8/16	7/5/27	8/22/9

Table 2: Ecologic comparison of the gastropod species reported from the five studied regions reveal high similarity. S, W, D, T are raupian parameters; Epi=epifaunal, Inf=infaunal; C=carnivore, H=harbivore and Scavengers.

Fig. 1. Studied locations with corresponding number of species (n) are presented. Grey thin regions along the coast indicate tidal flats. In inset, Jaccard correlation valuea (Table 1) and all ecological parameters of all areas (Table 2) shown.

compositions of these areas so that taxonomy can be studied along with the eco-morphological components.

The study finds that, ecologically all the areas are almost identical with almost similar infaunal-epifaunal and herbivore-carnivore ratios. Even more, morphologically the five locations are almost similar, i.e., majority of shells are open to elliptical apertures (S1-2), non- or shallow-umbilicate (D1-2), moderately elongate (T1-2) forms with low to moderate whorl overlap (W1-2). However, Satapada-Chilka region is taxonomically different from the rest; this region is influenced by the high fresh water influx of the lake, which is almost absent in other studied areas. In fact, the catchment area of Chilka Lake is located at Satapada. This spatial patchiness of the local environment might be responsible for this unique species assemblage of that region, indicating a decoupling nature of taxonomic and eco-morphologic diversity at that region and suggesting the importance of local environment controlling morphologic diversity of groups both in fossil and modern environment.

In-situ dating of monazite from Koraput Anorthosite Complex and geodynamic implications

Dicton Saikia*, Pritam Nasipuri
Department of Earth and Environmental Sciences, IISER Bhopal, Bhouri, M.P.
**Email: dicton@iiserb.ac.in*

A comprehensive study based on the U-Th-Pb (total) analysis of monazite from the Koraput anorthosite Complex, Eastern Ghats Granulite Belt was conducted to understand the temporal correlation between anorthosite magmatism and crustal dynamics of Eastern Ghats Granulite Belt (EGGB) in the Neoproterozoic. The monazite grains hosted within deformed orthopyroxene and plagioclases are circular to elliptical in shape having 400-500 um diameter, and complexly zoned. The monazites occuring as inclusions within orthopyroxene are classified into three varieties, e.g. Type-A monazites with low-ThO_2 core are mantled by high-ThO_2 rim, and Type-B monazites exhibit an additional low-ThO_2 outermost mantle, and the low-ThO_2 cores are largely absent. Type-C monazites along polygonized grain/phase boundaries are irregular in shape and characterized by patchy zoning. The U-Th-Pb (total) chemical ages obtained using EPMA exhibit four distinct age clusters. The oldest age (939±4.5 Ma) obtained from low-ThO_2 cores of Type A and B monazites are correlated with the emplacement of the Koraput anorthosite. The age is consistent with the tightly constrained Neoproterozoic (980–930 Ma) emplacement ages of anorthosite massifs in EGGB. The younger monazite mantles at 877±5 Ma and 749±18 Ma reflects episodic monazite growth culminating with the disintegration of Rodinia at ~750 Ma. The youngest age population (mean 574±19 Ma) obtained in the outermost monazite rims represents growth of new monazites during the Pan African assembly of the domain 3 and 4 of EGGB with the older cratonic nucleus of Peninsular India.

Depositional facies of Surma group of rocks in and around Nungba, Tamenglong district, Manipur

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

A thick sedimentary succession belonging to the Surma Group (Miocene) is well exposed along the road side (NH-37) in and around Nungba, Tamenglong, and Manipur. A study on lithofacies of the Surma Group has been attempted for the first time in the study area to understand the depositional environment. A total of five litho-sections were measured and carefully recorded at various locations in order to establish temporal and spatial distribution of various lithofacies. Based on five parameters including grain size, palaeocurrents, sedimentary structure, geometry and fossil content (including trace fossils) an attemt has been made to subdivide the Surma rocks into seven litho-facies i.e., Shale dominated facies (shale 70%, sand 30%), sand dominated facies (Sand 70%, Shale 30%), interbedded sand and shale facies (sand 50%,shale 50%), massive sandstone facies (sand 100%), siltstone facies (100%), cross-bedded sandstone facies and deformed sand–mud facies. Characteristic sedimentary structures in Surma sediments include flaser, wavy, and lenticular bedding, lunate ripple, current ripple, penecontemporaneous deformation structures and Hummocky cross-stratified sandstone (HCS). The study of lithofacies, including sedimentary structures assemblages indicate a nearshore environment influenced by tide and storm activity in the intermittent fluvial signature.

Palaeofloristics and palaeoclimatic interpretations of Yellandu coal belt area of Kothagudem sub-basin, Godavari graben

D.S. Seetharam*, H. Ramakrishna
Palaeobotany & Palynology Research Laboratory, Dept. of Botany, University College of Science, Saifabad, Osmania University, Hyderabad 500004, Telangana
Email: dsdssiddhu8@gmail.com

The present study deals with the palynofloristics and palaeoclimatic interpretations of subsurface sediments (B.H. Q - 563) of the Barakar Formation from Yellandu coal belt area (JK - 5 Coal block) of Kothagudem sub-basin, Godavari graben, Telangana State. A total of sixty samples were analyzed from the 414 m deep core of Jawahar khani-5 coal block. They yeilded well preserved and fairly diverse palynofloral assemblage of Gondwanic affinity. About 30 palynomorph taxa, belonging to striate disaccates and nonstriate disaccates, triletes, monoletes, and monosaccates have been recovered. The palynological data have been interpreted throwing light on its dating potential and environment of deposition. Frequency distribution pattern of the palynotaxa reveals that the assemblage is dominated by the non - striate disaccates (*Scheringipollentites* spp., *Ibisporites* sp.) followed by striate disaccates (*Faunipollenites* spp., *Striatopodocarpites* sp.), monosaccates (*Parasaccites* spp., *Plicatipollenites* spp., *Crucisaccites* spp.), pteridophytic spores (*Microbaculispora* spp., *Horriditriletes* sp.), acritarchs (*Leiosphaeridia* sp.) and thecamoeibians (*Arcella artocrea*) respectively. On the basis of quantitative analysis and stratigraphically significant palynomorphs, two distinct palynoassemblage zones are recognized in ascending order: (i) *Scheringipollentites – Faunipollenites* zone and (ii) *Faunipollenites – Scheringipollentites* zone. The palynoassemblage pattern indicates an Early Permian age of the sediments. Preponderance of non - striate disaccates indicates a warm, humid climatic phase of deposition of the coal sediments.

Sediment deposition history using radioactive isotopes ^{210}Pb and ^{137}Cs

Chinmay Shah*, Upasana S. Banerji, Ravi Bhushan
Geosciences Division, Physical Research Laboratory, Ahmedabad 380009
**Email: chinmayshah91@gmail.com*

Climatically, last two centuries have witnessed both natural and anthropogenically induced changes which have disturbed natural processes of the earth. These changes have brought significant variation in the recent environments and have influenced significantly in the sedimentation processes in the oceans. One of the most important and pertinent aspects for paleoenviornment studies is use of appropriate dating technique for ascertaining chronology as applicable for the last 100-200 years and this can be achieved using ^{210}Pb and ^{137}Cs. The long continental shelf on the western coast of India is a very unique region as it experiences monsoon reversal processes. Sedimentary deposition in the eastern Arabian Sea contributes significantly to the paleoclimatic and paleoenvironmental archives and can be retrieved from the coastal sediments of the Arabian Sea. The present study thus, demonstrates the use of ^{210}Pb in combination with ^{137}Cs as a potential tool for dating coastal sediments to address the sedimentation rates along the continental shelf of western India. ^{210}Pb with its short half-life of ~22.3 years has been extensively used for estimating the sedimentation rates during the last 100-120 years. Sediment cores collected from the region were dated using ^{210}Pb and ^{137}Cs dating technique and its results will be discussed in detail.

Geochronology and palaeomagnetic study of the newer dolerite dyke swarms from the Singhbhum Craton: Implications to Proterozoic continental reconstruction

Ravi Shankar[1,2]*, D.S. Sarma[2]
[1]*Academy of Scientific and Innovative Research, CSIR-NGRI, Uppal Road, Hyderabad 500007*
[2]*CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500007*
**Email: ravisingh82.2@gmail.com*

In this study, we identified two dyke swarms from Singhbhum craton with distinct strike orientation with the help of Precise Pb-Pb Baddeleyite geochronology and high quality paleomagnetic study. We identified for the first time the 1765 Ma WNW-ESE trending dyke swarm from Singhbhum Craton. We have identified three distinct events from NNE-SSW trending dykes, i.e., 2750 Ma, 2762 Ma, and 2800 Ma. Of these three events the 2762 Ma event is identified as NNE-SSW trending dyke swarm. A mean paleomagnetic direction with a declination = 329.4° and an inclination = - 26.6° (k = 21.5; á95 = 10.7°) for 1765 Ma WNW-ESE trending dykes were found from Singhbhum Craton. The pole position of Singhbhum craton at 1765 Ma is 43.4°N, 308.7°E (dp=6.3 and dm=11.6). Mean paleomagnetic direction of 2762 Ma NNE-SSW dykes: Declination = 226° & Inclination = 84° (k = 47; á95 = 6°). Pole position of Singhbhum craton at 2762 Ma is 14°N, 78°E (dp =11 and dm=12).

The two keypoles at 1765 Ma and 2762 Ma have helped us to constrain the paleoposition of India at respective times. At 1770Ma we propose the Baltica-India-North China spatial linkage and at 2800Ma 1770Ma we propose Singhbhum-Vaalbara ancestry, constrained by key-paleopoles and geological correlations. This work can be extended by conducting the Geochronology and Palaeomagnetic Study of dyke of orientations other than NNE-SSW and WNW-ESE. Further there is a possibility to find out the 2750 Ma and 2800 Ma dyke swarm as indicated by this study.

Ediacaran *Shaanxilithes ningqiangensis* from the Tal Group (Cambrian), GC-MS analysis and discussion on origin and biostratigraphic significance

C.A. Sharma*, Birendra P. Singh, Ramanpreet Kaur, Garry Singla
Panjab University, Chandigarh 160014
**Email: anuprcsharma@gmail.com*

Well preserved specimens of *S. ningqiangensis* were collected from the Earthy Dolomite Member (Krol Group) and calcareous siltstone beds of the Earthy Siltstone Member (Tal Group). *S. ningqiangensis* has been variously described as body fossil, ichnofossil and algae. GC-MS data shows that *S. ningqiangensis* structure is formed by hydrocarbon organic compounds which are filled with inorganic elements filler like silica, calcium and phosphorus, etc. The *S. ningqiangensis* structure is a mixture of organic compounds of high molecular weight containing several saturated rings with hydrocarbon chains having an occasional isolated carbon-carbon double bond, small amounts of nitrogen, sulfur and oxygen. Data revealed that the presence of nitrogen in the form of peptide chains means amide/amine and in chemical form means nitrates/nitrites, etc. The formula weight and the weight ratio of C/H shows that it would be expected for algae derived organics.

S. ningqiangensis is known from the late Neoproterozoic (Ediacaran) of southern and central China, Siberian platform and across the Pc/C Boundary from the latest Neoprterozoic to the earliest Cambrian of northern India. *Shaanxilithes* is considered an Ediacaran organism that spans the Precambrian–Cambrian boundary, an interval marked by significant taphonomic and ecological transformations that include not only innovation but also probable extinction. After the recovery of the *S. ningqiangensis* from Nigalidhar syncline, the stratigraphic status of *S. ningqiangensis* bearing Earthy Siltstone Member of the Shaliyan Formation of the Tal Group (Cambrian) is rendered uncertain, though the overlying Chert Member in the adjoining Korgai Syncline yielded definite early Cambrian acritarchs. The moot question is whether the Earthy Siltstone Member represents an Ediacaran or an early Cambrian age? It would be interesting to find if *S. ningqiangensis*, so far known from Ediacaran sequences, could transgress to the early Cambrian or in simple words could it withstand the Pc/C Boundary event.

Records of extreme hydrological events from the Indus and Zanskar river system, Ladakh, NW Himalaya

Pankaj Sharma[1]*, Poonam[2], Anil Kumar[1], Rupa Ghosh[1], Pradeep Srivastava[1], Y.P. Sundriyal[2]

[1]Wadia Institute of Himalayan Geology, Dehradun 248001

[2]Dept. of Geology, HNB Garhwal University, Srinagar 249161

**Email: ps09474@gmail.com*

Himalayan region is quite sensitive to the climatic variability and the quaternary period has witnessed numerous climatic oscillations that at times are detrimental to socio-economic development of Himalaya and its peripheral regions. In the recent past Indian Himalaya had witnessed many flash flood e.g. August 2010 flood in Leh and June 2013 disaster in Uttrakhand that lead to great loss in terms of lives and property. Studies have implied that the historical and instrumental records of such extreme events are unable to indicate the trends and long term geological records to understand the variability is needed. Majority of the studies related to extreme events are done from the core monsoon zones and a very few data is available from the higher altitudes arid regions of the Ladakh Himalaya. As the region lies between the Indian Summer Monsoon fed Higher Himalaya in the south and westerly dominated Tibetan plateau in the north, the paleoclimatic archives here provides evidences of the spatiotemporal interactions between these climate extremities.

This study presents the flood record of the past up to ~ 15 ka from the Ladakh Himalaya using slack water deposits preserved along the Indus and Zanskar river system. The field survey includes sedimentological and geomorphological analysis and the chronology of the events was established using ^{14}C-AMS and Optically Stimulated Dating technique. In all 10 sections were studied where several sections also exhibited hearth- burnt layers indicating anthropogenic activities and possibly post-LGM route of human migration. Chronology suggest four major cycles of flood events ranging from 4 to 16 ka that peaked between 6-4 ka. We speculate strengthening of winter monsoon to be cause of this flood episode.

New fossils from Barmer hill formation of the Barmer basin, western Rajasthan, India

N.S. Shekhawat, Saurabh Mathur*
Department of Geology, J.N.Vyas University, Jodhpur
**Email: sureshsushma09@gmail.com*

Petrified wood, wood-boring *Asthenopodichnium* and *Teredolites* trace fossils from Paleocene Barmer Hill Formation (BHF) of Barmer Basin in western Rajasthan, India are documented. The fossils are found in fine grained sandstone of the BHF at Gehun and Lunu sections which are located about three and eight kms from the Barmer city, respectively on Barmer –Bisala Road. The petrified wood occurs in fine grained sandstone at Gehun section along with Petrified wood clasts, plant leaves, and their veinlets. The petrified wood is sometimes silicified and jasperified, but mostly either ferrugenized and coalified or carbonaceous in nature (Plate 1). *Asthenopodichnium* (wood boring) trace fossils are found in full relief in fine grained sandstone dominantly at Gehun Section and ill preserved at Lunu section. They are identified as *Asthenopodichnium lignorum* and *Asthenopodichnium lithuanicum* which are abundant, well-preserved and uniformly distributed in ideal and bookish forms parallel to the bedding plane (Plate2 and 3)**.** *A. lignorum* seems to be feeding and dwelling small pouch like burrows produced by wood-rotting fungi whereas *A. lithuanicum* are interpreted as feeding and dwelling small pouch like burrows produced by Mayfly nymphs and larvae. The sedimentological and paleontological investigations of studied sections of the BHF suggest fresh water fluvial environment. The present paper embodies sedimentological and paleontological attributes of trace fossils and trace fossils bearing sections of the BHF of the Barmer Basin.

Plate 1: Petrified Wood

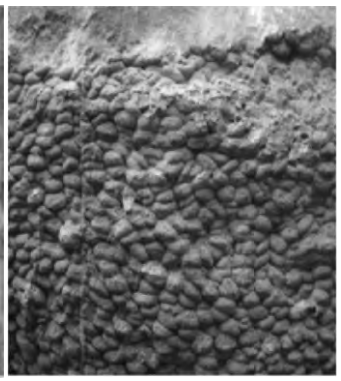


Plate 2 & 3: *Asthenopodichnium*

Plate 4. *Teridolites*

Evolution of allanite–magnetite bearing leucogranite and pegmatite plutons in the central part of Tamil Nadu: Evidences from field relationships and magnetic susceptibility

Sonam Singh*, Santosh Kumar
Department of Geology, Centre of Advanced Study, Kumaun University, Nainital 263002
**Email: sonamgeology@gmail.com*

The high-grade metamorphic complex (>2600 Ma) comprising hornblende-biotite gneiss (Peninsular Gneiss/Bhavani Gneiss) and charnockite with enclaves of supracrustal rocks of Sathyamangalam Group comprising banded haematite quartzite, amphibolite, dunite, pyroxenite of central Tamil Nadu are intruded by the Neoproterozoic-Cambrian granitoids. These granitic plutons are associated with the Palghat-Cauvery Shear Zone. The central part of Tamil Nadu comprises multiple felsic magmatic pulses represented by pink pegmatoidal granite (PPG), white to grey pegmatoidal granite (WPG), medium grained pink granite (PG), medium grained grey granite gneiss (GGG), and leucogranite. The texture of these units varies from medium to very coarse grained. The granitoids show three modes of occurrences, such as conformable bands (or sheets), cross cutting veins and as stock like bodies. Available geochronological data indicates a long period of felsic magmatism within the Southern Granulite Terrain. The whole-rock Rb-Sr isotopic ages of granites range from 498±12 Ma to 507±12 Ma which are related to Pan-African thermal orogeny. Small to large spindle shaped allanite occurs frequently commonly associated with medium to coarse grained pink granite and pegmatoidal granitic phases in the Karamadai, Sankari and Trichengode plutons. Coarse magnetite crystals are associated with pegmatoidal pink granite. The pink pegmatoidal granite associated with allanite and magnetite shows the highest and maximum magnetic susceptibility (MS) variations while those which do not bear allanite and magnetite are highly reduced types, belonging to magnetite (oxidized) and ilmenite (reduced) series, respectively. The MS values for the PPG vary from $0.001õ10^{-3}$ SI unit to $8.032õ10^{-3}$ SI unit with an average value of $0.922õ10^{-3}$ SI unit which represents moderately reduced type granite. The MS values for the WPG vary from 0.001 to $0.355õ10^{-3}$ SI unit with an average MS value of $0.055õ10^{-3}$ SI unit which shows highly reduced condition. In PG the MS values vary from 0.001 to $3.3õ10^{-3}$ SI unit with an average of $0.416õ10^{-3}$ SI unit indicating moderately to highly reduced conditions of granites. The MS value of GGG varies from 0.001 to $2.944õ10^{-3}$ SI unit and has an average MS value of $0.32õ10^{-3}$ SI unit. The leucogranite shows highly reduced condition measuring an average MS value of $0.0686õ10^{-3}$ SI unit which varies from zero to $1.109 õ10^{-3}$ SI units. Majority of granites described so far belong to the ilmenite series of granites which corresponds to reduced type granites. Therefore, it is likely that they may have been derived by the partial melting of metapelitic crustal sources and subsequently evolved the hydrothermal system precipitating the coexisting allanite and magnetite under an evolving oxidizing environment. This is being further investigated using biotite phase equilibria and elemental and isotopic studies.

Magmatic vis-à-vis xenocrystic origin of olivine in cumulate harzburgite

Ajay Kumar Singh*, Dewashish Upadhyay, Kamal Lochan Pruseth
Indian Institute of Technology-Kharagpur, Kharagpur
**Email: ajayksingh@gg.iitkgp.ernet.in*

The primary magma is generate by the partial melting of peridotite mantle source and it coexists with the residual solid and the part of solid may be extracted with melt as xenocrysts or xenolith. Olivine is one the earliest crystallized mafic phases from the magma that has the efficient probe to determine parental melt compositions and their mantle and crustal source region. The origin of olivine becomes important because of its consequences to determine the parental melt composition. Therefore, distinguishing the origin of olivine between magmatic and xenocrytic is the first and foremost work in this regard. The olivine cumulates from ultramafic rocks occurring in Amjori Sill, Simlipal at the eastern margin of the Singhbhum granite, show variable composition of CaO (0.024–0.154 wt. %). It is observed that the rims of larger grains have higher concentrations of CaO compared to the cores. Olivines with low CaO (<0.1 wt. %) are normally thought to be of xenocrystic origin. Olivines with low Ca concentrations can have the following origins: (1) Crystallization from basaltic magmas at shallow depth in different tectonic environments (2) Crystallization from magmas derived from a pyroxenite source or olivine poor/free lithology. Such olivines are expected to have low Mn and high Ni contents. However, the olivines from the Simlipal ultramafic rocks are inferred to be of magmatic origin and it also supported by following facts: (1) their euhedral to subhedral habit, (2) the cumulate texture of the rock, (3) the presence of inclusions of euhedral high-Cr spinel with TiO_2 >0.2 and Fe^{2+}/Fe^{3+} (up to 4) higher than that of spinels from mantle peridotite. The olivines from the Simlipal ultramafic rocks have low Ca, Mn and high Ni contents. Their parental magmas are therefore inferred to have been derived from a pyroxinitic mantle source.

Geochemical systematics of mafic volcanic rocks from the Older Metamorphic Group (OMG), Singhbhum Craton, eastern India: Evidence for Archean subduction processes

Mutum Rajanikanta Singh*, C. Manikyamba
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500007
**Email: rajanimutum@gmail.com*

The mafic volcanic rocks of the Paleo-Mesoarchean Older Metamorphic Group (OMG) from Jagannathpur area of the Singhbhum Craton occur as enclaves within the Singhbhum granites (SBG). The primary mineralogical composition of these rocks has been overprinted by plagioclase-chlorite-tremolite-actinolite assemblage reflecting upper greenschist to lower amphibolite facies metamorphism. Disseminated sulphides and minor amount of chromite are present as opaque phases. Clinopyroxene compositions correspond to augite. Geothermometric estimations of clinopyroxene record crystallization temperatures of the protoliths as 1160° to 1200°C. Major, trace and rare earth element compositions of these mafic volcanic rocks are characterized by high Mg# (80-82), MgO (12-24 wt.%), Ni (490-1262 ppm) and Cr (2404-4385 ppm) contents, high Al_2O_3/TiO_2 (29-50), Zr/Hf ratios with low TiO_2 (0.2-0.36 wt.%), Zr (1.0-3.1ppm) contents and $(Gd/Yb)_N$ <1 ratios. These geochemical features in conjunction with distinct negative Nb, Ta, Zr, Hf and Ti anomalies on primitive mantle normalized multi-element diagram, depletion in MREE compared to LREE and HREE, and high La/Sm and low $(Gd/Yb)_N$

ratios collectively attest to boninitic affinity and magma generation in an intraoceanic subduction zone setting. These boninites are associated with low Ti arc basalts that are characterized by enrichment in LILE with relative depletion in HFSE consistent with subduction zone process. The tholeiitic to calc-alkaline nature of these arc basalts reflects a transition from depleted to undepleted nature of the mantle wedge peridotite controlled by hydrous fluxes from dehydrated subducting slab. Chondrite normalized REE patterns of the OMG boninites coupled with their $(La/Sm)_N$ >1 and $(Gd/Yb)_N$ <1 features indicate a refractory mantle source previously depleted by melt extraction episodes and subsequently enriched by subduction-related slab-dehydration process. The LILE and LREE replenishment of the refractory mantle wedge is attributed to influx of hydrous fluids that are enriched in fluid mobile LILE and LREE, which lowered the solidus temperature and triggered partial melting at shallow level under hydrous conditions. The generation of both high- and low-Ca varieties of OMG boninites was influenced by the refractoriness of the mantle wedge and increase in the input of subduction-derived fluids/melts from high-Ca to low-Ca boninites. The PGE chemistry of the studied boninites and arc basalts marked by their S-undersaturated nature associated with higher Pd and Pd/Ir over lower Pt and Pt/Pd attest to fluid-fluxed metasomatism of mantle wedge and sulphide retention in the residual mantle due to high fluid pressure and high degree of mantle melting at shallow depth.

Significance of ophiolites of the Indus-Tsangpo Suture zone and other parts of Indian plate margin: A brief literature review

N. Lakhan*, S. Khogenkumar, A.K. Singh
Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: neesam10@gmail.com*

Ophiolites are the fragments of paleo-oceanic lithosphere that have been brought up on continents at suture zones along the convergent plate boundaries. At earlier times, ophiolites/oceanic lithosphere were believed to have formed only at mid-ocean ridges (MOR). Later, this paradigm had shifted to supra-subduction zone (SSZ) origin as first proposed by Miyashiro (1973) from the study of well-known Troodos ophiolite section. His finding thus changed the concept of ophiolite genesis and thereafter series of publications emerged and it is now understood that ophiolites can be formed at various tectonic environments; mid-ocean ridges, continental margin, plume, fore-arc and back-arc etc. In the context of Indian plate margin, there are patches of dismembered ophiolite sections lying as graveyards of Tethyan oceanic lithosphere along the Indus-Tsangpo Suture zone, Eastern Himalaya, Indo-Myanmar orogenic belt and Andaman island arc. Although these ophiolite sections are a common part of the Tethyan oceanic lithosphere, geochemical studies revealed that chemical compositions of similar rock types were highly variable and derived from different magma sources. This brings to a significant discovery which is that ophiolites along the Indian plate margin treasure a long history of the evolution of ocean basins that began from rift-drift activity during Gondwana separation through accretionary and back-arc spreading to collisional phase and formation of Himalayan orogeny. So these ophiolite sections are very important sites and can be considered as natural museums where we can study the geochemical activities going on deep within the paleo-oceanic lithosphere as magma ascends. Another significant aspect of wealth is that such ophiolite terrains are economically potential sites for several ore and mineral deposits such as magnetite, chromite, nickel, cobalt, base metals, limestone, platinum group elements (PGE) and gold. Mafic and Ultramafic rocks in ophiolite suites are favorable host rocks for polymettalic as well as noble metal mineralization. More interestingly, a number of diamond-bearing podiform chromitites were

discovered from Luobusa ophiolite of Tibet. So, to further discover more mineral deposits and understand the magmatic and melt-rock interaction processes occurred at the time of ophiolite formation, detailed geochemical and mineralogical studies are utmost required in the ophiolite suite of rocks that lie along the Indus-Tsangpo Suture zone and other parts of Indian plate margin.

Stream response to active tectonic deformation of the Sub-Himalayan wedge: Inferences on geological structure, tectonics and seismic hazard

Sarabjeet Singh[1], Hitander Singh Gill[1], Tejpal Singh[2]*, Seema Singh[1]
[1]Centre for Advanced Study in Geology, Panjab University Chandigarh 160014
[2]CSIR-Central Scientific Instruments Organisation, Sector-30, Chandigarh-160030
**Email: geotejpal@yahoo.co.in; tejpal@csio.res.in*

Drainage is extremely sensitive to subtle changes in the surface topography and tends to adjust its behaviour by modifying its geometry. In the Sub-Himalaya, the changes in surface topography largely manifest the active deformation processes. The key to understand the deformation processes is to study the drainage characters spatially either through morphometry or geomorphic features. For a better spatial control and improved understanding both (morphometry or geomorphic features) are used here as complementary phenomenon and inferences drawn accordingly. The focus of this article is on the outermost ranges of the Sub-Himalayan belt, proximal to the Himalayan Frontal Thrust (HFT). The streams here are smaller (lower order) and mostly ephemeral in nature. They benefit from the fact that they flow over similar lithologies of Upper Siwalik rocks and could permit spontaneous correlation with active tectonic deformation. The inferences drawn from morphometric analyses enabled detailed investigations using remote sensing imageries. Further, based on geomorphic features, it is concluded that the manifestations reported in the article relate to recent/young tectonic activity as young as 38-40 ka. Implications of the analyses on the geological structure, tectonics and modulation of seismic hazard are discussed.

Development of protocol for direct liquid ablation using Laser Ablation Inductively Coupled Plasma Mass Spectrometer

Tapasya Singh*, Dewashish Upadhyay
Department of Geology and Geophysics, Indian Institute of Technology- Kharagpur, Kharagpur
**Email: tapasyasingh91@gmail.com*

Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) has become a very sensitive, accurate and widely used technique for major and trace element analysis with high resolution. It was traditionally applied to the measurement of trace elements and isotopes in solid material. However, the technique is now being increasingly used to ablate liquid. The geochronology and isotope laboratory at IIT Kharagpur houses a New Wave 193 nm laser ablation system coupled to a Thermo Fisher ICAP-Q quadrupole ICPMS. Using this analytical setup, we are experimenting liquid ablation with an objective of measuring the trace element concentrations of fluids in fluid inclusions in quartz. There are certain applications of trace element measurement in fluid inclusions after proper quantification study of fluid inclusions through petrography, micro thermometry and LA-ICPMS analysis. Trace element concentration can be used to determine fluid evolution, track fluid source processes, fluid-fluid interaction like phase separation, fluid mixing and fluid-rock interaction which include rock dissolution, ore mineral precipitation and alteration. These are also

helpful to understand complex fluid processes that can be useful to determine the large scale mass transfer in Earth's crust and formation of felsic rock mass. Repeated analyses of synthetic fluids (volume used during one analysis?) with trace element concentrations of 5 ppm and with 2.5 wt. % NaCl matrix give accuracies in the range of 5-8% and precision better than 15% for most elements. Thus, direct liquid ablation is not only suited for analyzing small volumes of complex aqueous solutions (e.g, the quantitative microanalysis of fluid inclusions in minerals), but also provides a new approach for calibrating laser ablation ICP-MS microanalysis of solids.

Field evidence of partial melting of granites and metapelites and their ascent and emplacement from Madurai and Rajapalayam, Madurai block, south granulite terrain (SGT), Tamil Nadu

Anjali Solanki, Santosh Kumar
Department of Geology, Centre of Advanced Study, Kumaun University, Nainital 263002
**Email: anjali92solanki@gmail.com*

Neoproterozoic to Cambrian (Pan-African) event affected the entire Southern Granulite Terrain (SGT) and the Palaghat-Cauvery Shear Zone (PCSZ). The Madurai Block of the SGT, lying south of the PCSZ, contains several granitoid bodies exposed at Puddukotai, Vanjinagram, Melur, Mottamalai, Vellur and Pulangkurichi, which are emplaced within charnockite and khondalite groups of rocks and their migmatized equivalents. The Madurai Block also contributes significantly towards understanding the Ultra-HighTemperature (UHT) metamorphic condition.

Peninsular gneissic complex is well exposed in the south-west of the PCSZ, showing roughly E-W trend. The area is commonly represented by medium grey granite gneiss (MGG), migmatized gneiss (MG), medium grained pink granite (MGG), and pegmatoidal granite (PG). Peninsular gneiss has undergone metamorphicm. Garnet and tourmaline crystals are the result of local metamorphism whereas pink granite and leucogranite are melting products involving the infracrustal sources during the Pan-African thermal event in the tectonic segment of the PCSZ. The host granite gneiss shows stretching and boudinage leading to augen formation, caught up patches of khondalite and amphibolites along with CO_2 degassing prevailed along the fractures. Here the granite is emplaced within the hornblende-biotite granite gneiss. The minerals present in these rocks are k-feldspar, quartz, biotite, garnet, magnetite and allanite. The magnetic susceptibility (MS) value of MGG varies from 0.064 to 0.853×10^{-3} SI unit with an average of 0.216×10^{-3} SI, which represent ilmenite series. The MS value of MGG varies from 0.165 to 10.532×10^{-3} SI with an average of 2.546×10^{-3} SI due to the varying amounts of accessory minerals like garnet, magnetite and allanite.

Rajapalayam area of Madurai Block in the south-west part of the SGT exposes charnockite interbanded with metapelites, khondalite, and calc-granulite. Pyroxene granulite occurs as enclaves within the charnockite. Leucogranite and pink granite also occur in some areas. Charnockite and associated meta-sedimentaries have suffered deformation along with high to ultrahigh condition of metamorphism. The high temperature mineral assemblage, such as garnet, orthopyroxene, cordierite, sillimanite and sapphirine in metapelite indicate high grade granulite facies of metamorphism. Ultra high temperature (UHT) metamorphism has also been seen in some parts of Rajapalayam block. The MS values of charnockite varry from 0.617 to 5.054×10^{-3} SI with an average of 3.517×10^{-3} SI and for leucogranite average MS value is 0.338×10^{-3} SI, both corresponding to ilmenite series whereas khondalite has shown average MS value of 10.137×10^{-3} SI, which represents magnetite series granites favoring oxidizing environment.

Taphonomic analysis of Campanian Maestrichtian shell accumulation in Kallankurchi Formation, south India

M.A. Sonar[1], Gaurav K. Kadu[2], Dnyaneshwar V. Wayal[2]
[1]Dept. of Geology, Govt. Institute of Science, Aurangabad
[2]Dept. of Geology, Govt. Institute of Science, Aurangabad

Shell accumulations are important events to understand and decode taphonomic and paleoecological changes occurring during their deposition. Upper cretaceous Campanian Maestrichtian sediments of Kallankurchi formation are rich in shell accumulation. The shell accumulation are dominated by large and thick bivalve shell with varying degree of preservation and commonly encrusted by bryozoans, etc and bored by various types of boring. Systematic lateral analysis in the Kallankurchi mines reveles that most of the shell accumulation types were deposited in low sedimentation input (favoring encrustation and boring) alternating with high energy condition usually in shallow marine condition especially in between normal wave base and storm wave base condition during Campanian Maestrichtian times.

Taxonomic composition of shell bed accumulations are characterized as *monotypic* or *polytypic* based on whether they have single or several types of skeletons. To study biofabric i.e. the three dimensional arrangement of skeletal elements in the matrix constituting skeletal orientation, close-packing, and sorting by size and shape is considered.

Crustal thickness estimation of Indian Ocean Ridges using Rmba and direct Inversion

K.S. Sreenidhi[2]* , John Kurian P[2]
[1]Indian Institute of Technology-Bombay, Mumbai
[3]NCAOR, Goa
**Email: nidhisree94@gmail.com*

The crustal thickness of the three mid-Indian Ocean Ridges- Southwest Indian ridge, Southeast Indian ridge and Central Indian ridge, is calculated using two different methods. The first method involved the calculation of Residual Mantle Bouguer Anomaly (RMBA) of the two ridges and downward continuation of it to get the crustal thickness. To avoid the curvature effect of the globe and for the computational ease the total area of interest is divided into 16 blocks and calculations are done individually in each of them. The second method involved a direct nonlinear inversion of gravity data by using the well-known Levenberg – Marquardt Algorithm to get the Moho depth. For carrying out the two-dimensional inversion 11 profiles of gravity and bathymetry data were extracted across the ridge axes, particularly within the blocks used for RMBA calculation. The method of solving forward problems introduced by Parker (1972) is used in both methods; in RMBA method to calculate the gravity effects of interfaces and in inverse modeling method as the forward algorithm to carry out iterations and successive updation of the results. Both results were compared and interpreted. The results from the downward continuation of RMBA are found to be more reasonable due to the calculation of thermal related density structure of the mantle which was not included in the inversion method.

Heavy mineralogical analysis and ZTR (Zircon-Tourmaline-Rutile) index studies of the coastal sediments of Digha and Sagar Island, West Bengal

S. Sri Hari, G. Shaik Fareeth, V. Ram Mohan , P. Seralathan, S. Srinivasalu
Institute or Ocean Management, Anna University, 600025, Chennai
**Email: srihariseralathan@gmail*

Sagar is known to be the largest island in the Sundarban biosphere and is formed due to continuous sedimentation from Hoogly estuary flowing west of the island and Muri Ganga in the east. This island is built primarily by silt and clay, with minor amount of sand and the coast is influenced by large tidal waves and aeolian activities. The coastal area falls under macrotidal setting (>5 m) and linear islands and tidal shoals are aligned perpendicular to the coast, separated by tidal creeks.

Digha coast, extends for about 15 km in which the dunes attain heights of 20 mts and the coast has a low gradient with gentle sandy beaches shaped by moderate tidal waves and with large dune fields behind the beach. On either side of Digha two medium level rivers namely the Subarnarekha on the south and Champa on the north influences the coast contributing sizable sediments to it. The wide beach sediments are reworked by the tides (mesotidal, 3.5- 5m), waves and wind action and are transported to the backshore beaches and dunes. The study is based on 25 shallow surface samples (< 100 cm depth) collected from different nearshore environments, namely foreshore, backshore and dune, of which 14 samples are from Sagar island coast and the rest from Digha coast (Tajpur to Talsavi).

The individual heavy minerals identified in the nonmagnetic minerals fraction from Sagar samples are Ilmenite, sillimanite, garnet, hornblende, clinopyroxene, zircon, rutile, tourmaline, kyanite, biotite, staurolite, xenotime, monazite, magnetite and muscovite. In the sagar island ,relatively higher concentration of zircon, tourmaline and rutile are found in medium to fine sized sand particles in the fore shore part of Baghukhali region situated in the south west part of Sagar Island accounting for around 10 -12% and Chandipur accounting for 24%. The Digha coast reveals the presence of minerals such as ilmenite, sillimanite as the major constituents while garnet, zircon, rutile, tourmaline, hypersthene, clinopyroxenes, hornblende, sphene and biotite are less in quantity. The ilmenite grains are almost altered in the major part of the area. Higher proportion of zircon, tourmaline and rutile are noticed in northern part of stretch from Talsavi to Digha accounting for 7.5%, 4.21% & 2.06%, respectively whereas they are found in trace quantities in new digha beach.

The minerals Kyanite, Biotite, Staurolite, Xenotime,and Monazite are present in the Digha coast while they are absent in Sagar island. Whereas Hypersthene, Sphene and Biotite are present in the Sagar Island but they are absent in Digha coast.

ZTR (Zircon-Tourmaline-Rutile) Index indicates how mature the sediments are. The textural maturity indicates how much mechanically the samples are weathered and the distance travelled by the sediment from the source rock. ZTR index has been calculated and compared between the two sediment source systems. The mineral composition of the study area suggests that the Sagar island sediments have a sizable population of mica and are derived from the Himalayan sources. In contrast the Digha coast has less mica. ZTR index of Sagar Island ranges from 2.04 - 28% whereas in Digha coast it ranges from 6.35-30.33%.

The relatively higher concentration of heavy minerals in sand fraction of South west Sagar Island (Baghukali and Chandipur) indicates that sediments have been transported from south to north by the northward moving longshore currents till Digha; from there they would have been transported

to the south west of Sagar Island by the waves and tides resulting in its deposition in the foreshore region. In the Digha coast, the chief source of sediments is from the Subarnarekha river as the tides in the coast are highly mesotidal (3.5-5m), the wide beach is being reworked by tides and waves and are transported to the backshore beaches and dunes.

The comparable and low maturity index of the samples from these two locations indicates that these sediments are derived from nearby source rocks namely the Archean granites, and gneisses of southern part of Singhbhum Craton that fall within the Subarnarekha river basin. The sand sediments of the Sagar Island, as suggested by heavy mineral composition and ZTR, could have transported from south to north by the northward moving longshore currents.

Depositional environment of sedimentary sequences in Matanomadh area, western Kuchchh : Foraminiferal evidences

Hema Srivastava*, Ajoy K. Bhaumik
Department of Applied Geology, Indian Institute of Technology (Indian School Of Mines) Dhanbad 826004
**Email: hemasrivastava22@gmail.com*

The Eocene to Miocene sedimentary succession in Matanomadh area, western Kachchh, is well developed. The late Paleocene to early Eocene is characterized by the presence of lignite deposits over the Deccan trap. Middle Eocene to upper Miocene sequences consists of fossiliferous grey shales, limestone, variegated clay, and sand rich clay. The present study is carried out to decipher the depositional environment of the sedimentary beds deposited within middle Eocene to upper Miocene. Sixty two core samples were collected from an exploratory drilling site penetrated up to 92 meter, out of which 22 samples are productive in terms of foraminifera. The core samples from 10.55 to 17.50 m are characterized by the presence and dominance of benthic foraminifera *Ammonia spp., Cibicides spp, Nonion spp, Elphidium edvena*. All these species are considerd as shallow water inner shelf forms. This association is also considered as upper Miocene (Vindobonian). Samples from depth between 17.50 to 30.90 m are barren in foraminifera. Depth between 31 to 40 m shows presence of benthic (*Halkyardia minima, Triloculina bhallai, Valvulineria rugosa*) and planktic (*Orbulinoides beckmani*) foraminifera. Presence of Orbulinoides beckmani clearly indicates the age of this segment of sediments as middle Eocene. The benthic species obtained from this part suggest deposition of sediments in inner shelf condition. However, documentation of planktic foraminifera along with these benthics advocate greater water depth during deposition with respect to 10.55 to 17.50 m.

Petrogenetic and tectonic significance of the Paleoproterozoic mafic intrusive rocks from the western Arunachal Himalaya, northeastern India

Rajesh K. Srivastava, Amiya K. Samal*
Centre of Advanced Study in Geology, Banaras Hindu University, Varanasi 221005
**Email: amiyasamal007@gmail.com*

Mafic magmatic rocks, in the form of dykes, sills and volcanic flows, are widespread in the entire Himalayan Mountain Belt, ranging from Precambrian to Eocene. However, these are mostly restricted to the Lesser Himalaya. Here, we present bulk-rock major, trace and rare-earth elements

compositions of the Paleoproterozoic mafic intrusive rocks from the western Arunachal Himalaya to understand their petrogenesis and emplacement tectonics. These rocks are well exposed in the Higher as well as the Lesser Himalayan sequences and mostly concentrated in and around Bomdila, Dirang, Rama Camp, Jung, Jaswantgarh, and Tawang. On the basis of geochemistry, two suites of rocks are identified and, therefore, grouped into high-titanium and low-titanium mafic intrusive rocks. High-titanium mafic intrusive (HTMI) samples have comparatively low Mg number (Mg#) and high high-field strength element (HFSE) contents in comparison to low-titanium mafic intrusive (LTMI) rocks. These two identified groups also have very distinct Multi-elements (ME) and rare-earth elements (REE) patterns. There is no any serious effect of crustal contamination observed from its trace element composition and MEREE patterns. Trace elements based petrogenetic modeling suggests that the LTMI rocks are derived from melts generated through a high percentage of melting (~20-25%) of a lherzolite mantle source in spinel stability field where as the HTMI samples are thought to be derived from a low percentage melting (~10-12%) of a similar mantle source but generated in garnet stability field. Probably these two distinct mafic rock types have been juxtaposed during the Himalayan orogeny by crustal shortening through development of imbricated thrusts. It is suggested that a plume head has initiated rifting in the Indian plate, which has given sufficient force for movement of the Indian plate towards northern direction; which is probably responsible for subduction tectonic signature at the plate margin. This probably leads production of VAB type mafic rocks at plate margin (the LTMI rocks) and WPB type mafic rocks within plate setting (the HTMI rocks). Widespread Paleoproterozoic mafic occurrences in the Indian shield suggest presence of a large igneous province (LIP) during ~1.9 Ga.

Depositional environment and provenance of the late Paleocene Matanomadh sandstones, Kachchh, western India

V.K. Srivastava*, B.P. Singh
Centre of Advanced Study in Geology, Institute of Science, B.H.U. Varanasi 221005
**Email: vsrivastava152@gmail.com*

A 17 m thick sandstone-dominated succession in the late Paleocene Matanomadh Formation is studied for the depositional environment and provenance determination based on facies analysis, petrography and dense mineral analysis. Three facies associations are reconstructed in the succession in three different sections. Facies association-1 contains matrix-supported pebbly conglomerate facies, horizontally-laminated sandstone-mudstone alternation facies, hummocky- and swaley cross-bedded sandstone facies, wave-rippled sandstone facies and climbing ripple cross-laminated sandstone facies. This facies association is developed between shoreface and foreshore zone under the influence of storms on a barrier ridge. Facies association-2 contains sigmoidal cross-bedded sandstone facies, sandstone-mudstone alternation facies, flaser-bedded sandstone facies, herringbone cross-bedded sandstone facies and tangential cross-bedded sandstone facies. This facies association possessing tidal bundles and herringbone cross-beds is developed on a tidal flat with strong tidal influence. Facies association-3 comprises pebbly sandstone facies, horizontally-bedded sandstone facies, and tangential cross-bedded sandstone facies exhibiting reactivation surfaces and tabular cross-bedded sandstone facies. This facies association represents sedimentation in a river-dominated estuary wherein presence of reactivation surfaces and herringbone cross-beds indicated tidal influence. The NW-SE directed bipolar paleocurrent pattern changes to WNW-directed unipolar up-section because of the change in the depositional currents from tidal to fluvial.

Compositionally, these sandstones reveal an abundance of sub-angular to sub-rounded monocrystalline non-undulatory quartz while polycrystalline quartz, feldspar and rock fragments occur as minor constituents. The rock fragments in these sandstones are dominated by mica-schist, slate, chert and limestones. Thus these sandstones are classified as quartzose arenite. Q-F-L and Qm-F-Lt diagrams suggest margin of the craton interior to transitional continental stable craton provenance for these sandstones. Furthermore, the dense mineral assemblages of these sandstones show sub-angular to rounded grains of magnetite, tourmaline, monazite, rutile, kyanite, staurolite and hematite where magnetite is the dominant component, and therefore suggest that the heavy minerals might have been supplied from a basic igneous source, low- to medium-grade metamorphic rocks and reworked sedimentary rocks. Thus it is envisaged that the Matanomadh sandstones were deposited during the transgressive phase where barrier ridge succession is succeeded by the tidal flat succession and the latter, in turn, is succeeded by the estuarine succession, and the basic igneous rocks of the Deccan Plateau, metamorphic rocks of the Aravalli basement and Mesozoic sedimentary rocks of the basin itself acted as provenance for these sandstones.

Distribution of Ostracoda and Foraminifera in the beach sands of La Paz, Baja California (south), Mexico

D. Sunitha[1]*, S.M. Hussain[1], M.P. Jonathan[2]
[1]Department of Geology, University of Madras, Guindy Campus, Chennai 600025
[2]CIIEMAD, IPN, MEXICO
Email: sunithasajitha@gmail.com

In order to study the distribution of foraminifera and ostracoda, the calcareous microfauna, occurring in La Paz beach samples, a total of 31 beach sediment samples were collected (Collection was made by M.P. Jonathan) from the La Paz beach, Baja California (South), Mexico. Distribution pattern of individual taxon was examined and their sediment relationship was determined for ecologic/environmental interpretation. Sand-silt-clay ratio estimation was carried out using the procedure of Krumbein and Pettijohn (1938). Organic matter was determined by titration method of Gaudette *et al*. (1974). Estimation of $CaCO_3$ was made by adopting the procedure proposed by Piper (1947). The widely utilized classification proposed by Loeblich and Tappan (1987) has been followed in the present study for foraminiferal identification and taxonomy. A total of 30 foraminiferal species belonging to 19 genera and 1 suborder have been illustrated. The species belonging to *Rotaliina* are dominant than *Miliolina*. In the present work, the classification proposed by Hartmann and Puri (1974) has been followed for the ostracod taxonomic studies through which 16 ostracod taxa belonging to 15 genera, 8 families, 3 superfamilies, and 2 suborders of the order Podocopida have been identified. Among these, 1 species belong to suborder Platycopa and the remaining to suborder Podocopa. For lucid illustrations, SEM photomicrographs of selected species depicting different views have been given. The species of foraminifera and ostracoda recorded are characteristic of shallow to inner shelf to beach environment and tropical in nature. Sedimentological parameters such as $CaCO_3$, organic matter and sand-silt-clay ratios were estimated and their distribution is discussed. An attempt has been made to evaluate the favourable substrate for the foraminifera and ostracod population abundance in the present area of study. The ratio between the carapaces and open valves has been taken into consideration for determining the rate of sedimentation in the study area. Based on the type of the sediment samples, it is inferred that the deposition of beach sands in the La Paz beach took place under medium to high energy conditions. It is also reflecting on the preservation as well as the

broken and much corrosive tests and carapaces of foraminifera and ostracoda. The colour of foraminiferal tests and ostracod carapace indicate that the sediments are deposited under normal oxygenated environmental conditions.

Benthic foraminiferal and geochemical studies in Palar estuarine core sediments, Tamil Nadu and its implication on environmental degradation

N. Suresh, M. Suresh Gandhi
Department of Geology, University of Madras, Guindy Campus, Chennai 600025
Email: Sureshgeo2@gmail.com

The response of foraminifers to the changed environmental conditions is reflected in the variation in abundance and morphology of tests. The tests of foraminifers have high preservation potential thus making these microorganisms one of the most useful proxies for the long as well as short-term term temporal variation in the amount and type of toxins in all kinds of marine environments. A two meter long sedimentary core was retrieved from 2.8 m water depth in the Palar estuary environment and sub-sampled at 5 cm interval for further studies. The surface substratum sediments are dominantly sandy clay, and fine sediments of silty sand and clay are moderate to negligible in distribution. However, at a sub-bottom depth interval of 5-55 cm the sandy silt is considerable. Otherwise, in general, the sediments are silty sand to silty clayey sand. A stratigraphic column was also constructed based on lithological differences in the core. The relationship between benthic foraminifera and ecological parameters of the Palar estuary have been carried out in this study.

In the present study, the total species are considered as the basic unit as the number of species in each genus is quite low. A total of 41 foraminifera taxa, belonging to 14 genera have been recognised. Six families, 5 superfamilies, and 3 suborders have been identified. The Foraminifera were present in all the sampling stations. Among the identified foraminifera *Ammoni beccarii and A. tepida* are abbundant. *Nonionoides elongatum, Trochammina inflata, Pararotalia nipponica are common in this area.* Numbers of individuals are very less in this area. In Palar the core sediments are moderately polluted by the concentration of Cr and Ni and unpolluted to moderately polluted by the elements Co and Cu. The trace element contamination partially or completely affects the species distribution of foraminifera. Less number of species is recorded in the Palar estuary and the size of the foraminifera is very minute. This is because of the impact of trace element concentration in the area. The area consists of very fine substrate which is rich in trace metal concentration due to their large surface area sediments act as a sink or source of heavy metals.

Identification of mineral and its assemblage on the basis of XRD analysis of beach sands of Shrivardhan, Harihareshwar and Dive Agar, district, Raigad, Maharashtra, India

Dnyaneshwar V. Wayal[1], Animesh Mishra[2]
[1]*Dept. of Geology, Govt. Institute of Science, Aurangabad*
[2]*Dept. of Geology, Deogiri College, Aurangabad*

To identify the source rock of unconsolidated sand, it is important to know its mineral constituents. Shrivardhan, Harihareshwar and Dive Agar beaches are associated with basaltic Deccan Traps of central eastern part of the peninsular India. The Harihareshwar beach is influenced by the sediments carried by Savitri River. The study area is facing the Arabian ocean and there is continuous erosion of cliffs of basaltic lithology by waves and tides.

XRD analysis of samples carried out to know the mineral assemblage of the formation shows an abundance of *Feldspars* and *Pyroxenes* which is the basic composition of Basalts. The XRD results interpreted on the basis of 2è values show that *Bytownite* and *Andesine* of feldspar group are aggregated in plenty. *Diopside* and *Augite* of pyroxene family are occurring in lesser amounts. The rare carbonate mineral *Sabinaite* is found in considerable amount in association with *Calcite* which is a common mineral in beach sands. *Hematite* is rarely found in the samples. On the basis of the XRD results it is infer red that the source rock of the unconsolidated sediment is Basalt.

Mid-late Holocene climate variability in the Indian monsoon: Evidence from continental shelf sediments adjacent to Rushikulya river, eastern India

Ankit Yadav [1], Praveen K Mishra[2], Prem Kumar[1]*, Anoop Ambili[1]
[1]*Indian Institute of Science Education and Research, Mohali, Manauli 140306, Punjab*
[2]*Wadia Institute of Himalayan Geology, Dehradun 248001*
**Email: premkumarakesh@gmail.com*

We present elemental and grain-size distributions obtained from the sediment core of the continental shelf adjacent to the Rushikulya river mouth, eastern India to quantify the paleoclimatic changes. The retrieved 1.60 m long well- dated core spans the past ca. 6800 cal BP. The modern spatial distribution of grain size and geochemistry of the inner-mid shelf sediments has been carried out to understand the seafloor morphology and sedimentary processes. Based on modern investigations, the proportion of particle size (clay vs sand) and variation in elemental values (TiO_2 vs Al_2O_3) has been used to interpret the changes in terrigenous supply. The grain-size and elemental distribution data from the core sediments indicates a period of enhanced surface water runoff from 6800 to 3100 cal BP followed by a drier condition (3100 cal BP to present) suggesting weakening of monsoon. The weakening of the monsoonal strength is coeval with other records from the Indian sub-continent and suggests response of Indian monsoon to changing solar insolation during the late Holocene.

Assessment of copper ore deposits of India

Masood Ahmed*, F.N. Siddiquie, Mohd Shaif, Juned Alam
Department of Geology, Aligarh Muslim University, Aligarh 202002
**Email: magrk90@gmail.com*

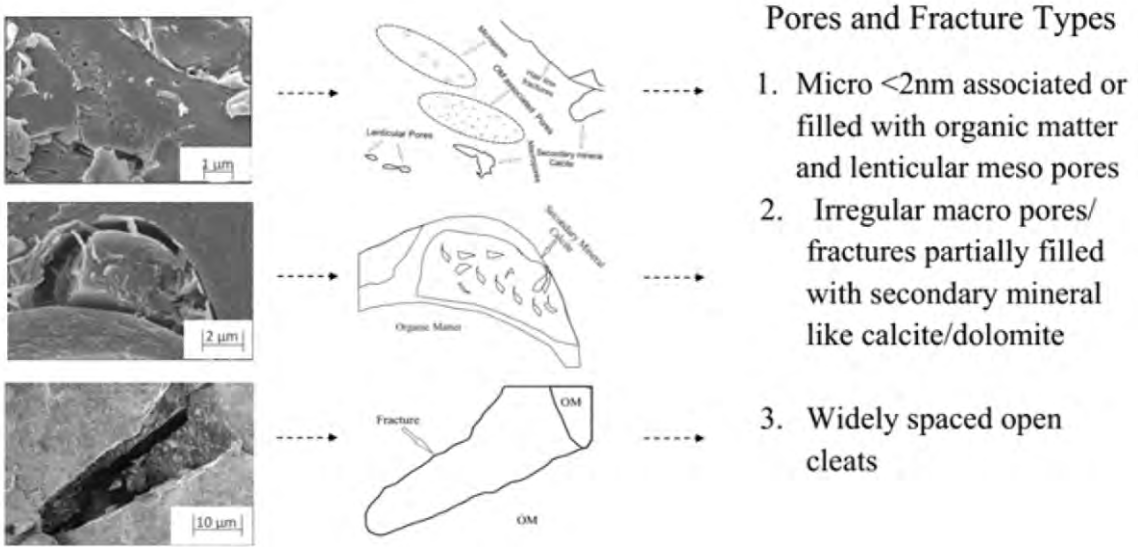
Copper is considered as the most important metal used in the country next to iron. In India, copper ore belts are found in several regions. Promising deposit of copper ore occurs in the Rajasthan state of India, where copper deposit is hosted in Proterozoic rock formations of Delhi Super Group popularly known as Khetri Copper B. It has the highest potential for copper ore in the country. Singhbhoom and Malanjkhand are the two other copper ore deposit hosting belts in India. Small scale copper ore deposits have been identified in varying structural and geological formations of different geological age in other states also. The total copper resources are estimated at 1.55 billion tonnes, reserves 720 million tonnes with total metal content 12 million tonnes. India has great opportunity to increase ore production through expansion and green field exploration. Copper metallogeney in India is attributed mainly to Precambrian. Major ore mineral, style of mineralization, host rock, genesis and type of deposits and various other characteristics of the copper ore deposits is reviewed. A comparative study has been made for major copper producing deposits. The supply position, resources, reserves and production in the country has been dealt with in detail. The scrap processing industry to augment the supply position for meeting both domestic demand and export market is also discussed. An attempt has been made to study the present and future availability of metal from primary as well as secondary sources and their demand in present and future based on the role in overall development of end-user industry. The domestic demand of copper and its alloys is met through domestic production, recycling of scrap and by imports. In the recent past, the country's status has changed from a net importer to a net exporter.

Gas genesis, accumulation and transport mechanism of coalbed methane reservoir of east Bokaro basin, Jharkhand

Mollika Bannerjee[1]*, Vinod Atmaram Mendhe[1], Atul Kumar Varma[2]
[1]CSIR - Central Institute of Mining and Fuel Research, Dhanbad 826015
[2]IIT (ISM) -Indian Institute of Technology (Indian School of Mines), Dhanbad 826004
**Email: mollikabanerjee.01@gmail.com*

The lower Gondwana coal seams of Permian age of East Bokaro basin have become one of the most promising coalbed methane, producing methane since 2010. However, no significant information is available on geological controls on genesis, storage and flow mechanism of CBM gas reservoir. In this study, detailed investigation on gas genesis, sorption capacities, pore structures, pore volume, pore size and permeability have been carried out using analytical methods such as desorption, stable isotope, high pressure and low pressure N_2 sorption, SEM-EDX and permeability measurements under reservoir simulated confining pressure. The pore distribution varies from 2.99 to 10.20 nm indicating abundance of meso pores (>2 nm). The high pressure sorption capacity (V_L) determined in the range of 14.8 to 24.6 m^3/t specifying significant gas storage potential of coal seams. The pore structures and pore volume indicate complex nature of pores, mostly blinded, combined bottle neck and relatively lower percentage of open slit pores these may influence the flow of gas in the reservoir while recovery. The in-situ gas content obtained by direct method varies in the range of 1.57 to 24.07 cc/g, indicating significantly saturated coal seams. However, the large amount of desorbed gas (0.5 to 14.50 cc/g) in the in-situ gas content, suggest control of overburden/hydrostatic pressure to retain gas in coal seams. The large quantity of methane concentration in total combustible

desorbed gases compared to C_2 and C_3 and ratio of $C_1/(C_2+C_3)$, designates thermogenic origin of gas generated during bituminisation and de-bituminisation stages. The enriched $ä^{13}C_1$ stable isotopic values also confirm thermal origin of desorbed gas. However presence of small amount of C_2 and higher hydrocarbons could be due to the mixing of methane generated at high temperatures with C_2+ hydrocarbons during transport and storage. The images of SEM-EDX show cleat, fractures and pores like i) micro <2nm associated or filled with organic matter and lenticular meso pores, ii) irregular macro pores/fractures partially filled with secondary mineral like calcite/dolomite, iii) widely spaced open cleats. The mesopores are suitable for gas adsorption while macropores support the flow of gas (>50 nm). It is concluded that the meso and macro pores filled with secondary mineral may influence the flow of transport of gas in the coal seam. However acidic treatment during hydrofac of the seams may resolve blocking effects of calcite/dolomite minerals in cleat/fractures and macro pores of the seams. The above statement can be explained by the figure shown below:



This study shall help to assess the influence of different parameters on diffusion, desorption, efficiency of Darcy flow and production potentiality of coal seams. Though, desorption and other properties of coal seams are highly encouraging for production and development of CBM reservoir in East Bokaro basin.

Genetic history of BIF and iron ores of the Badampahar greenstone belt, Iron ore group, east Indian shield

Rupam Ghosh
Department of Geological Sciences, Jadavpur University, Kolkata 700032
Email: rupamkumarsp@gmail.com

The Singhbhum granite-greenstone terrain contains three major Archean iron ore belts, viz., the Jamda-Koira belt in the west, the Gorumahisani-Badampahar belt in the east, and the Tomka-Daitari belt in the south. Badampahar greenstone belt (N22°04', E86°08') belongs to the Gorumahisani-Badampahar iron ore belt. Mesoarchean Badampahar greenstone belt (3.3-3.1 Ga) contains medium grade iron ores hosted by the banded iron formations (BIF). BIF occurs interlayered with metavolcanic rocks, quartzite, phyllite and chert forming typical greenstone sequence. Detailed

petrographic, mineralogical, oxygen isotopic and geochemical studies on the BIF and associated rocks reveal several facts regarding the BIF deposition in the Badampahar greenstone belt e.g. depositional setup, tectonic setting, environment, role of seawater and volcanogenic hydrothermal fluids etc. Geochemical and sedimentological evidences suggest the deposition of BIF below the wave base part of a back-arc like basin with insignificant detrital input. Interaction of seawater and volcanogenic high temperature hydrotherms, generated from spreading centre, supplied metals for the BIF deposition. Distinctly negative Ce anomalies in some lower BIF horizons indicate an oxygenated hydrosphere and Fe^{2+} oxidation by free oxygen derived from microbial photosynthesis. Subsequent stages of deformation, metamorphism, hydrothermal and supergene processes after deposition led to the formation of the present iron ore bodies.

Assessment of thermal maturity and hydrocarbon source rock potential of the Eocene lignite deposits of Nagaur, western Rajasthan, India

Alok Kumar[1], Alok K. Singh[2]*
Rajiv Gandhi Institute of Petroleum Technoloyg, Jais, Amethi 229304
Email: asingh@rgipt.ac.in

The present study is an attempt to evaluate the source rock characteristics and hydrocarbon generation potential of the lignites of Nagaur. During the investigation, the results from bulk and quantitative Rock-Eval (RE) pyrolysis coupled with detailed organic petrographic characteristics have been applied to get the information. Petrographic analysis indicates the dominance of huminite group of macerals with significant amount of liptinite group, while the concentration of inertinite group is small in comparison to other two groups. A significant amount of liptinite macerals indicate that the Nagaur lignites act as a source rock for hydrocarbon. Results from the RE pyrolysis reveals that lignites of Nagaur are characterized by relatively high hydrogen index (HI) values and moderate oxygen index (OI). These results suggest that the Nagaur lignites contain Type III to mixed Type II-III kerogens. Therefore, it is considered that it can generate gaseous hydrocarbon. The values of reflectance (Ro mean) and T_{max}, of the analyzed samples entails that these lignites contain thermally immature organic matter. The overall studied samples reveal that Nagaur lignites have good hydrocarbon potential, dominated by Type III to mixed Type III-II kerogens. In addition, the high conversion factor (93-95%) and high oil yield (63-65%) make them industrially important, considering the huge lignite resource of the region.

Desulphurization of selective lignite coal sample of India with the help of *Ralstonia* and *Pseudoxanthomonas* bacterial strain

Aniruddha Kumar, Alok K. Singh*
Petroleum Engineering and Geological Sciences Division,
Rajiv Gandhi Institute of Petroleum Technology, Jais 229304, Amethi U.P.

All fossil fuels contain some amount of sulphur. However, major sulphur content in coal occurs in inorganic form which includes pyritic sulphur and sulphatic sulphur, and minute amount of elemental sulphur, In some coals a considerable amount of organic sulphur occurs in organic structures of coal. During combustion, the sulphur is emitted as SO_x and is responsible for air pollution. The most of the applied technologies of coal utilization are focused on sulphur removal before, during or after the combustion processes. It is believed that the best methods to limit the amount of sulphur oxide emissions are based on preliminary sulphur decrease. The removal of total sulphur (S_t) from different

lignite fields coal sample of India by *Ralstonia* sp. and *Pseudoxanthomonas* sp. Minimum desulphurization (in relative %) was observed in Nagaland coals which contain maximum quantity of S_t (6.86%). Among the samples of the study area higher removal (on relative %) was observed in coals containing relatively low quantity of S_t. However, a positive correlation observed between S_t and removal percentage in samples of all coal fields with increase in the removal % with increase in the concentration of S_t. The removal percentage (with respect to its initial S_t) *by Pseudoxanthomonas sp.* in the investigated area is in order of: Vastan (mean 41.84%) > Nagaland (mean 18.26) coals. In case of removal by *Ralstonia* sp. the order of removal % can be put as: Vastan (mean45.50%) >Rajpardi (mean 42.93%) > Nagaland (mean 11.83%) coals.

Impacts on ecology and environment in extraction of non-renewable energy resources

Gangadhara Rao Kunja
Department of Geology, Andhra University, Visahapatnam 530003
gangageology@gmail.com

Nonrenewable resource mining is essentially a destructive development activity where ecology suffers at the altar of economy. Unfortunately in most regions of earth, the underground geological resources (minerals) are superimposed by above ground biological resources (forests). This is particularly more prominent in India. Hence mining operations necessarily involves deforestation, habitat destruction and biodiversity erosion. The extraction and processing of ores and minerals also lead to widespread environmental pollution. However, mankind also cannot afford to give up the underground geological resources which are basic raw materials for development. An unspoiled nature can provide ecological security to people but cannot bring economic prosperity. Scientific mining operations accompanied by ecological restoration and regeneration of mined wastelands and judicious use of geological resources, with search for eco-friendly substitutes and alternatives must provide the answer.

The ecological impact of mining can be summarized as follows: Saltiness, aridity and scarcity of water caused by the waste of enormous amounts of fresh water during the extraction process. Heavy metals which are liberated and migrate into the ecosystem. The dislocation of thousands of tons of minerals causes sedimentation in rivers and susceptibility to both erotic and water erosion. Ecological passive after exploitation and the complete destruction of the original local ecosystem. Migration of highly toxic cyanide into the subsoil and surface waters as well as the whole ecosystem. Acid drainage, which especially in the case of sulphite winning is a major risk. Acid drainage is a serious problem in many metal mines, because metals like gold, copper, silver and molybdenum often appear together with sulphites. When acid drainage happens uncontrolled, the drainage water oozes through to streams, rivers and subsoil water. The acid water and the heavy metals are lethal to fish, other animals and plants and can be harmful to the environment for indefinite time after the closing of the mine.

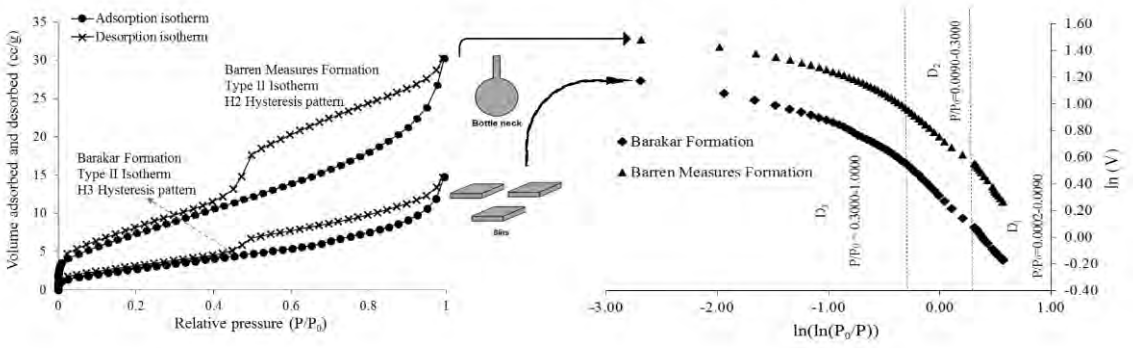
The traditional image of mining, which consists of the deep subterranean exploitation of ores, no longer corresponds to present-day reality. Modern-day mining happens by means of bulldozers, which excavate rocks in an enormous open pit. During the digging of ores, a material is liberated which contains heavy metals and is easily picked up by the wind. In this way, the establishment of a mine can destroy the existing ecosystems. The consequences of mining for the environment are not only problematic from an ecological point of view, polluted soils and shortage of pure water make agriculture impossible. People who suffer health problems cannot work as long and as hard as they used to, which leads to the loss of income. Instead of fighting against poverty, then, mining makes poverty increase.

Significance of fractal dimensions in gas storage and flow mechanism of shale reservoirs of Raniganj basin, West Bengal

Subhashree Mishra[1]*, Vinod Atmaram Mendhe[1], Atul Kumar Varma[2]
[1]CSIR-Central Institute of Mining and Fuel Research, Dhanbad, 826015, Jharkahnad
[2]Indian Institute of Technology (ISM), Dhanbad, 826004, Jharkhand
**Email: Subhashree.geology@gmail.com*

In India, shale gas exploration is gaining importance inspired from USA's multi-fold production in the past decade. There are a large number of sedimentary basins containing thick shale horizons of Gondwana and Tertiary age. The shale is an intrinsically impermeable and low porosity rock. The recovery of gas from shale beds needs understanding of storage, diffusion, desorption and flow mechanism. In addition, the information of requisite controlling parameters like pore distribution, throat structure, mineral assemblage and inter-connectivity fracture network are equally imperative. In this study, the low pressure N_2 sorption experiments were performed on the shale core samples of Raniganj Basin to determine surface area, pore size, pore volume and fractal dimensions following multipoint BET, BJH and FHH methods. The pore throat structure, pore space topology and surface roughness have been evaluated to understand the storage and transport phenomenon.

The multipoint BET surface area, total pore volume and pore size for Barren Measures vary from 5.34-31.27 m^2/g, 0.01-0.05 cc/g and average pore size ranges from 4.14-9.21 nm, whereas for Barakar Formation shales vary from 5.46-17.31 m^2/g, 0.01-0.03 cc/g and 5.76-8.95 nm respectively. The low-pressure N_2 adsorption and desorption isotherm of Barakar and Barren Measures shales suggest Type II curves indicating meso to macro-porous nature with both monolayer and multilayer adsorptions. The identified H2 hysteresis loop for Barren Measures shale is attributed to bottle neck to slit pores, while Barakar shale shows H3 pattern indicating presence of non-rigid aggregates of plate like openings giving rise to narrow slit-shaped pores. It is observed that the pore structure and throat/openings of Barren Measures as well as Barakar Formation are complex and have a strong heterogeneity, controlled by organic and inorganic content. The plot of relative pressure and volume adsorbed illustrated division of curve in three different sections pointing towards fractal nature of pores. In this study, fractal dimensions are classified as D_1 - micropores associated, D_2 - transitional and D_3 - mesoporous. It is found that both the Barren Measures and Barakar shales have tri-modal fractal characteristics. The D_1, D_2 and D_3 values of Barren Measures ranges from 0.978-2.012, 1.827-2.461 and 2.690-2.865, whereas for Barakar Formation ranges from 1.654-2.104, 2.118-2.606 and 2.687-2.799, respectively. The mean value of $D_1<D_2<D_3$, signifying the complexity of pore structure of larger pores (meso) is more than that of small pores (micro). The schematic illustration of pore structures and associated fractal dimensions is given in the given figure.



Fractal dimensions shows positive correlation with clay content whereas negative correlation with total organic content indicates that inorganic content plays vital role in gas storage and release. It is concluded that larger value of D_1 specifying rougher pore surface, provide supplementary sites for gas adsorption, while the larger value of D_3 points towards complicated nature of pore structure and clogged interconnectivity may strongly influence the gas transport or flow capacity of shale gas reservoir of Raniganj Basin.

Potential utilization of Kasnau-Matasukh lignite, Nagaur basin, Rajasthan, western India

Pramod Kr. Rajak*, Prakash K Singh, Vijay Kr. Singh, M.P. Singh, Deepak Kumar, Atif Faheem

Department of Geology, Institute of Science, Banaras Hindu University, Varanasi 221005
**Email: bhupramodgeo@gmail.com*

The sedimentary tract of Rajasthan is spread over a large area of 120000 km^2 and forms the eastern flank of the Indus shelf. Nagaur basin is isolated in nature and Kasnau-Matasukh block is located in Jayal Tehsil of Nagaur district. The lignite bearing Lower Tertiary sediments of the Palana Formation are deposited unconformably over the Nagaur Formation. The lignite seam of Kasnau-Matasukh mine is seen to be intersected by a number of dirt bands. These lignites have a vitrinite reflectance (VRo mean) of 0.23 to 0.30% (av. 0.26%). The volatile matter varies from 52.6% to 67.0%, av. 58.3% (daf). The ultimate analysis data reveals that the carbon content ranges from 52.6% to 55.7%, mean 54.0% (daf), hydrogen content varies from 5.1% to 5.6%, mean 5.4% (daf), nitrogen content ranges from 0.8% to 0.9%, mean 0.8% (daf) and oxygen content varies from 34.6% to 36.5%, mean 35.9% (daf). The sulfur content of this seam is relatively high and ranges from 3.0% to 3.9%, mean 3.5% (daf). Rock-Eval Pyrolysis data provides the crucial information about the degree of thermal maturity of organic matter and its hydrocarbon content which are vital for the characterization of source rock. The total organic carbon (TOC), in Kasnau-Matasukh lignites (av value) is 31.1%, while T_{max} is 420.5°C (av value). Similarly, the average value of S_1 is 2.3 mg HC/g, S_2 is 52.7 mg HC/g, and S_3 is 27.2 mg CO_2/g. The average Hydrogen Index (HI) is 204.0, while the Oxygen Index (OI) is 71.6. The petrographic analysis of Kasnau-Matasukh lignite shows that there is dominance of huminite which ranges from 83.9 - 92.5 %, (av 87.3 % on mmf basis) while liptinite ranges from 5.7 - 13.2 %, (av 10.9 % on mmf basis), and inertinite ranges from 0.2 - 4.0 %, (av 1.9 % on mmf basis). Mineral matter varies from 3.5 - 12.0 %, (av 7.7 %). The study indicates that the lignites of Kasnau-Matasukh mine have dominance of reactive macerals and contain substantial quantity of hydrocarbon which is likely to be obtained through thermal cracking. These lignites are thus oil-prone and could be used as a source for hydrocarbon through liquefaction.

Mineralogical characteristics and geochemistry of Banded Iron Formation to blue dust, from Precambrian Jamda- Koira deposits eastern Indian craton

Vadde Ramesh

Department of Geology, Andhra University, Visakhapatnam 530003
Email: vadde.ramesh@gmail.com

Numerous economic deposits of high grade iron ores occur in the Singhbhum-Odisha craton. Most of the Indian iron ores are of hematitic variety and 60% of Indian hematite ore deposits are found in the state of Odisha (33%) and Jharkhand (27%) and also the Jamda-Koira valley, contained within

eastern Indian Singhbhum-Odisha craton. Constraints in assessing models for iron ore genesis are the paucity of basic information concerning the transformation of Banded Iron Formation (BIF) to blue dust/hard massive iron ore. The colour, composition and structure of the BIF and shale horizons do not vary dramatically between the western limb areas and the eastern limb despite the fact that the blue dust deposits are characteristically concentrated abundantly in the eastern flank ores of the synclinorium. Blue dust is generally in the form of steel blue colored, fine to very fine grained, powdery hematite with metallic luster and occurs in small exposure, in association with Banded Hematite Jasper (BHJ) and iron ores. The prinicipal iron ore bearing mineral of blue dust are oxides (hematite and martite) and hydroxide (goethite). The BHJ that occurs with blue dust are characteristically laminated, altered, and deformed and extensive leaching of thin silica occurred along the planar directions. Geochemical interpretation of samples clearly corroborates the silica leaching process. Core drilling data as well as analysis of samples show the decreasing order of SiO_2 content from BHJ to blue dust. Leaching out of silica from pre-existing BHJ has blue dust. The alkali metals are highly depleted in blue dust compared to BHJ. Hypogene fluids affect primary unaltered BIF by simultaneously oxidizing magnetite to martite and replacing quartz with hydrous iron oxides. The supergene processes upgrade the hydrous iron oxides to micro platy hematitie and causes the leaching of remant silica from hydrothermally upgraded iron ore under suitable Eh and p^H conditions leading to the formation of blue dust.

Rock eval data analysis of Kopili shales from the Litang valley, Meghalaya

N. Reshma Devi, Y. Raghumani Singh
Department of Earth Sciences, Manipur University, Impal 795003
Email: yengmani@gmail.com or reshdev747@gmail.com

The hydrocarbon potential of samples of the lower Kopili Formation from three borehole sections (Shyrwang Village; Borehole no. JS-06, JS-07 and JS-11) in the Litang Valley, Meghalaya was assessed by Rock-Eval pyrolysis. The analysis of these samples was carried out to define quantity, type and thermal maturity of the associated organic matter. The total organic carbon (TOC) values range from 0.2 to 1.54 wt. % (averaging 0.38 wt. %). The genetic potential (GP) and hydrogen index (HI) values range from 0.05 to 0.89 mg HC/g rock and 9 to 61 mg HC/g TOC, respectively. These values of the studied samples suggest that all the shale samples have very low total organic carbon (TOC<0.5%), S1, S2 and hydrogen index (HI) values. However, T_{max} value (average 447.77^0C) and production index (average 0.24) indicate their potentiality towards oil generation, but low genetic potential (S1+S2) and TOC do not support this. Most of the samples are in mature stage. A few of them are immature and post mature. The organic matter is predominantly gas prone rather than oil (mostly type III and type IV). Thus, the source rock potential for the Kopili Shale of this valley appears to be poor potential for hydrocarbon.

Geochemistry of ultramafic rocks of Torappadi layered complex, Thiruvannamalai district, Tamil Nadu

K. Saranya[1]*, M. Lingadevaru[2], M. Sundararajan[3], P. Nandini[4]
[1]Dept. of Geology, Central University of Karnataka, Kalaburagi 585367
[2]National Institute for Interdisciplinary Science & Technology (NIIST), Thiruvananthapuram 695019
[3]Council of Scientific & Industrial Research (CSIR), Thiruvananthapuram 695019
**Email: saranyajanani90@gmail.com*

The Torappadi ultramafic complex is located at about a km to the east Torappadi village. Torappadi ultramafic complex occurs within the migmatised charnockite and pink gneissic granite

interbanded with pyroxene granulites (enclaves). The ultramafic rocks are represented by Pyroxenite, Gabbro, Gabbro-norite and Gabbroic anorthosite. Field observations indicate that the rocks from Torappadi ultramafic complex show wreathing with the development of magnesite veins. Two types of Pyroxenite are noticed in the area: medium grained bottle green coloured pyroxenite (diopsidite) and coarse to very coarse grained bronzitite. Primary igneous structures such as rhythmic layering and cumulus layers are noticed within Pyroxenite, gabbro, gabbro-norite and gabbroic anorthosite. The ultramafic rocks are analysed for major oxides by XRF method, such as SiO_2 MgO, Al_2O_3, CaO, Fe_2O_3, TiO_2, Na_2O and data is plotted in various discriminate diagrams in order to know their petrogenetic histories and same is discussed in this paper.

Radioactive element distribution and rare-metal mineralization in A-type granites of Khanak and Devsar area, Bhiwani, southwestern Haryana, India

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

The present study discusses about the radioactive element distribution and Rare-metal mineralization potential in granitic rocks of Khanak and Devsar areas. Based on detailed field and petrographical observations, 28 samples were selected for geochemical analysis (major, trace and rare earth elements) and analyzed in the Wadia Institute of Himalayan geology, Dehradun by X-Ray Fluorescence Spectrometer (XRF) and ICP-MS (Inductively Coupled Plasma- Mass Spectrometry). Khanak and Devsar areas in southwestern Haryana having granitic rocks are a part of Neoproterozoic Malani Igneous Suite (MIS) (55000 sq. km area) in Northwestern Indian Shield. Granites from the studied area are categorized as grey, green and pink. Khanak granites consist of quartz, k-feldspar, plagioclase and biotite as essential minerals and hematite, zircon, annite, monazite and rutile as accessory minerals. In Devsar granites, plagioclase is replaced by perthite and occurs as dominantly. Geochemically, major oxide elements and trace elements (Ba, Sr, Cr, Ni, V, Cu, Zn, Ga, Pb, Th and Zr) are more in green and grey granites of Khanak and Devsar areas than pink granites. Generally, they show enrichments in SiO_2, Na_2O+K_2O, Fe/Mg, Rb, Zr, Y and and AI (Agpaitic Index ranges from 0.10 to 1.18) and depletion in MgO, CaO, P, Ti, Ni, Cr and V indicate their A-type affinity which is very similar to the A-type granites of MIS (Malani Igneous Suite) in the Northwestern Peninsular India. Green and grey granites of Devsar area show high concentrations of heat production (HP) 9.68 and 11.70 ì Wm^{-3} and total Heat Generation Unit (HGU), i.e, 23.04 and 27.86 respectively. On the other hand, pink granites of Khanak area display a higher enrichment of HP (16.53 ì Wm^{-3}) and HGU (39.37) than the granites of Devsar area. Overall, they have much a 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 the MIS. The enrichment of Zr, Nb and high Zr/Rb ratio in the rocks indicate Nb-Sn-W mineralization. The progressive differentiation of magma supported by negative correlation of Rb against Sr indicates the mineralization of the granite. Chondrite-normalized REE patterns show enriched LREE, moderate to strong negative Eu anomalies and more or less flat heavy REE. In primitive mantle-normalized multi-element variation diagrams, the granites show pronounced depletion in the high-field-strength elements (HFSE) Nb, Zr, Sr, P, and Ti. Their trace and REE characteristics along with the use of various discrimination schemes revealed their correspondence to magma derived from crustal origin. Based on petrography as well as the chemistry of Khanak and Devsar granites, it is suggested that they might have derived from a different degree of partial melting from the similar source of magma. Field, petrography and whole rock geochemisty suggest potentiality for rare metals and rare earth elements mineralization in the study areas of the MIS.

Coal petrography a tool to determine the paleo-mires: a case study from Barka sayal area, south Karanpura coalfield, Jharkhand

Alok K. Singh*, Mrityunjay K. Jha
Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi, Uttar Pradesh 229304
**Email: asingh@rgipt.ac.in*

The present study explores the detailed petro-chemical variation, rank and depositional environment of the Barka Sayal (Sayal, Bansgarha, and Hathidari coal seams) of South Karanpura Coalfield. The south Karanpura coalfield is a part of the Gondwana basin of India and is located in the western part of the Damodar Valley in Ramgarh district of Jharkhand. Pillar coal samples were collected from the working faces of all of the above mentioned three coal seams. Coal samples having similar megascopic properties were clubbed together to form a single composite band. The microscopic petrographic analysis reveals the dominance of vitrinite followed by liptinite and inertinite in these coals. Mineral matter is represented by argillaceous minerals, followed by carbonates and pyrite. At microlitho type level, the coals of Sayal and Hathidari seams are vitrite rich followed by inertite and clarite, while coals of Bansgarha seam are enriched with vitrite followed by clarite and inertite. Carbominerites are represented mainly by carbargillite, while the concentrations of carbankerite, carbopolyminerite and carbopyrite are insignificant. The vitrinite reflectance characterizes these coals as sub-bituminous 'A' to high volatile 'C' bituminous in rank. The coal petrography based depositional model suggests that the coals of Barka Sayal area have originated in a forest swamp with high tree density and sufficient water level in ombrotrophic to the rheotrophic conditions. It is also stated that the peat accumulation got influenced by moderate flooding spells with increasing bacterial activity.

The hydrocarbon potential of Vastan lignite, Cambay basin, Gujarat

Vijay K. Singh*, P. K. Rajak
Department of Geology, Centre of Advanced study,Banaras Hindu University, Varanasi 221005
**Email: vijaygeologybhu@gmail.com*

The purpose of this study is to characterize the relationship between organic material and thermal maturity during the process of evaluation of hydrocarbon potential. The samples were collected from the Vastan lignite mine. The study has been carried out on the basis of petrological, geochemical and rock-eval analysis. The study shows that these lignites are 'low rank C' and exceedingly rich in reactive macerals (huminite + liptinite) while inertinite occurs in low concentration. The rock-eval data indicates the dominance of kerogen type-III with a little bit of type-II. The study also shows that the lignites of Vastan upper seam are more gas-prone while the Vastan lower seam are oil-prone and the Vastan lignites are dominantly composed of huminite (63.6-89.1%) with small concentrations of liptinite (7.8-17.5%) and inertinite (1.1-19.2%. Further, the ? xed hydrocarbons are several times higher than the free hydrocarbons. The relation between TOC and ? xed hydrocarbon indicates that these lignites are excellent source rock for hydrocarbon which could be obtained mainly through thermal cracking. The empirically derived values reveal a high conversion (94-96%) and high oil yield (62-66%) making them industrially significant.

Geo-electromagnetic induction vectors in northern Indian Ocean

Anusha Edara*, Kusumita Arora
Magnetic Observatory, CSIR-National Geophysical Research Institute, Hyderabad 500007
Email: anushaedara.geotech@gmail.com

Significant results of induction arrows from magnetometers deployed along the northern Indian Ocean are analysed for evidence of electrical conductivity structures in the Andaman Nicobar Subduction zone and Chagos Laccadive ridge. Here we are using short period geomagnetic variations (minute mean data) containing information about the crust and upper mantle depth.

The Andaman-Nicobar subduction zone is the one of the most seismically active regions of the world, which is also characterised by several factors like oblique subduction, arc volcanism, and Andaman spreading ridge in the Andaman Sea. Electromagnetic studies are used to derive lithosphere conductivity structure, which provides constraints on the dynamics of the Andaman-Nicobar subduction zone. To investigate the conductivity structure of the crust and upper mantle, electromagnetic variation data over a period of two years was acquired at six sites along the northern Indian Ocean. Induction vectors were estimated at six sites: NBG (Nabagram) and PBR (Portblair) in Andaman, KTC (Katchal) and CBY (Campbell Bay) in Nicobar, VEN (Vencode) in Kanyakumari and MNC (Minicoy) in Lakshadweep using one minute magnetic variation data over the periods 4-140 minutes. On the whole the amplitudes of the real and imaginary components approximately vary between -0.5 to 1 and -0.5 to 0.5, respectively. The directions of the real vectors are mostly eastward, however, there is a significant variation at the sites from north to south and also in different seasons at Andaman-Nicobar Islands. Impedance tensors calculated at each site are used to generate 1D conductivity models of the subsurface. It is possible to infer that the conductivity structure differs significantly over the 800 km length of Andaman-Nicobar subduction zone and along northern Indian Ocean, which is being further investigated by construction of 3D model.

Soil index property of a sinking zone at Marem area along NH-150

H. Bidyashwari[1]*, R.A.S. Kushwaha[1], M. Chandra Singh[2], M. Okendro[2]
[1]Department of Earth Sciences, Manipur University, Manipur 795003
[2]Department of Geology, Imphal College, Manipur
**Email: bidyashwariheisnam@gmail.com*

Water plays an important role in determining the behaviour of soil. Increase of water content reduces the stability of slope and when the moisture content exceeds plastic limits, the soil slope begins to deform. Bulk density, moisture content and specific gravity of the study area are 2.09, 17.19 and 2.43, respectively. Consistency limit is the most distinctive property of fine grained sediments and may be used to distinguish silts from clays. Soil samples collected from the Marem area are used for the determination of the soil property. Liquid limits and plastic limits are determined by using static cone penetration and thread rolling method. Plastic limit (W_P), liquid limit (W_L), and shrinkage limit (w_S) values of Marem area are 22.18%, 45% and 21.23%, respectively. Plasticity index (I_P), consistency index (I_C) and liquidity index (I_L) values are 22.82, 1.219, and 21.87, respectively. From these index properties the soil sample collected from Marem area are found to be highly plastic, stiff and semi solid. In the plasticity chart the soil sample falls under the CI group which indicate organic silt and clay soil with medium compressibility and plasticity. Higher plasticity index in the study area may result in sudden and unpredictable failure due to volumetric changes in soil.

Lithospheric structure in NW Himalaya, India: Seismotectonic implications

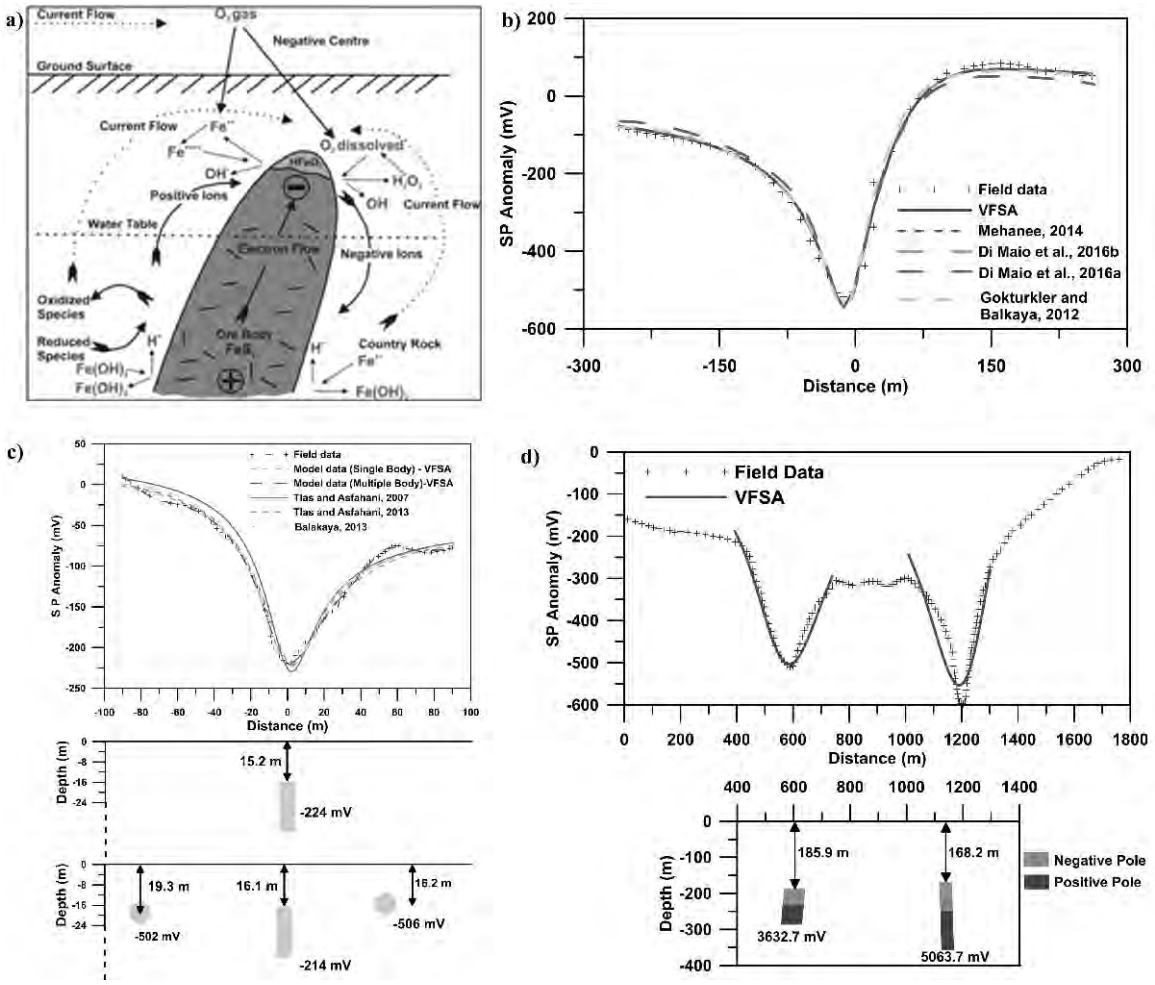
Shubhasmita Biswal[1]*, Sushil Kumar[2], William Kumar Mohanty[1], Mahesh P Parija[2]
[1]Indian Institute of Technology-Kharagpur, Kharagpur
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: susmitabiswal123@gmail.com*

An integrated approach using major seismological tools was undertaken to understand the nature and behaviour of the Indian lithosphere in the NW Himalaya. The study includes the determination of the optimal 1 D crustal velocity model for the upper crust, quantification of the characteristic behaviour of the Indian lithosphere as evidenced from Shear wave splitting phenomenon, the estimation of the frequency dependent attenuation characteristics, and the extent of the Indian Moho under the NW Himalaya. The derived minimal 1 D crustal velocity model is a seven layer velocity model showing a sharp velocity increase at about 18 km depth. This compensates for the thicker crust in the area. Shear wave splitting indicates a significant anisotropy in the region along the NW–SE direction due to the Indian plate motion with the source lying in the upper mantle. The frequency dependent indicate observed from coda wave analysis conclude for the heterogeneous and sheared crust due to ongoing India-Eurasia convergence. The Receiver functions computed in the area characterise that the Moho gradually thickens as it moves from south to northwards from a depth ranging from 40 km in the Indo-Gangetic plain to 60 km in the Tethys Himalaya and it extends upto the Trans Himalaya.

Self-Potential method in mineral exploration: A review on modeling and inversion methods

Arkoprovo Biswas
Wadia Institute of Himalayan Geology, Dehradun-248001
Email: arkoprovo@gmail.com

Self-Potential (SP) method has been widely used in many exploration purposes. SP is a passive method which employs the measurements of naturally occurring potential differences due to electro-chemical, electro-kinetic and thermoelectric fields in the earth's subsurface. The present study focuses on the fundamental concept, dynamic alterations and improvements of different modeling, inversion and elucidation approaches to SP anomaly associated with close surface to shallow subsurface and deep-rooted mineralized bodies. Forward modeling of different subsurface geo-bodies is studied with various inversion and interpretation approaches developed over time. A comparison of different linear, non-linear and global optimization inversion techniques are presented in this study. The uncertainty associated with the understanding of SP interpretation is also examined. Field illustrations are examined and a similar investigation is conducted for different interpretation strategies. The noteworthiness of this kind of study is its multi-use application in researching different subsurface structures associated with mineral exploration. These types of studies will likewise help experts who are intrigued to work in presenting the advantages and inversion of SP data for various investigation purposes.



(a) Self-Potential mechanism; (b) Field example from Bavarian Woods anomaly, Germany; (c) Field example from Malachite mine, Jefferson County, Colorado, USA; and (d) Field example from KTB anomaly, Bavaria, Germany.

Reverse time migration using wave propagation direction

A. Chuchra[1]*, Kamal[2]

[1]Department of Earth Sciences, Indian Institute of Technology, Roorkee
[2]Department of Geophysics, Kurukshetra University Kurukshetra
**Email: nanniues@iitr.ac.in, aakash.chuchra001@gmail.com*

Reverse Time Migration (RTM) can be carried out by forward-extrapolating the source wavefield and backward-extrapolating the receiver wavefield, both explicitly in time and applying an imaging condition. The migrated section consists of primary reflections accompanied by certain artifacts. Our primary objective is to retain the primaries and remove the artifacts. This can be accomplished by constraining the direction of wavefield, while applying the imaging condition. Determining the propagation direction of waves in a wavefield can be achieved using the Poynting vector method, however it performs ineffectively when waves overlap, returning false wave amplitude and direction. An alternative, the local slowness method, is capable of separating

overlapping waves, but suffers from low angular resolution. We analyse these techniques and propose certain modifications to these two approaches that enhance the ability to extract the wave amplitude propagating in different directions, hence removing the artifacts from the migrated section.

The forward modelling is achieved by numerically solving the acoustic wave equation using centered finite differences in space and time. The minimum phase Ricker wavelet is chosen as source because it is simple to understand and often seems to represent a typical earth response. The absorbing boundary conditions are applied by attenuating the reflections exponentially in the extended artificial boundary area by multiplying with a factor less than one. A displacement wavefield, or source wavefield, is thus obtained as a function of t, x and z.

A synthetic seismogram is generated from the source wavefield which is henceforth input as source to generate the receiver wavefield. The two wavefields are then correlated to collapse the time axis giving the migrated section. In this study, we have generated the migrated section and observed that absorbing boundary conditions have annihilated some of the artificial reflections. Limiting the wavefield direction will further eliminate the artifacts significantly.

There are three primary steps in processing seismic data- Deconvolution (Time-axis), Stacking (Offset-axis) and Migration (Midpoint-axis), in their usual order of application. Our study will assist the data processing sequence to reach its goal of enhancing signal to noise ratio and present the data in interpretable format with minimal artifacts.

Geodynamics of Indian plate using GNSS and sensitivity of plate velocity with reference frames

Sravanthi Gunti[1]*, J. Narendran[1], S. Muralikrishnan[1], K. Vinod Kumar[1], M. Subrahmanyam[2]

[1]National Remote Sensing Centre, Indian Space Research Organization, Balanagar, Hyderabad 500037

[2]Department of Geophysics, Andhra University, Visakhapatnam 530017

**Email: sravsgeophysics@gmail.com*

This research work has been taken up to compute the Indian plate velocity in the light of various earthquakes with different magnitudes and intensities that have occurred in the Indian sub-continent in the last two decades. In this study, the Indian plate velocity for six Indian IGS stations are re-estimated by processing the GNSS datasets for the period from August, 2014 to 2016 in International Terrestrial Reference Frame 2008 using Long baseline GNSS scientific software Bernese 5.2. Out of the six IGS stations, two stations, namely IISC in Bengaluru and HYDE in Hyderabad are located on the Deccan plateau, two stations LCK3 and LCK4 in Lucknow are located in the Indo-Gangetic plain area, and the remaining two stations, namely PBRI and PBR2 are located in Port Blair area of Andaman and Nicobar Islands. A total of 13 IGS sites data have been used, of which 06 sites on Indian plate and the remaining 07 sites on the adjacent plates (Eurasian plate, Arabian plate, and Australian plate) have been used as reference stations. The result indicates that the Indian plate is moving with a velocity of 52 to 60 mm/year at Hyderabad, 54 to 55 mm/year at Bengaluru, 48 to 52 mm/year at Lucknow and 20 to 22 mm/year at Port Blair. The results confirm that the Southern part of India is moving as a rigid plate at velocity of 50 - 60 mm/year and the Andaman and Nicobar area at a velocity of 20 mm/year in the north east direction. The estimated velocities have been compared with different global plate models and the sensitivity of the velocity estimates with reference to the different Terrestrial Reference Frames namely ITRF2005, ITRF2014 has been analysed.

Modelling of SMGAs of the 2005 Kyushu earthquake, Japan using modified semi empirical technique

Sandeep[1], A. Joshi[2], S.K. Sah[1]*, Parveen Kumar[3], Sohan Lal[2], R.S. Singh[1]
[1]Department of Geophysics, Banaras Hindu University, Varanasi
[2]Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee
[3]Wadia Institute of Himalayan Geology, Dehradun
**Email: sksahbhu@gmail.com*

An earthquake of magnitude M_w 6.6, M_{JMA} 7.0 occurred in the northwest part of Fukuoka City, Japan on 20th March 2005. Data recorded from field stations has been used for the source model estimation of this earthquake. Two isolated envelopes were identified in the recorded data. Each envelope in the observed record represents an isolated source and termed as strong motion generation area (SMGA) in the rupture plane. Using source displacement spectra parameters of each SMGA has been estimated. Possible location of SMGAs over the rupture plane was identified using spatio-temporal distribution of aftershock events. Records have been simulated with this estimated rupture model using modified semi-empirical technique (MSET). Observed and simulated acceleration records have been compared at different stations. Comparable match between these two approves the fitness of estimated rupture model with two SMGAs and ability of the MSET to simulate strong ground motion.

Signatures of geomagnetic storms in H-Component and total magnetic field during solar cycle 24 at low latitudes and its association with solar wind and IMF parameters

Shivam Joshi[1]*, M.S.B.S. Prasad[2], C.P. Simha[3], K.M. Rao[4]
Institute of Seismological Research, Department of Science & Technology, Gandhinagar
**Email: iamshivamjoshi@gmail.com*

A dynamic phenomena on the sun known as coronal mass ejection (CME) is the main causative factor for the change in inter planetary magnetic field (IMF) and large geomagnetic storms. Interplanetary plasma emission produces global disturbances in the Earth's Magnetic field which are called Geomagnetic Storms and are well observed in ground-based magnetometers. We studied the effect on magnetic field component (H) and total magnetic field of three severe magnetic storms which are observed during the maximum of solar cycle 24. We used the data of one digital fluxgate magnetometer and one overhauser magnetometer installed at Desalpar and Badargadh MPGO observatories, in Kachchh region. The data are collected at one sample per second. In geomagnetic storms three phases are mainly observed particularly in the H component. First one is the initial phase in which the geomagnetic field is compressed and hence increase in the H component can be seen; later comes the second phase in which the H component gradually falls due to ring currents and then third phase comes in which the H component gradually reaches to the normal value which takes about 2 to 3 days. The Global Dst average values are also plotted in the corresponding period and are showing similar pattern during the magnetic storm. Similarly, we also studied variations in the solar wind parameters such as plasma density, velocity, etc. and its influence on ground magnetic field variations. The present study aims to understand the relationship between solar wind and IMF parameters with ground magnetic field. Cross correlation analysis has been applied between the solar wind dynamic pressure and surface magnetic field observations. This correlation is found to be significant, which infer that there is direct impact of solar wind on magnetic field variations at low latitude.

Effects of basin shape, shape-ratio and angle of incidence of Body waves on ground motion characteristics

Kamal[1]*, Dinesh Kumar[1], J.P. Narayan[2], Komal Rani[3]
[1]Department of Geophysics, Kurukshetra University, Kurukshetra
[2]Department of Earthquake Engineering, Indian Institute of Technology-Roorkee, Roorkee
[3]B.A.R. Janta College, Kaul, Kaithal
**Email:kamalbattan@gmail.com*

This paper presents the effects of basin-shape, shape-ratio, impedance contrast (IC) sediment-damping and angle of incidence of body waves on the ground motion characteristics and associated spatial variations of average spectral amplification (ASA) and differential ground motion (DGM) in the basins. Seismic responses of basin models were simulated using a P-SV wave fourth-order spatial accurate time-domain finite-difference algorithm based on staggered-grid approximation of viscoelastic velocity-stress wave equations. The obtained ASA and DGM were largest in the triangular basin and least in the trapezoidal basin for the considered model parameters. On an average, an increase of ASA and DGM were obtained with an increase of IC, sediment quality factor and the basin shape-ratio (in the shape-ratio range 0.03 - 0.16). An increase of ASA and DGM with the increase of angle of incidence of body wave was inferred.

Determination of Focal mechanism of earthquakes with moderate magnitude (Mw ~5) in Gujarat region, India by moment tensor inversion technique

Charu Kamra[1]*, Sumer Chopra[1], R.B.S.Yadav[2]
[1]Institute of Seismological Research, Raisan, Gandhinagar 382009
[2]Department of Geophysics, Kurukshetra University, Kurukshetra 136119
**Email: charukamra007@gmail.com*

Gujarat is situated on the west coast of India and boasts a 1,600 km long coastline. Geomorphologically, Gujarat region comprises three distinct regions namely, Saurashtra, Mainland and Kachchh. Out of these, Kachchh region is seismically the most active and has been assisgned seismic zone V by Bureau of Indian Standards (BIS). The seismicity has increased after the devastating 2001 Bhuj earthquake (Mw7.6). It has also migrated to newer areas. The Kachchh had experienced three large earthquakes prior to 2001: 1819 Allah Bund (M7.8), 1845 Lakhpat (M6.3) and 1956 Anjar (M6) earthquakes. It has many active faults like Allah Bund Fault, Katrol Hill Fault, Kachchh Mainland Fault, South Wagad Fault, Gedi Fault and Island Belt Fault. The Allah Bund, Kachchh Mainland and Island Belt Faults are major faults capable of generating large/great earthquakes. The other faults are smaller /discontinuous and have potential to generate earthquakes of M<7. The mainland Gujarat comprises of two failed rifts, Narmada and Cambay. The Narmada rift has a potential to generate earthquake of M6.5 while the Cambay rift has potential of M<6. In Saurashtra, small fault lines of 30 to 50 km have become active since 2006 and have potential of M<6 earthquakes and recently some moderate events have occurred in Talala and Jamnagar. The Institute of Seismological Research (ISR) has established a dense network of seismic stations in Gujarat state. Since 2006, ISR is monitoring seismicity in Gujarat with a network of over 54 broad band seismic stations. In the last few years, four moderate earthquakes are recorded by this network on 06/11/2007 (M5), 09/03/2008 (M4.9), 20/10/2011 (M5.1) and 19/06/2012 (M5.2). These earthquakes have caused minor shaking in the surrounding areas. The waveform records of these earthquakes provide

an opportunity to investigate the source mechanism and study faulting characteristics of the earthquakes. In this study, we have used moment tensor inversion method to determine the focal mechanism of earthquakes. We inverted for full moment tensors from the displacement records from at least 3 local stations. The inversion was performed at each depth and for each time shift, and the optimum solution was found as the solution with the best fit over all depths and times. Comparison of the correlation coefficient and variance reduction between the observed and the best fitting synthetic seismograms is more important for success of the inversion. The results are consistent with the tectonic regime in the region and the mechanism suggests mostly strike-slip movement along fault. It implies that transverse tectonics is dominant in the region at present.

Identification and characterization of sea water intruded coastal aquifer using electrical resistivity techniques

G. Kanagaraj, L. Elango*
Department of Geology,Anna University, Guindy, Chennai-600 025
**Email: elango34@ hotmail.com*

Seawater intrusion increase the salinity of groundwater and it is of great environmental significance in several parts of the world. Electrical resistivity method is useful for understanding about the coastal aquifers, geology of the subsurface and seawater intrusion. Schlumberger method is very popular geophysical method because it strongly investigates groundwater source and subsurface condition based on the vertical electrical sounding (VES). The present studies identify the characterization of the coastal aquifer due to seawater intrusion with groundwater around the south of Chennai, Tamil Nadu, India. About 21 VES surveys were carried out around the Kalpakkam region from coast to inland adopting the Schlumberger configuration using DDR-2 instrument. The study area consists of 4 four layers (2 KH, 2 QH), sixteen 3 layers (9A, 7H) and one two-layer type. The true resistivity values, ranging from 0.5 to 8008 ohm-m have been observed in the study area. The thickness of the layers ranges between 0.6 and 25. The true resistivity value decrease near the coastal area because of increasing salinization with groundwater. The zonation map shows lower true resistivity values for the first and second layers in the central and northern regions. The electrical conductivity of groundwater ranges from 302 to 6132 ì S/cm. The EC, Na^+, Cl^- of groundwater increase towards the sea confirming the mixing of seawater with groundwater. It is necessary to change the pumping pattern from shoreline to inland and improve rainfall recharge to create freshwater ridges, which would control seawater intrusion.

Crust and upper mantle structure of the western Himalaya through waveform modelling

Nagaraju Kanna*, K.S. Prakasam, Sandeep Gupta
CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad 500007
** Email: nagarajugeo@gmail.com*

We present the seismic image of crust and upper mantle along varied tectonic units from Indian shield to Ladakh-Karakoram region using regional and teleseismic waveform data obtained from 44 digital broadband seismic stations operated by the CSIR-NGRI in the western Himalaya in different time span, during 2002 to 2012. Regional data analysis through two-way travel time technique suggests that the Indian Moho is underthrusting at shallow angle (~2.5º) beneath the Himalaya and steepens abruptly (~6.6º) further north of Southern Tibet Detachment and continues at a

shallow angle (~3.8º) beneath Ladakh. The study reports higher uppermost mantle *Pn* and *S*n velocities (8.37±0.07 and 4.70±0.1 km/s) similar to shield or stable craton beneath the NW Himalaya compared to Ladakh (7.73±0.08 and 4.33±0.09 km/s). Tele-seismic Receiver Function analysis beneath most of the seismic stations shows strong azimuthal variations in the crustal structure indicating a complex structure beneath the region. To understand the variation in the structure along (SE direction) and across (NE direction) geological strikes in the Himalaya, we modelled the Receiver Functions from both the directions. The modelling results show significant variation in the crustal thickness (2 to 11 km) in both the directions. The highest difference in crustal thickness (11 km) observed near the Karakoram Fault indicates that the fault extended in to deeper depth. Average crustal thickness varies from ~50 km in the foothills of the Himalaya, to ~60 km beneath the Higher Himalaya in the NW Himalaya and Kumaon-Garhwal Himalaya, and further north it varies from ~72 to 85 km beneath Ladakh-Karakoram region. This study reports significant variability of sedimentary layer thickness from 1.0 - 2.0 km beneath Delhi region to 2.0-5.0 km beneath the Indo-Gangetic Plain and the Siwalik range. Low shear velocity (~2.5 to 3.2 km/s) layer (~5 to 20 km thick) in the upper and middle crust, indicate that the thick sediments are underthrusting along with Indian crust. We observed high shear velocity (~3.9 to 4.2 km/s) in the lower crust and this high velocity may be due to the presence of dry metastable granulite material in the lower crust. Further, to understand the nature of underthrusting Indian plate, we carried out imaging of seismic discontinuities like 410 and 660 km. The results show sharp and elevated 410 km discontinuity from the Gangetic Plain till Indus Zangpo Suture (IZS), and disturbed (double peaked) further north of the IZS. The 660 km discontinuity is flat and sharp in the Gangetic Plain through Himalaya and elevated beneath Tibetan Himalaya to the north of the IZS. We observed a distinct northward dipping velocity interface to the north of the IZS in the depth range of ~460 to 490 km which indicates the down going Indian subducting slab as reported in earlier studies. Thickened mantle transition zone (~10 km more than normal) is observed beneath the Gangetic Plain and NW suggests the presence of cold material within.

Depth-dependent empirical relations between earthquake magnitude scales in the Himalayan seismic belt

Rajiv Kumar[1], R.B.S. Yadav[2]
Department of Geophysics, Kurukshetra University, Kurukshetra

A homogeneous, Poissionian, and complete earthquake catalogues are the primary source and basic requirements for the seismological studies such as seismotectonic modeling, microzonation and seismic hazard and risk assessment of any seismically active region. The Himalayan seismic belt is one of the most active seismic regions of the world which has experienced at least four earthquakes of $M \geq 8.0$ in the past. The earthquake catalogues available for this region are heterogeneous and inconsistent in space and time. Therefore, in the present study, we aim to develop depth-dependent magnitude conversion empirical relations during the period 1964 - 2016 to convert classical magnitudes into related Mw proxy estimates. For this purpose, different published earthquake catalogues have been collected from different seismological agencies, such as International Seismological Centre (ISC), National Earthquake Information Centre (NEIC) of USGS, Harvard Centroid-Moment Tensor Catalog (HRVD), International Data Centre (IDC) of CTBTO, China Earthquake Information Center, Beijing (BJI), and National Center for Seismology, New Delhi, India (NDI). We have established twenty-four empirical regression relations between moment-magnitude (Mw), body-wave magnitude (m_b), surface-wave magnitude (Ms) and local magnitude (M_L) scales for three depth ranges: 0 - 25 Km, 25 - 70 Km and >70 Km. The magnitude conversion relations have been derived using two regression methods: Orthogonal Distance Regression (ODR) and General Orthogonal Regression (GOR). The conversion relations between M_W-M_S show bilinear trends for

depth ranges 0-25 Km and >70 Km, while for a depth range of 25 - 70 km, it shows linear trend. We have considered linear as well as quadratic regressions to develop empirical relation for M_W-m_b. Subsequently, we have applied linear regressions to develop relations for M_L, M_D and M_W magnitude scales. The ODR regressions have been preferred to make Mw proxy homogeneous magnitude, for which no direct moment magnitudes are available, due to its key advantage of non-linear regression model, which was ignored in GOR.

3D Topography correction applied to magnetotelluric data: Synthetic study

Sushil Kumar[1]*, Prasanta Kumar Patro[2], Bhagwan Singh Chaudhary[1]
[1]Kurukshetra University, Kurukshetra
[2]National Geophysical Research Institute, Hyderabad
**Email: sushil_gp24@yahoo.co.in*

Magnetotelluric method is a useful technique to investigate the crustal image of mountainous regions. Topographic variations due to irregular surface terrain distort the resistivity curves and hence may not give accurate interpretation of magnetotelluric data. The 2-D topographic effect in Transverse magnetic (TM) mode is only galvanic whereas inductive in Transverse electric (TE) mode, thus TM mode responses is much more important than TE mode response in 2D. In 3D, the topography effect is both galvanic and inductive in either TE or TM mode and hence the interpretation is complicated. The paper represents the effects of 3D topography for a hill model using a finite difference method. The paper presents the impedance tensor correction algorithm to reduce the topographic effects in MT data. In this study we analyze the response of conductive, resistive dyke, ramp and the comparison of inversion from flat earth response, inversion with topography and inversion after correction.

Reservoir characterization from seismic data using Genetic algorithm techniques

S.P. Maurya[1]*, K.H. Singh[2], N.P. Singh[1]
[1]Department of Geophysics, Institute of Science, BHU, Varanasi 221005
[2]Department of Earth Sciences, Indian Institute of Technology-Bombay, Mumbai 400076
**Email: spm.bhu@gmail.com*

Reservoir characterization is about extraction of information contained in the seismic data as accurately and reliably as possible. The elastic properties that can be derived from a rock are: Impedance, P-wave, S-wave velocity, density, porosity, clay content, lithology and gas saturation. They all affect the seismic waves travelling through rocks. To characterize the reservoir, Blackfoot data from Alberta Canada has been selected. The 3D seismic survey was acquired over a Lower Cretaceous incised channel filled with sand and plugged shale. The producing formation is sand channel deposited above the Mississippian carbonate formation. The sand layer is very thin, and therefore, it is hard to interpret from seismic data alone. To characterize the reservoir, and diminish the prospective risk a Genetic Algorithm based post-stack seismic inversion is proposed. The Genetic Algorithm is a technique for solving both constrained and unconstrained optimization problems which is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. First, the algorithm is tested with synthetic seismograms to optimize the parameters. The error analysis between the expected and the inverted results, pointed out a good algorithmic performance. Next, Genetic Algorithms are applied

to the post-stack seismic data from the Blackfoot field. Seismic data are inverted into velocity, density and impedances. The correlation coefficient is estimated to be 0.89 between real and inverted data which shows very good correlation. The other statistical parameters are like the RMS error is 0.26, mean is 7.66 and standard deviation is 0.12. The inverted section shows a low velocity zone between 1055 ms -1065 ms which may be due to presence of reservoir (sand channel) in this zone. Density and acoustic impedances are also estimated and are found to be low values between 1055 ms - 1065 ms which confirm the presence of reservoir (sand channel) in this zone. Above and below the sand channel, shale formations are interpreted which act as seal rock for the reservoir. The most effective feature found in Genetic algorithm is that this can be used to estimate petrophysical parameters from seismic data where well log informations are not available.

Artificial intelligence model for earthquake magnitude prediction in Himalayas, India

S. Narayanakumar[1]*, K. Raja[2]

[1]Department of Computer Science and Engg., Anna University, University College of Engg. Ramanathapuram, Tamilnadu

[2]Department of Mechanical Engg., Anna University, University College of Engg. Dindigul, Tamilnadu

**Email: narayanakumar82@gmail.com*

The earthquake magnitude prediction methods are of considerable importance for humanity. Artificial Intelligence model approach is presented starting out from non-linear changes in six different mathematically computed indicators: total number of events from past years to present (2014), frequency-magnitude distribution b-values, Gutenberg-Richter inverse power law curve for the *n* events, the rate of square root of seismic energy released during the *n* events, energy released from the event, the mean square deviation about the regression line based on the Gutenberg-Richer inverse power law for the *n* events and coefficient of variation of mean time and average value of the magnitude for last *n* events. All the data are clustered time period every 10 days. These parameters are extracted from the Himalayan Earthquake catalogue comprising all minor, major events and their aftershock sequence for the past 128 years (1887-2015). This Data contains event data, event time with seconds, latitude, longitude, depth, Standard deviation and magnitude. These field data were converted into eight mathematically computed parameters known as seismicity indicators. These seismicity indicators have been used to train the Artificial Intelligence methods for better decision making and predicting the magnitude of the pre-defined future time period. The present research proposed and used three intelligence methods viz. Back propagation neural network, Cascade-Correlation Neural Networks and Neuro-Fuzzy model. The neural networks are employed to estimate the future parameters from observed data catalog associated with the bell-shaped Gaussian membership functions used in the fuzzy inference mechanism. This model take training from old data and predicted the earthquake magnitude *M* and eight mathematically computed parameters seismicity indicators as input and target vectors in Himalayan basin area. We infer through compare curve as observed from seismometer Himalayan Earthquake catalogue comprised of all minor, major events and their aftershock sequences in the Himalayan basin of 2015 and using seismicity indicators trained neural network predicted earthquakes for 2015. The Neuro-Fuzzy model yields good prediction result for the earthquakes of magnitude between 4.0 and 6.0.

Geophysical investigation in the foothills of Courtallam, Tamilnadu, India

Banajarani Panda*, S. Chidambaram, N. Ganesh
Dept. of Earth Sciences, Annamalai University, Sadagopan Nagar, Annamalai Nagar 608002 Tamilnadu
**Email: banajapanda523@gmail.com*

Geophysical resistivity survey was conducted in 35 locations along the foothills of Courtallam, Tamilnadu, in order to depict the groundwater potential zones in this region. The layer parameters like apparent resistivity (ρ_a) and thickness (h) of different layers are arrived. A maximum of 4 layers was identified in a few regions, but major part of the study area is dominated mainly by 3 layers. Three major zones have been delineated as weathered, fractured and massive. The thickness and resistivity of weathered layer is more in the riparian zones away from the mountain front. Whereas the thickness and resistivity of fractured layer is more along the foothills. Generally, A, H, KH type curves are dominant in this region and minor representation of HK is also observed and H is the predominant type. So the groundwater may be fracture governed.

Estimation of surface Rayleigh wave spectrum using continuous GPS data from recent Nepal earthquakes

John P Pappachen[1]*, S. Rajesh[1], V.S. Gokul[2]
[1]*Wadia Institute of Himalayan Geology, Dehradun 248001*
[2]*Dept. of Marine Geology and Geophysics, Cochin University of Science and Technology, Cochin 682022*
**Email: johnpappachen@gmail.com*

Surface Rayleigh waves are low frequency (<1 Hz), long wavelength waves, that travels through the surface of the earth. The study of surface waves that generated during an earthquake is an important indicator of ground shaking, peak ground velocity, peak ground acceleration and site effects. We investigate the kinematic offsets, peak ground acceleration and analyze the surface wave pattern associated with one of the most significant and recent Himalayan earthquake, the 25th April 2015 Nepal(Gorkha) earthquake of Mw 7.8 that struck near Gorkha, ~80 Km northwest of Katmandu at a depth of ~15 Km (USGS) .

In this study, we used hourly rinex data from 15 continuously operating GPS stations, including the near and far field (> 500 km) stations, around the earthquake epicenter. We estimated the kinematic co-seismic offsets and peak ground accelerations at each station with respect to IISC situated in the Indian peninsular region at ~2000 Km from the earthquake location using the TRACK module of GAMIT/GLOBK. The Rayleigh wave pattern, clearly showing significant co-seismic displacements in both horizontal and vertical components, associated with this great event. The near field stations like CHLM and KKN4 showing a surface displacements of about 1.37 m and 1.87 m respectively in the horizontal component and CHLM station shows a subsidence of 0.6 m; while station at KKN4 was uplifted ~1.25 m in the vertical component. Other near field stations like NAST, SNDL and SYBC also show significant surface displacements in both horizontal and vertical components. The near field stations CHLM and KKN4 show peak ground accelerations of 0.0949 m/s^2 and 0.1261 m/s^2 respectively in their horizontal and 0.0436 m/s^2 and 0.0866 m/s^2 in their vertical components.

A continuous wavelet transform based on mother wavelet of Morlet was used to analyze the acceleration of surface waves in different frequency and time. Time-frequency wavelet spectrum was used to analyze the acceleration response spectrum of the generated surface waves. Continuous wavelet transforms analysis show the dissipative spectrum of ground acceleration at low frequency

related with local ground conditions. We also analysed the ground acceleration spectrum of the surface waves associated with the great aftershock of Mw 7.2 that struck on 12th May 2015 for the comparison.

Shear wave splitting and crustal anisotropy in the eastern Ladakh-Karakoram zone

Arpita Paul, Devajit Hazarika, Monika Wadhawan
Wadia Institute of Himalayan Geology, Dehradun 248001
**Email paul.arpitageo@gmail.com*

Seismic anisotropy of the crust beneath the eastern Ladakh-Karakoram zone has been studied by shear wave splitting analysis of *S*-wave of local earthquakes and *Ps* converted phase originated at crust-mantle boundary. The splitting parameters (Ö and ät) derived from *S*-wave of local earthquakes with shallow focal depths reveal complex nature of anisotropy with NW - SE and NE oriented Fast Polarization directions (FPD) in the upper ~22 km thick crust caused by combined effect of existing tectonic features as well as regional tectonic stress. The maximum delay time of fast and slow wave in upper crust is ~0.3 s. The splitting parameters have also been derived from *Ps* phase originated at crust-mantle boundary to explore anisotropy characteristics of the entire crust. The *Ps* splitting analysis shows more consistent results that shows predominantly NW - SE oriented FPDs which are parallel or sub parallel to the Karakoram fault (KF) and other NW - SE tectonic features existing in the region. The strength of anisotropy is higher (maximum delay time ä: 0.75 s) compared to upper crust. This indicates that the dominant source of anisotropy in the Trans-Himalayan crust is confined within the middle and the lower crustal depths. The predominant NW-SE orientated FPD consistently observed in the upper crust as well as in middle and lower crust near Karakoram Fault Zone supports the fact that the KF is a crustal scale fault which extends at least upto the lower crust. Dextral shearing of the KF creates shear fabric and preferential alignment of mineral grains along the fault strike which causes the observed fast polarization direction. Similar observation in the ISZ also suggests crustal scale deformation owing to India-Asia collision.

Processing and analysis of semi-detailed high resolution aeromagnetic survey over the Kutch rift basin

P.R. Radhika*, S.P. Anand
Indian Institute of Geomagnetism, Navi Mumbai 410218
**Email: radhuponoly@gmail.com*

The Kutch Rift basin, an east - west oriented pericratonic rift basin, is an important tectonic unit of the Indian sub-continent where the disastrous Bhuj earthquake of Mw 7.8 occurred on 26 January 2001. Major part of the basin is covered by the inaccessible salt panes of Great and Little Rann of Kutch due to which the existing geological and geophysical data coverage is very poor. Basin configuration, so far, is studied only by using surface geological data, available gravity data which are dictated by road access and sparsely spaced geophysical data along profiles. To have coherent and realistic basin configuration, it is necessary to synthesize data having uniform coverage and in this regard the aeromagnetic data that has fairly uniform data coverage can prove to be useful. To have a better understanding of the structural and tectonic frame work and basin configuration, a semi-detailed high-resolution airborne magnetic survey, at an altitude of 300 m and line spacing of 1 km, was conducted over the Kutch basin and surrounding areas. The acquired raw magnetic data contains

errors which can be classified into systematic errors and systematic noise. The main sources of systematic errors are diurnal variations, aircraft heading, instrument variation, lag between aircraft and sensor and the inconsistencies between flight and tie lines. The corrections which are applied to correct the systematic errors are diurnal correction to eliminate temporal variations of magnetic field, lag correction to adjust for the sensor positioning, heading correction to correct for systematic shifts in the data that change with the survey direction, and the IGRF correction to eliminate effect the main magnetic field. Systematic noises are the residual errors after applying systematic corrections which can be corrected by leveling techniques. The crustal total field anomaly map and the reduced to pole anomaly map generated after applying these corrections depict several major E-W, NE-SW and NW-SE oriented lineaments and faults, which are extending up to the Indian plate boundary. All major geologic and tectonic elements including the trap flows, the Kutch Main land Fault, the volcanic plugs, etc. find expression on the anomaly map. Different data enhancements techniques like, vertical derivatives, downward continuations and high pass filtering are applied to throw light on shallow subsurface features and it is correlated with the geological map of the region. Through the analysis of this data set, we were able to delineate the presence of traps flows to the regions north of Kutch Mainland and signatures of several hitherto unknown subsurface sedimentary basins, dykes, faults and intrusive. The magnetic basement depth analysis is done using various methods like 3D Euler, Analytic signal and Located Euler. The basement depth generated using located Euler deconvolution, by and large, corroborated well with the deep wells drilled by ONGC and the sedimentary thickness calculated from other geophysical methods. Our analysis suggests that the Banni basin is divided into western and eastern sub-basins in the region covered by Rann of Kutch to the north of the Kutch Mainland Fault (KMF). The results of these including the processing of acquired aeromagnetic data will be presented.

Effect of seasonal hydrological loading over Indian sub-continent and Nepal Himalaya from GPS and GRACE observations

Ajish P. Saji[1]*, P.S. Sunil[1], Param K. Gautam[2]
[1]Indian Institute of Geomagnetism, Mumbai
[2]WadiaInstitute of Himalayan Geology
Email: ajishps12@iigs.iigm.res.in

Apart from the tectonic motions, deformation of the Earth's surface measured from GPS observations is also contributed from mass redistributions in the fluid realm. Seasonal hydrologic variations are prominent in mountainous regions like Himalaya. In the present study, data from 15 permanent GPS stations spread across the Indian sub-continent and 36 stations spread across the Nepal Himalaya were utilized for the study. The atmospheric loading effects on the GPS sites were reduced with the help of available atmospheric loading models. GRACE (Gravity Recovery and Climate Experiment) time variable gravity field coefficients have been converted to crustal deformations in three components. The temporal mass variations in ice and water have been quantitatively estimated from GRACE. Hydrologic loading is a seasonal signal traced out from both GRACE as well as GPS data. Vertical deformation from GRACE data is well correlated with GPS signals in terms of seasonal signals. Subtraction of GRACE derived vertical displacements from GPS observed time series separates out tectonic effects from hydrological effects which is of interest for deformation study. The seasonal signals obtained from GPS and GRACE are compared and analyzed for the periodic monsoonal effects in the region. The WRMS reduction in GPS vertical rate due to reduced GRACE derived vertical displacement essentially compares the consistency between GPS and GRACE measurements.

Emanation of radon as a precursor to earthquakes - A review

Meetu Singh[1]*, Amit Sarin[2], Neerja[3], Sameer Kalia[3]
[1]Department of Applied Sciences, IK Gujral Punjab Technical University, Jalandhar
[2]Department of Applied Physics, IK Gujral Punjab Technical University, Jalandhar
[3]P.G. Department of Physics and Electronics, DAV College, Amritsar
**Email: meetu4587@gmail.com*

Radon (222Rn), a radioactive gas with a half-life of 3.82 days, is continuously emanated in soil, rocks and water by the radioactive decay of ^{226}Ra. Radon is released from the ground into the atmosphere, where it is transported mainly by turbulent diffusion. The relationship between an observed radon anomaly and the subsequent time and location of earthquake occurrence is a root concern of earth sciences. Various eminent researchers and scientists came to consensus that electric field driven mechanism is more probable to explain ionospheric anomalies before earthquakes than the acoustic-driven mechanism. Anomalous radon emanation in the epicentral area has been reported in numerous studies to change the atmospheric electrical conditions. As a geological tool radon monitoring technique can be used in uranium and hydrocarbon exploration, earthquake prediction, study of active geological faults and geothermal energy sources. In the present paper, an attempt has been made to review radon measurements performed all over the world and how the emanation of radon forecasts the earthquakes. This paper focuses on the potential benefits of radon and its daughters in the field of geosciences.

Investigation of source parameters and radiated energy of local earthquakes in Garhwal-Kumaun region, NW Himalaya

Rakesh Singh[1]*, Ajay Paul[1], Arjun Kumar[2], Praveen Kumar[1], Y.P. Sundriyal[3]
[1]Geophysics Group, Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Department of Civil Engineering, Arni University, Kathgarh (Indora), H.P.
[3]Department of Geology, HNB Garhwal University, Srinagar, Uttarakhand
**Email: rakeshgosain@hotmail.com*

Source parameters of the small to moderate earthquakes are significant for understanding the dynamic rupture process, the scaling relations of the earthquakes and for assessment of seismic hazard potential of a region. In the present study, the source parameters were determined for 58 small to moderate sized earthquakes ($5.0 \leq M \geq 3.0$) from July 2007 to October 2015, recorded by the ten Broad Band Seismographs (BBS) installed in the Garhwal region by Wadia Institute of Himalayan Geology.

In order to evaluate the source parameters, the authors estimate quality factors of the attenuation factor $Q_{\hat{a}}$. The authors estimated and applied the $Q_{\hat{a}}$ values for each station for different frequencies to eliminate any bias in the determination of source parameters. The $Q_{\hat{a}}$ has been estimated by using extended coda wave normalization method in the frequency range 1.5 to 16 Hz. We find frequency-dependent S wave quality factor as defined by the $Q_{\hat{a}} = 143 \pm 7f^{0.86\pm0.005}$ by fitting a power-law frequency dependence model for the estimated values over the whole study region. A software EQK_SRC_PARA based on Brune's source model and a high cut-filter has been employed to estimate spectral parameters of the source spectrum has been employed.

The average seismic moment of these earthquakes lies between 1.59×10^{13} and 3.09×10^{16} Nm causing deformation of source radius in the range of 141 to 589 m. The stress drop varies from

2.13 to 70.04 bars with 73% of events having average stress drop $\geq$ 10 bars. The total radiated seismic energy is varying between 6.5 x 10^{7} and 4.16 x 10^{12} joules. The scaled energy (ê) ratio of radiated seismic energy to the seismic moment is evaluated to determine the dynamic failure process of the events. The estimated scaled energy is consistent with global observations and it increases with moment magnitude. The estimation of Zúñiga parameter (å) suggests the partial stress drop mechanism in the region.

Ground Penetrating Radar (GPR) studies of some Landslides along National Highways NH-37 (53) and NH-39 (2) of Manipur, northeast India

Thounaojam Joyraj Singh*, Heisnam Sanatomba Singh, Soibam Ibotombi, Maisnam Pradip Chandra Singh

Department of Earth Sciences, Manipur University, Imphal-795003

**Email: luwangchajoy@gmail.com; ibotombi2002@yahoo.co.uk*

Ground Penetrating Radar (GPR) is a pulse-echo or pulse-electromagnetic technique to determine the structure of buried features. It works like ultrasound, but uses radio waves rather than sound waves to penetrate the ground materials. It is a non-destructive and environment friendly method to detect, locate and map subsurface features. GPR systems yield accurate data where a modern modular GPR instrument can be used for a wide variety of applications. As the GPR can provide a detailed image of the ground materials upto some depth, revealing the subsurface configuration and thickness of the ground materials, in this paper, an attempt is made to study the relationship between the structural configuration and overburden thickness, and the landslide susceptibility of a slope mass. GPR surveys have been carried out using MALA Low Frequency System comprising a Control Unit (CUII including Data Storage Device, GPS), unshielded ground-coupled antenna (100 MHZ centralfrequency, MALA RTA) over some slide areas in order to generate radar grams of the slides, i.e., soils and rocks forming the slope masses. The surveys were conducted over half a dozen landslide sites, viz., Leinganglok, Laijang, Awangkhul, Vizang, Tupul and Thangjalok along the NH-37(53) and Phesama Landslide, Nagaland, along the NH-39. The GPR data of the slides reveal wide information on the subsurface structural features of the ground materials and thickness of the soil columns as well as about the different reflection patterns of the various structural elements, and variation in the physical properties of the ground materials (soils and rocks) of the slide areas. Normally, in majority of the slides, thickness of soil column ranges from 1.2 to 2.8 m as evident from the GPR data radar gram diagrams. Combination of GPR profile data and field outcrop studies indicate that any slope mass that has a thickness of 1.8 m (2.0 m) or more are susceptible to slide provided the slope angle is moderate or steep. The study reveals that thickness of overburden soil column plays an important role in causing landslide or destabilising the slopes.

Dependence of near field co-seismic ionospheric perturbations on surface deformations: A case study based on the April, 25 2015 Gorkha Nepal earthquake

A.S. Sunil[1]*, Mala S. Bagiya[1], Joshi Catherine[2], Lucie Rolland[3], Nitin Sharma[1], P.S. Sunil[1], D.S. Ramesh[1]

[1]Indian Institute of Geomagnetism, Navi Mumbai 410218, India
[2]National Geophysical Research Institute, Uppal Road, Hyderabad 500007, India
[3]Universite´ Cote d'Azur, OCA, CNRS, IRD, Ge´oazur, Sophia-Antipolis, France
**Email: sunnil.as@gmail.com*

Large earthquakes (Mw>6.5) can induce near and far-field ionospheric perturbations by direct/secondary acoustic and gravity waves through Lithosphere-Atmosphere-Ionosphere (LAI) coupling. The earthquake generated pressure waves grow in amplitude by about five orders of magnitude as they propagate upward and produce ionosphere electron density perturbations. Ionospheric response from the recent 25 April 2015 Gorkha, Nepal earthquake is studied in terms of Global Positioning System-Total Electron Content (GPS-TEC). The present study is carried out from the view points of source directivity, ruptures propagation and associated surface deformations, over and near the fault plane. The azimuthal directivity of co-seismic ionospheric perturbation (CIP) amplitudes from near field exhibit excellent correlation with east-southeast propagation of earthquake rupture and associated surface deformations. In addition, the amplitude of CIP is observed to be very small in the opposite direction of the rupture movement. Conceptual explanations on the pole ward directivity of CIP exist in literature, we show the observational evidences of additional equator ward directivity, interpreted in terms of rupture propagation direction. We also discuss the coupling between earthquake induced acoustic waves and local geomagnetic field and its effects on near field CIP amplitudes. We suggest that variability of near field CIP over and near the fault plane are the manifestations of the geomagnetic field-wave coupling in addition to crustal deformations that observed through GPS measurements and corroborated by Interferometric Synthetic Aperture Radar (InSAR) data sets.

Observational biases in seismically induced ionospheric perturbation from GPS-TEC Observations

Dhanya Thomas[1]*, Lucie Rolland[2]

[1]Indian Institute of Geomagnetism, Navi Mumbai, India
[2]Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, IRD, Géoazur, France
**Email: dhanyathomas999@gmail.com*

Coupling between the lithosphere and Ionosphere is one of the interesting phenomena for the entire geophysical community especially in the field of earthquake studies. The lithospheric disturbances due to activities like earthquakes and volcanic eruption are manifested as Ionospheric variations through the coupling between lithosphere-atmosphere and Ionosphere. So, a deep understanding of the mechanism as well as a comprehensive knowledge in various factors influencing the observation of the phenomena is necessary in the study of Ionospheric seismology. The present study is focused mainly on the shallow (25 km) Mw 8.1 Iquique earthquake that occurred on 1st April, 2014. We have estimated the TEC (Total electron content) variation during the earthquake and have observed spatial variation in the perturbation. We describe the observational biases arising from geomagnetic field and GPS satellites geometry. An insightful understanding of the coupling process and observational biases will be a valuable contribution in field of ionospheric

seismology. Further, it will contribute to Tsunami early warning systems and remote sensing of earthquake signals in future.

A Robust technique for conductivity-depth imaging of large loop TEM sounding data

Ashish Kumar Tiwari*, N.P. Singh
Department of Geophysics, Faculty of Science, Banaras Hindu University, Varanasi 221005
Email: ashish.bhu011@gmail.com, singhnpbhu@yahoo.co.in

Conductivity-depth imaging (CDI) is a tool for the transformation of TEM data into an apparent resistivity or conductivity curves which present a qualitative understanding of the basic characteristics of the subsurface conductivity distribution. CDI has proven to be a useful tool in mapping the distribution of the geologic conductivity and identifying the source within variably conductive host geology. The imaging is useful especially for the situation where data are in abundance, as such as in the interpretation of large volume of airborne TEM data or ground TEM data using large loop sources. In the present research, an attempt is made to develop a conductivity-depth imaging technique for rapid and robust interpretation of large (finite size) loop TEM sounding data acquired using central loop, coincident loop, arbitrary in-loop and offset-loop configurations for step and/or impulse source excitations using a horizontal thin sheet model. In this technique the data obtained from an airborne TEM survey or ground TEM survey is taken as a derivative of the secondary field, i.e. impulse response of secondary field. The transmitter is considered as a loop (magnetic dipole) for airborne system and a large loop for the ground and borehole systems. A horizontal sheet of infinite extent have been used to fit the data at two or more successive delay times to find the conductance and depth of thin sheet using iterative least-square inversion method. Further, from the set of conductance depth values, the conductivity-depth values are derived using the conductivity as the first derivative of conductance with respect to depth. Finally, the conductivity and corresponding depth values are processed and presented in a form to depict conductivity-depth sections, which represent pictorial distribution of conductivity with depth. The algorithm have been checked initially for synthetic data (noise free and random noise data), and attempts are being made to apply it to the available real field data. The proposed technique is a rapid and robust one and possesses an option for inclusion of modification needed for its adaption for imaging TEM data acquired using conventional commercial ground and airborne systems.

Late Ordovician – Silurian biodiversity from Takche formation of Spiti valley, Himachal Pradesh

Husain Shabbar[1]*, Anju Saxena[1], Kamal Jeet Singh[1], S.K. Parcha[2]
[1]Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226007
[2]Wadia Institute of Himalayan Geology, Dehradun 248001
**Email: shabbarnaqvi92@gmail.com*

The Spiti valley, popularly known as the cold desert, is a remote part of Himachal Pradesh in the North-Western Himalaya, offers a remarkably thick sequence of sedimentary rocks resting over the Precambrian Crystalline Basement and ranging from Cambrian to Cretaceous in age. The Palaeozoic successions of Spiti Valley comprise of Kunzum La (Early to Middle Cambrian), Thango (Ordovician), Takche (Late Ordovician - Late Silurian), Muth (Late Silurian – Late Devonian), Po and Ganmachidam (Carboniferous-Early Permian) and Guiling (Late Permian) formations.The

Ordovician-Silurian time interval is of great interest regarding the study of early land plants as it witnessed their origin, subsequent diversification and finally successful colonization of the land. In this pursuit, the Takche Formationin the Spiti Valley near Losar Village has been studied for its palaeofloristic and trace fossil assemblage.

However, so far, plant macrofossils have not been found in sediments older than the Silurian. Hitherto, there are only two doubtful records of macroplant remains, i.e. *Taeniocrada* and *Psilophytonprinceps* from the Silurian and Lower Devonian of Spiti valley respectively; the age of the strata and identification of which still remains questionable. The search for the miofloral remains (cryptospores and plant debris) have never been carried out from Ordovician-Devonian strata of the Tethyan Himalayas sequences. Attempt has been made to analyze the cryptospores/palynomorphs from the Takche Formation. Well documented records of mega and microfossil plant remains, associated ichnofossils and palynomorphsfrom the study area will help to understand the regional stratigraphic occurrences of fossils, their ecology and their palaeogeographic distributions.

Different types of ichnofossils have been documented from the Late Precambrian and Early Palaeozoic successions from Kashmir, Zanskar, Kinnaur, Kumaon region and from the Cambrian succession of the Lesser Himalaya. Invertebrate trace fossils *Arenicolites, Arthrophycus, Chondrites, Planolites, Skolithos* and *Rusophycus* are recorded from Manchap Formation in the Kinnaur Basin. Kumar & Kashkari (1987) described *Palaeodictyon* and *Chondrites* from Takche Formation in the Pin Valley. Except *Arthrophycus*, no other ichnofossils from the Takche Locality, near Takche Village has been reported hitherto by any researcher. The fossil assemblage of studied section includes trace fossils, brachiopods, bivalves and corals. Some of the shales samples of the Takche Formation (Late Ordovician - Late Silurian) have yielded rare occurrence of cryptospores. Their affinity is yet to be ascertained. Recovered trace fossils belong to genera *Palaeophycus*, *Planolites*, ?*Bergauria,* ?*Arthophycus* and ?*Meniscate* burrow. Their detail study is under progress.

Petrographic studyof Paleo-proterozoic Banswara phosphorite deposits from Aravalli Supergroup, Rajasthan, India

Samsuddin Khan*, K.F. Khan, Mohd Shuaib
Department of Geology, Aligarh Muslim University, Aligarh 202002
**Email: shamsuddin.amu@gmail.com*

Paleo-proterozoic phosphorite depositsof Banswara district belong to kalinjara formation of lunavada group of Aravalli Super Group of Rajasthan.Sallopat, Ram Ka Munna Shivpora and Jhermoti, are the important blocks of phosphorites in this district These deposits of phosphorite are hosted in dolomite, multicolored chert and calcareous quartzite.. Salloapat phosphorites are stromatolitc, brecciated and bedded in nature whereas Ram ka munna, they occur in form of thin bluish-grey stringers which are composed of phosphate, carbonate and siliceous materials.

In Shivpora and Jhermoti blocks, the phosphorites are found to occur as massive, fragmental and brecciated which are dark greyish to blackand brecciated phosphorites are pinkish to light red in colour.

Petrographic studies of phosphorite samples was carried out by using petrological microscope, X- ray diffractometry, FEG- SEM, EDX and Raman spectroscopy. It is observed that Apatite-(CaF) is dominant phosphate mineral which is intermixed with insignificant amount of carbonate material. Small amount of Carbonate-fluorapatite is also observed in Shivpora and Jhermoti phosphorites. Sporadic findings of the identical tiny granules of partially anisotropic Apatite-(CaF) along with dolomite, calcite, quartz, muscovite, zeolite and other gangue minerals

have been observed with the replacement of phosphate material by quartz and carbonate. Organic matter in hexagonal crystal of Apatite-(CaF) microbial filaments (algal mats) reveal the involvement of micro-organism in the formation of deposition.

The findings of phosphate minerals with mutual replacement of phosphate-carbonae-silica and organic matter, algal mats reveal that the deposition of the phosphate might have taken place in shallow marine oxidizing environmental conditions leading to the formation of phosphorite layers as primary biogenic precipitates by micro-organism. Different forms and texture of phosphate minerals may due to environmental fluctuations at the time of deposition followed by some diagenetic processes.

Lesser Himalayan affinity of Chiplakot Klippe, Kumaun Himalaya, India: Constrained from Zircon U-Pb geochronology and geochemistry

Purbajyoti Phukon[1]*, Koushik Sen[1], Hari B. Srivastava[2], Saurabh Singhal[1], Aranya Sen[1]
[1]Wadia Institute of Himalayan Geology, Dehradun 248001
[2]Department of Geology; Institute of Science; Banaras Hindu University, Varanasi
**Email: purba.phukan205@gmail.com*

The U-Pb geochronology and whole rock geochemistry of thegranitic gneisses of Chiplakot Crystallines klippe (CC) and orthogneisses of Munsiari Formation along Kaliganga valley, Kumaun Himalaya reveal the Lesser Himalayan tectonic lineage of the Chiplakot Klippe. Zircon Pb^{207}-Pb^{206} ages of the Chiplakot Crystallines provide the crystallization age in a range from 1861.2±3.3Ma to 1969.8±3.5Ma. Zircon Pb^{207}-Pb^{206} ages of Munsiari orthogneisses have also given crystallization ages in a range from 1857.6±4.5Ma to 1963.0±5.0 Ma. The trace element distribution patterns in both litho-units aresimilar and they are consistent with a volcanic/collisional arc setting.Based on these integrated U-Pb ages and Trace element geochemical study, it can be interpreted as Chiplakot Crystallines is contemporaneous with the Munsiari orthogneisses and, they are both ofLesser Himalayan origin.

Heavy metals in groundwater, Aiyar sub-basin of Cauvery river basin, Tamil Nadu, India

M. Mohamed Rafik*, S.G.D. Sridhar
Department of Applied Geology, School of Earth and Atmospheric Sciences,
University of Madras, Guindy Campus, Chennai 600025
**Email: mohamedrafik786@gmail.com*

Water pollution or contamination is a danger to the health of people living in developing countries such as India. Studies were carried out to find out the concentration of heavy metals in groundwater of Aiyar Sub-basin of Cauvery river basin, Tamilnadu, India. Totally, 43 groundwater samples from forty three locations were collected during post and pre-monsoon (January and May 2015) seasons. The heavy metals such as Mn, Cu, Ni, Co, Pb, Zn, Fe and Cr (mg/l) were analyzed by Atomic Absorption Spectrophotometry (Graphite Furnace) in accordance with APHA (1998) procedures. The study reveals that groundwater samples are having high concentration of Mn, Ni, Pb, Fe and Cr in most of the samples as per BIS (10500:2012). The high concentrations of heavy metal ions in groundwater was attributed to unsafe discharge of effluent from municipal wastewater and fertilizers. Based on over all observation, increasing trend of each parameter is influenced by natural and anthropogenic activities

Application of geophysical electrical resistivity tomography to identify seawater intrusion during Tidal fluctuation

M. Thirumurugan, S. Raghu, L. Elango*
Department of Geology, Anna University, Chennai 25
**Email: elango34@hotmail.com*

Seawater intrusion is a major problem in the coastal regions of India which is due to over exploitation of groundwater for various purposes and also due to the tidal fluctuation. Though the impact of tidal fluctuation on groundwater hydraulics has been studied extensively, tide induced saltwater in the freshwater zone of coastal aquifer remains largely unexplored. Hence an attempt has been made to trace the implication of tidal fluctuation on seawater intrusion in the coastal aquifer of south Chennai, Tamil Nadu, India using high resolution electrical resistivity tomography. The high resolution electrical resistivity 2D tomography was carried out using the ABEM terrameter, by Schlumberger array. The maximum profile length was 123 m and the depth of profile obtained was about 25 m. The measurement was carried out hourly during the high tide and low tide periods. The apparent resistivity measured in this area ranges between 1 ohm m to 20000 ohm m. Salt water intrusion is highly observed towards the landward during high tidal activity which are characterized by the spatial distribution. The maximum distance of seawater intrusion from the coast was 100 m during this tidal fluctuation. The present study demonstrated the application of 2D high resolution electrical resistivity tomography to identify the seawater intrusion in the coastal aquifer..

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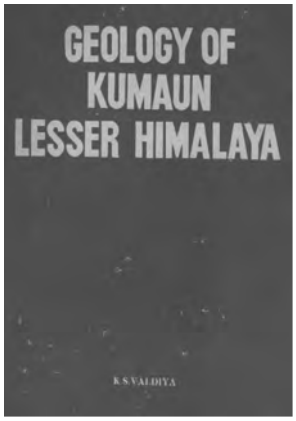

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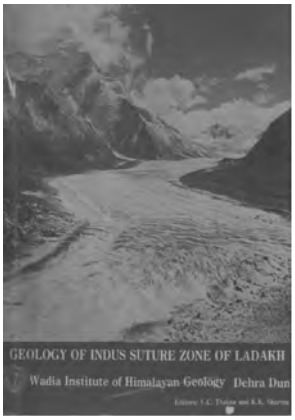

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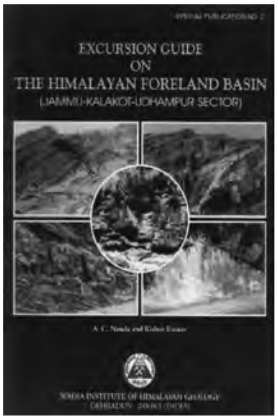

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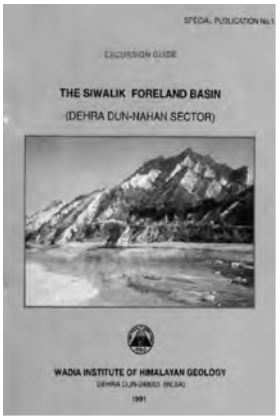

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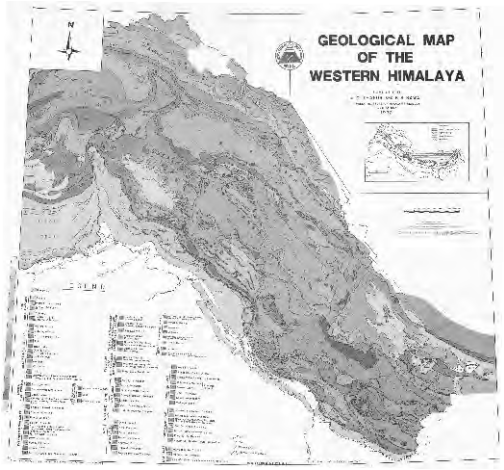

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