3rd National Geo-Research Scholars Meet

June 6-8, 2019

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, Dehradun- 248001, Uttarakhnad (India)

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(An autonomous Institute of Department of Science & Technology, Government of India)
33, General Mahadeo Singh Road, Dehradun-248001
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WIHG, Dehradun, India
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(भारत सरकार के विज्ञान एवं प्रौद्योगिकी विभाग का एक स्वायत्तशासी संस्थान)
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WADIA INSTITUTE OF HIMALAYAN GEOLOGY
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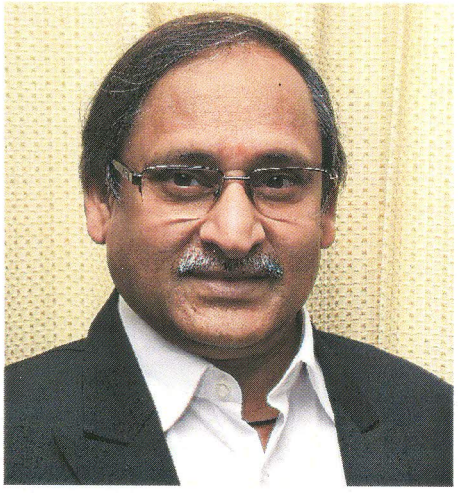
डॉ. कालाचाँद साँइ, एफ.एन.ए.एससी.
निदेशक
Dr. Kalachand Sain, FNASc
Director

Director's Message

The Wadia Institute of Himalayan Geology (WIHG)), an autonomous institute of the Department of Science and Technology (DST), is the only Institute pursuing research on the Himalayan seismogenesis, geodynamics, natural hazards, natural resources, glaciology and climate variability for the well-being of mountainous population.



It gives me immense pleasure to share with you that WIHG is organizing the 3rd National Geo-Research Scholars Meet (NGRSM) at its campus during June 6-8, 2019. Proposed by the Governing Body of WIHG and accepted by the DST, the NGRSM has been an annual event of WIHG. The purpose of this meet is to provide an opportunity to the young researchers for presentation and receiving feedbacks from peers; interaction with the experienced geoscientists; understanding the societal problems; and mitigating them through geoscientific innovation. I am extremely happy to see that ~200 researchers from a number of central & state Universities, IITs, IISERs, and Research Institutes are participating to this event.

It is gratifying that the Secretary of DST, Joint Secretary of DST, Director General of UCOST, Director of CSIR-IIP, Head of AI-Cell of DST, and several other dignitaries have kindly agreed to grace the occasion.

I congratulate all the staff of WIHG, faculty members and researchers for involving in this nation-building initiatives. I am sure that the deliberations during the 3-day meet covering different fields of 'Geosciences for Society' is likely to enrich our knowledge related to the Earth and understanding the challenges coupled with providing probable solution to them.

I wish the Meet a resounding success.

Date: 4th June, 2019

(Kalachand Sain)
Chairman, NGRSM &
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Sedimentation and Tectonics

Snake Fossil assemblages from the Middle Miocene Deposit of Hominid locality, Ramnagar, Jammu and Kashmir (India)

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Lower Siwalik fossil localities near the town of Ramnagar, India are well known to vertebrate palaeontologists. Over the past century, numerous specimens collected near Ramnagar have proven important to understanding the evolution and biogeography of many mammalian groups. Although fossil mammals have been recovered in abundance from the Lower Siwalik Ramnagar (India), there is no significant work on fossil snakes from this area. Here, we report snake fossil assemblages from different localities around Ramnagar. The fossil snake includes two types, large and small. The small size snake fossils were recovered by maceration of sediments. We compared the morphology and measurement of the Ramnagar specimens with those of Acrochordae, Boidae, Colubridae and Pythoninae. Our result suggests that the fossil snakes include *Acrochordus dehmi*, *Chotaophis* sp. and indeterminate serpentines. *Acrochordus dehmi*, a fully-aquatic taxon is characterised by the presence of a lymphatic foramen on cloacal vertebrae and neural spines of non-posterior part with straight anterodorsal margins, whereas the *Chotaophis* is recognised by the unique combination of anteriorly positioned lateral foramina, presence of parazygantral foramina, and elongated centrum. The presence of these two taxa in the Ramnagar suggests that a well-watered landscape existed in the area during the Middle Miocene. The Ramnagar region in general appears to be Chinji-age equivalent, ~14 to 11 Ma based on mammalian fauna.

Microfacies and depositional setting of Upper Eocene Carbonate in Meghalaya, NE India

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Well preserved Cenozoic sedimentary successions are found at Meghalaya, on the southern edge of the Shillong Plateau. Palaeocene – Eocene deposit of Meghalaya is termed as Jaintia Group which includes Langpar, Shella and Kopilli Formations. The Shella Formation is constituted by alternating limestone and sandstone members. The Upper most limestone member of the Shella Formation is named as Upper Sylhet Limestone or Prang Limestone. The present work is confined in the Upper Sylhet Limestone member exposed near Therriaghat, Meghalaya (Latitude N 25°10'66"; Longitude E 91°44'81'').

Extensive field work has been done on two quarry section of the area (Q1 and Q2) where first quarry represents the lowermost part (16 m) and second quarry is the uppermost part (8 m) of upper Sylhet limestone. Both sections have been measured in the field and closely sampled for understanding detailed micropaleontological and microfacies studies to interprete the depositional environment. Forty nine samples were collected from the area with a frequency of 0.5 metre and 20 selected samples were used in preparing thin section The limestone in the studied area were hard, compact and extremeely rich in large benthic Foraminifera and calcareous algae. The identified Microfossils from Prang limestone were *Nummulites* sp., *Assilina* sp., *Discocylina* sp., *Operculina* sp., *Milliods* sp., *Alveolina* sp., *Ostracod* sp., *Texularia* sp., *Melobesioides* sp., *Lithoporella* sp., *Distochyplax biseralis, Sporolithon* sp., *Lithothamnion* sp., *Spongites* sp., *Ovulites* sp., *and Mesophyllum* sp. Thin section investigation has allowed us to identify 9 microfacies viz, Algal- Foraminiferal Packstone, Nummulitic- Algal grainstone, Foraminiferal Grainstone, Discocylinal-nummulitic wackestone, Algal wackestone, Alveolinal wackestone, Alveolina- Nummulitic packstone grainstone and Algal Grainstone. These microfacies contributed in the identification of various environment changing from open marine to restricted marine and shifting it to open Marne condition again. The microfacies that demonstrated open marine setting are The foraminiferal- algal assemblages of Prang carbonates indicates overall warm shallow outer shelf (outer ramp) setting under somehow deeper and low energy reduced light condition in a tropical climate of Upper Eocene age.

Use of Magnetic Susceptibility as a proxy - to determine the pollution rate from Chilika lake sediments

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The aim of this study is to estimate the environmental pollution of Chilika Lake, Odisha. Here we use Magnetic Susceptibility (MS) as a proxy for rapid and flexible means of monitoring a wide range of environmental processes. The Chilika Lake is mainly used for aqua culture and tourism purpose, not only these effects but also the lake gets enriched by catchment sediments. Previous workers show that MS (k) value mainly tells us about the lithological variations of depositions and K values reveal the metallic contamination level in the finer sediments. The studies also show that magnetic response is consistent with a contaminated upper layer with the thickness of up to 5 m. In this study we collected soft bottom sediments from 54 locations along the in- and outward parts of the mouth of Chilika Lake. The magnetic susceptibility of collected samples were done. Our data shows the large ranges of MS values, i.e., ranging from 113.29×10^{-6} to 3.08×10^{-6} SI unit. The susceptibility map which is prepared from magnetic survey data shows a close relationship with surface magnetic susceptibility and provides a clear picture for classifying contaminated sediments. Our data shows a low range near the coast side and exhibits a high range towards the inner part of lake side. So, our results suggest, that magnetic susceptibility can be used as a proxy to determine the increased pollution level due to local sources. This can be explained in terms of complex inlet that comes from different types of pollution sources.

A review of tectonic models for the evolution of the Greater Himalayan Sequence (GHS); evidence from Alaknanda-Dhauli Ganga Valleys, Uttarakhand Himalaya

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The Greater Himalayan Sequence (GHS) is bounded by the south-verging Main Central Thrust (MCT) in the south and the north-verging South Tibetan Detachment System (STDS) with a normal sense of movement in the north. This study evaluates different existing models, proposed for the exhumation of the GHS, with respect to the new field evidence and structural fabric data.

Existing models can be grouped into two types. Type-1 models assume simultaneous movement along both the upper and the lower tectonic surfaces. Examples of this type of models are: (i) The Channel Flow Model (Beaumont et al., 2001, 2004), (ii) Wedge Extrusion Model (Hodges et al., 1992), and (iii) Wedge Insertion Model (Webb et al., 2007). Type-2 models are those which do not require simultaneous movement along the upper and lower bounding surfaces. This type of models include; (i) combined Ductile Shear Zone and Channel Flow Model (Jain and Manickavasagam, 1993; Jain et al., 2005), (ii) Critical Taper Model (Kohn, 2008), and (iii) In-Sequence Shearing Model (Carosi et al., 2017).

The Channel Flow Model involves a low viscous fluid-filled channel of the GHS, lying between two rigid sheets. This model a hybrid between two end-members of Couette flow and Poiseuille flow. Coupling between focused surface denudation and erosion leads to ductile extrusion of hot channel material, hence the model reconciles the apparent coeval nature of the MCT and the STD.

The combined Ductile Shear Zone and Channel Flow Model postulates small-scale displacement of the metamorphic isograds along c-foliation in the ductile shear zone. The initiation of the exhumation was during simultaneous ductile shearing along the channel boundaries followed by the channel flow by Couette and Poiseuille flows.

Critical Taper Theory assumes a wedge of deforming rock acting at a position of critical failure such that the erosion at its upper surface is balanced by underplating of new material at its base. The short residence time of the peak temperature in the GHS is explained by synthrusting and inverted metamorphism in these models. The In-Sequence Shearing Model assumes sequential reactivation of the tectonic packets of the GHS, from the STDS to the MCT, without continuous deformation.

Abundance of ductile shearing and relates structures, inverted metamorphism and overprinting of top-to-the north structures over top-to- the south structures in Alaknanda–Dhauli Ganga Valleys, points to the inference that the combined Couette and Poiseuille channel flow model is tenable for the exhumation of the GHS.

Late Quaternary Sedimentation and Tectonic history of the Chitwan Intermontane Valley, Central Himalaya

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Intermontane valleys in the Sub-Himalaya (locally named as duns) comprise of several Late Quaternary landforms (viz., relict fans, surfaces, and terraces) that bear evidences on the past tectonic and climatic history of the region. The Chitwan dun located in central Nepal is investigated in this study for its morphotectonic evolution during the Late Pleistocene to Holocene. We report the first geochronological data from this region.

The landforms in the Chitwan dun comprise of sediments deposited mainly by the debris flow and channel flow as indicated by their facies analysis. They are primarily distributed in five different levels i.e., Level 1-5. Optically Stimulated Luminescence (OSL) dating of the samples collected from the dun landforms suggest four major phases of aggradation - >120 ka, ~110-80 ka, ~65-25 ka, and 19-10 ka, that coincide well with the interglacial periods when precipitation was high to moderate. The Levels 1 and 2 geomorphic units dating older than 25 ka occur in the hanging wall of the Jharahi thrust (JHT), Belani thrust (BT), West Chitwan thrust (WCT), and the Central Churia Thrust (CCT); based on these constraints on the timing of activity on the thrusts is derived. Climatically controlled incision in the valley is observed during the Last Glacial Maxima (LGM) and then again towards the start of the Holocene. The Level 3 surfaces were abandoned during the LGM (25-19 ka) and subsequently incised. Aggradation in the post-LGM period gave rise to the Levels 4 and 5 geomorphic units. Tectonic activity in the valley towards the end of the Pleistocene is marked by the upliftment of the Level 4 surfaces along the Danda Thrust (DT) and Shaktikhor Thrust (ST). The incision of the Level 5 landforms probably occurred due to climatic changes during the Holocene, as there are no evidences of surface rupturing.

Provenance and Tectonic setting of the Oligocene Barail Group of rocks around Sonapur area of Jaintia Hills, Meghalaya, India

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The area under study is a part of Shillong shelf, Meghalaya and is situated in the southeastern part of the Jaintia Hills. A continuous tertiary sequence is exposed in the Jowai-Badarpur road section in the Jaintia Hills. The Eocene-Oligocene sediments are well exposed along a part of Jowai-Badarpur Road in between Lumshnong and Sonapur. The representative sandstone samples were collected systematically along Lubha River section a part of Jowai-Badarpur Road in Sonapur village. The study on the provenance and tectonic setting of the Oligocene Barail Group of rocks is based on the detrital modes and heavy mineral assemblages. The detrital modes of the sandstone samples show the proportion of quartz – 60.58 to 80.03, feldspar -0.90 to 3.89, mica – 1.90 to 7.56, lithic fragments -1.97 to 4.98 respectively. The studied sandstones are mainly classified as quartz arenite, quartz wacke and sublith arenite. QFL triangular plot reveals that the detritus were derived mainly from cratonic interior sources with minor contribution from recycled orogen. Q_mFL_t triangular plot reflects that the provenance of the sediments was mainly of craton interior type. The Diamond diagram indicates that the studied sandstones were derived from middle and upper rank metamorphic sources. Heavy mineral study indicates the presence of zircon, tourmaline, rutile, sillimanite, kyanite, staurolite, garnet, epidote, sphene, hypersthenes, hornblende, chlorite, chloritoid, andalucite, apatite and opaque minerals. The presence of sillimanite, kyanite, garnet and andalucite indicates high rank metamorphic source. Rounded zircon and tourmaline indicates reworked sediments. The ZTR maturity index varies from 10.37 to 28.15, which reveal that the sediments are mineralogically immature. So the petrographic and heavy mineral study of the sandstones suggest that the sediments was probably derived from raised Shillong Massif where Precambrian metamorphic rocks of pelitic and arenaceous composition with plutonic bodies are exposed around the shelf margin.

New palaeontological data from Plio-Pleistocene Upper Siwaliks exposed along Pataili Ki Rao, Chandigarh

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The Upper Siwalik deposits of the Quranwala zone in the Masol village near Chandigarh (India) are well known for their rich faunal assemblages since decades. These paleonto-archeological sites consist of deep cut mountainous valleys by Pataili ki Rao (Rao = stream) with high rates of weathering and differential erosion exposing the Tatrot Formation in its core. Recently, these deposits have generated a lot of interest due to a discovery of alleged cut marks on long bones recovered. This find has generated curiosity on the role of early humans if they were involved in the modifications of bones or the cut marks are made by other processes. Fossils in this area are generally very large in size, disarticulated and fragmented and occur mainly as floats in the badland area and gullies formed by river systems. In this area, fine to medium grained sandstone, variegated mudstone/siltstone is characteristic of Tatrot Formation followed by the presence of brown to greyish brown medium to coarse grained sandstone with pedogenic or non-pedogenic mudstone of the Pinjore Formation. In the current study, we undertook detailed geological mapping along the Pataili ki Rao section with the help of high precision GPS data from the area. Systematic sampling of the fossils and pedogenized mudstones for stable isotope analysis, wherever present, has been done to accurately determine the ecological shift based on in-situ fossil sites. In the past the collection were not in-situ and therefore provided a broad range of ages. DEM and 3-D models (using Arc-GIS 10.3) have been prepared to clearly correlate the different fossil sites within this area. During the field survey, one bone fragment bearing a possible cut mark by humans has been collected. The preliminary investigations of the alleged marks on the bone do not show any possible correlation with that of marks made by any animal activity such as that of hyena, rodent or lizard. Further, an in-situ microvertebrate fossil locality has been discovered in the Masol area. Maceration of 1.5 tonn of sample has yielded fossils of fish (teeth, spines, and scales), rodent (incisors) and frog for the first time. This study will provides a sturdy base for correlation and discussion in relation to the other Upper Siwalik localities for paleoclimatic, sedimentological and taphonomic processes that operated in the Plio-Pleistocene times.

Surface texture of quartz from a High Energy Coast, Thiruvananthapuram, SW coast of India

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The micro texture of Quartz grains in the beach sediments of Poovar- Varkkala Coastal stretch has been studied to decipher the variation in the morphology and the processes responsible. The Poovar -Varkala sector with the highest energy level is characterized by coarser to medium size. The Poovar-Adimalathura and Veli–Varkala beaches along the sector characterizes medium to coarser sand with a mean size of 0.80-1.84φ. The quartz grains of these area exhibit angular to subrounded outline. The beach sediment in the sector showed more subrounded outline except at Neduganda and Varkala. The dominance of angular grains at Neduganda-Varkala region suggests that the grains have undergone short transportation and rapid deposition representing a calm environment. The presence of abundant angular grains support a local source rock origin as suggested by Folk (1978). V-shaped patterns (V's), are present on many quartz grains in the sector and such features are characteristics of moderate to high energy subaqueous conditions as suggested by Margolis and Krinsley (1974) in their studies. It mainly occur on quartz grains from shallow marine, fluvial (high energy) and deltaic (seaward) environments (Higgs, 1979). V-shaped patterns result from both mechanical and chemical processes. V-shaped features of mechanical origin are caused by grain-to-grain collision in subaqueous environment when one grain strikes another (Manker and Ponder, 1978). Quartz grains of the sector also show features of silica precipitates which must have been formed by the precipitation of silica from the chemical solutions, due to longer residence of the sediments in the depositional basin. Chemical factory (Travancore Titanium limited) at Veli forms a major reason for the occurrence of abundant chemical features. Sediments in Open beaches and seawall dominated region undergoes either longshore or crosshore transportation. Besides the long shore drift, the sediments in the tidal inlets were transported to the area by fluvial and aeolian processes and subsequently deposited in the marine environment. Sediments in the pocket beaches divulge the winnowing action existing in the highly energy regime.

Sedimentological Investigation of the Glauconitic Sandstone Formation, Lower Vindhyan, Central India

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Glaucony is present in the lower part of the Vindhyan basin. It is represented as Glauconitic Sandstone Formation which is well exposed in the Newari area (Sonbhadra district) and Karvi- Chitrakoot area (Chitrakoot district), U.P, Central India. The Glauconitic Sandstone Formation in the area is around 13-15 m thick comprising alternate thick and thin laminated sandstone facies. Entire sedimentary package is homogenously green coloured because of finely disseminated silt and clay-grade glaucony. Presence of wave ripples, intermittent subaerial exposure features like wrinkle marks, shrinkage cracks, polygonal cracks suggests the deposition might have taken place in shallow marine tidal flat depositional environment. Petrographical facies shows abundant glaucony from olive brown fillings (nascent stage) to dark green granules (slightly evolved stage). These are basically clay-rich fine to medium grained, moderately sorted, arkosic silty sandstone. Strongly undulose monocrystalline quartz and abundant K-feldspar as fresh to completely altered grain suggests input from granitic Bundelkhand Gneissic Complex. Heavy minerals like magnetite, zircon, tourmaline (blue and brown), rutile, epidote and iron oxide reflect a mixed igneous and metamorphic provenance for it. XRD data is in consistence with petrographical finding showing glauconite, quartz, orthoclase, feldspar as the dominant minerals. Bulk rock chemistry shows dominance of SiO_2, Fe_2O_3, K_2O, and Al_2O_3. Glauconite is found as a replacement of K-feldspar which contributes towards higher K_2O content of around 5% that corroborates with the petrographical evidence of slightly evolved glaucony.

Hydrological and Sediment Connectivity in an Intermontane Valley: A case study from Dehra Dun, NW Himalaya

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A river acts as a 'conveyor belt' that connects various landscape units and moves matter, energy, and life. These landscape units can be categorised as sources, buffers and sinks. Transfer of materials between these units is not continuous, and its efficiency depends on the degree of connectivity. In the case of Ganga River the Himalaya acts as the major source zone. However, the sediment load studies suggest that a small yet significant portion of sediment produced in the Himalayas gets trapped in the buffer zones before the mountain exit. The intermontane valleys present in the frontal Himalaya are such buffer zones that store and evacuate sediments at different time scale. However, the sediment storage and movement in such valleys depends on their connectivity structure. In this work, we have explored the connectivity structure of Dehra Dun, an intermontane valley in the NW Himalaya. Dehra Dun forms small part of the catchments of two large Himalayan rivers—the Ganga and the Yamuna.

We have investigated (i) the channel width variations along the rivers of Dehra Dun, (ii) hydrological connectivity of three ungauged rivers—the Asan, the Song, and the Jakhan Rao—by estimating their bankfull discharge, and (iii) the evolution of gravel size and composition by analysing mid-channel bars of the same three rivers. The results of these analyses are compared to the connectivity index (IC) map of the study area. We found that northern part of the valley, i.e., the Lesser Himalayan Mussoorie Range, has greater potential to contribute to the two large Himalayan rivers than the southern part, *i.e.* the Mohand Range. However, in the northern part disconnectivity is introduced by various surfaces as they receive and store the sediment influx, and do not transfer them to the rivers flowing in the valley effectively. Further, the longitudinal connectivity along the rivers flowing in the valley is poor. Highly variable sediment fining rates along the studied rivers indicate that both abrasion and selective sorting play important role in sediment evolution. Selective sorting is a result of seasonal nature of the rivers in the valley. In the southern part, presence of dense forest hinders the connectivity between the Mohand Range and the trunk rivers in the valley. However, we conclude that because of the availability of huge amount of sediments and the proximity to the Himalayan mountain exit of the Ganga and the Yamuna rivers, Dehra Dun has potential to impact the sediment dynamics in these large rivers in the proximal Ganga plains.

Record on *Cervus* sp. (Artiodactyla) limb bones from lower Karewa Formation, Jammu & Kashmir, India

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The large, well preserved *Cervus* sp. Limb bones have been recovered from lower Karewa Formation, Khaigam, Pulwama District, Jammu & Kashmir, India which are represented by metatarsal, navicular cuboid, astragalus and calcaneum. The metatarsal is characterized by broad, distinct along the posterior and anterior surface both side of a long groove and differ from bovidae by one side of groove. The astragalus is characterized by distinct lateral and medial trochelar crest, sustentacular surface, subsustentacular fossa on posterior side and distinct navicular and cuboid trochlea on the anterior side which has close affinities with recent Cervidae astragalus. The *cervus* is known by two species i.e. *Cervus punjabiensis* and *Cervus sivalensis* on the basis of horn and dentition from lower Karewa Formation. The age of lower Karewa Formation is considered late Pliocene to early Pleistocene on the basis of published palaeomagnetic data (B.S. Kotlia, 1990) and Miocene to Pliocene on the basis of Diatoms fossil study (D.K. Roy, 1972).

Sources of the Paleocene sandstones of the Jaisalmer basin, Rajasthan, India

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The present study focuses on to determine the sources of the Paleocene sandstones of the Jaisalmer basin by using petrography, heavy minerals analysis and geochemistry. Petrography indicate that the sandstones are of quartzose-arenite nature with abundance of sub-angular to sub-rounded monocrystalline non-undulatory quartz and some amount of feldspar and rock fragments. The heavy minerals assemblages present in these sandstones are magnetite, zircon, tourmaline, kyanite and staurolite suggesting basic igneous and low- to medium-grade metamorphic rocks as the main contributor to them. The rock fragments are metamorphic and basic igneous along with limestone fragments. The ternary diagrams of Q-F-L and Qm-F-Lt suggest marginal cratonic interior and transitional continental provenance for the studied sandstones. Geochemical studies show that among major oxides, the SiO_2 shows highest concentration followed by Al_2O_3 and other oxides. The Log (SiO_2 / Al_2O_3) versus Log (Na_2O / K_2O) indicate sub-arkosic nature (quartzose-arenite of Okada, 1971) of the studied sandstones. Moderate to strong correlation exists between Al_2O_3 and other oxides such as K_2O and Na_2O indicating clay mineral control on geochemistry. The higher concentration of TiO_2 suggests basic igneous source for the studied sandstones with CaO rich cementing material. The A-CN-K ternary plot and CIA values suggest that the source rocks suffered low to moderate chemical weathering under sub-humid climate. The SiO_2 versus (K_2O / Na_2O) diagram suggest passive margin tectonic setting for the studied sandstones.

Dynamics of the Crust and the Upper Mantle beneath the Northwest Himalaya and Ladakh-Karakoram Zone, based on *Ps* and SKS Splitting

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The northwest Himalaya and Ladakh-Karakoram zone are located at the western extremity of the Himalaya-Karakoram-Tibet orogeny and provides a unique opportunity to study the interaction between the two continental plates. The dynamics of crust and upper mantle has been studied with the help of teleseismic earthquakes recorded by a network of 29 broadband seismological stations starting from the Himalayan Frontal Thrust (HFT) to the Karakoram Fault Zone (KFZ). Seismic anisotropy is a powerful technique to characterize the dynamic processes in the crust and upper mantle. We adopted shear wave splitting analysis of Moho converted *Ps* phases and core refracted SKS phases to characterise the anisotropic structure of the crust and upper mantle based on splitting parameters (fast polarization direction, FPD and delay time □*t* between slow and fast wave). Shear wave splitting of *Ps* phases in Satluj valley and LKZ predominantly shows NW-SE orientations. The NW-SE anisotropy in Satluj valley region suggests effects of orogeny parallel extension tectonics in response to NE oriented stress field owing to India-Asia collision. The anisotropy directions near the KFZ follows the trend of Karakoram Fault suggesting effect of dextral shearing of the KF. The SKS splitting analysis, on the other hand, shows a distinct variation along the study profile suggesting a complex source of anisotropy in the upper mantle. In the frontal part of the Himalaya, the FPDs are mostly parallel or sub-parallel to the strike of the Himalayan orogeny indicating effect of lithospheric strain induced by compression at the collision front. In contrast, over a large part of the Northwest Himalaya, NE orientated mantle anisotropy is observed that roughly coincides with the direction of absolute plate motion (APM) of the Indian plate supporting the asthenospheric flow model. In Satluj valley region, there is a contrasting difference of orientation of crust and mantle anisotropy suggesting mechanical decoupling. The FPDs in crust and mantle near the Karakoram Fault Zone (KFZ) are parallel or sub-parallel to the strike of the Karakoram Fault (KF). The study reveals that strike-slip or transpressional deformation in the lithospheric mantle in the KFZ is the major source of anisotropy beneath the KFZ. From anisotropic direction in the crust and mantle, it can be envisaged that the KF is a lithospheric scale fault that largely accommodates the India-Asia collision and extrusion in the Tibetan Plateau.

The enigma of Brahmaputra River paleo-course: Analysis based on field evidence and heavy mineral assemblages from Cenozoic deposits of Assam and Siwalik Basins, NE Himalaya

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The Brahmaputra River is one of the prominent river in the eastern Himalaya. There exist different perspectives regarding the paleo- drainage configuration of the Brahmaputra River. According to some researchers, Siwalik Group sediments were deposited by a drainage course like the present Brahmaputra River and recommended different timing for the establishment of the modern drainage pattern of Yarlung-Siang- Brahmaputra River System. On the other hand, the second group of researchers reflect the survival of a paleo- Brahmaputra River, initially flowing east of the Shillong Plateau, and consider that the present drainage configuration of the Brahmaputra River occurred when paleo- course of Brahmaputra River deflected from east to the west of the Shillong Plateau. Together with field evidence and heavy mineral assemblages we document the provenance for the Cenozoic sedimentary units of Assam-Arakan and Siwalik foreland basins. The work also provides new insights towards the drainage migration history of the paleo - Brahmaputra.

The documentation of some distinct heavy mineral species and the contrast in the profusion of heavy mineral assemblages in both the basins suggest a diverse source. The present study indicates two different rivers before upliftment of the Shillong Plateau. One flowing north of the present Plateau, that deposited the Siwalik sediments and the other flowing from the northeast deposited sediments in Assam-Arakan Basin. The study suggests rivers seem to have merged due to the combined effect of Plateau uplift and north-westward hinge migration of the Indo-Burman Ranges (IBR). Our detrital muscovite Ar-Ar thermochronometry and zircon U-Pb dating work in progress from these deposits will provide unequivocal insight towards a better understanding of the sources for these two foreland basins.

Exploration of "Frac Sand" in Cuddapah Basin, Andhra Pradesh

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Expanded oil and gas development in the world has driven demand for high quality industrial silica sand, also called "*frac sand*". Frac sand is high purity quartz sand with very durable and very round grain. It is a crush resistant material used in the oil and gas industry for hydraulic fracturing. Frac sand is also known as a "proppant" because it props the fractures open by forming a network of pore spaces. The uniformity of the sand particles enables petroleum fluids and gas to flow out of the rock into the well. So far alternative proppant ceramic beads made from sintered bauxite or small metal beads made from aluminum is used. The *frac sand* is natural proppant and cheaper than synthetic proppant. A high quality "*frac sand"* is resistant to crushing and comes in various sizes (0.1mm to 2mm in diameter).The most used *frac sand* in oil and gas industry is between 0.4 to 0.8mm in size. Rocks units composed of quartz grains that have gone through multiple cycles of weathering and erosion are potential sources of *frac sand* material. This is why sand from rivers and beaches is unlikely to produce a good product. Cuddapah basin located in Andhra Pradesh is of Proterozoic age and has undeformed western margin .It consists of Kurnool formation which is least disturbed and are nearly horizontal. The multicyclic sedimentation, transitional environment, aeolian, fluvial and near shore environment has given rise to the deposition of quartzite (orthoquartzite) and sandstones. The identification of sand with specific size and shape from these deposits can be used as "*frac sand"* which is in high demand globally.

Comparing River Exits of Active/Inactive Mountain Belts for River Flow Direction

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As a function of the steepest slope being perpendicular to any active growing fold belt, a river follows downstream over the regional slope of the land. Drainages likewise are expected to follow the slope perpendicular to the strike of the mountain front. In this study we look into 20 major river systems to analyze their drainage directivity and pattern from Google Earth imagery as well as SRTM DEMs (30 m) as they enter the plains in transition from a high to a low relief domain.

A link between the topography and the drainage can be observed in the 15 rivers along the boundary of the tectonically active Main Frontal Thrust and the Indo Gangetic Plains and 5 rivers along the tectonically inactive slopes of the Alps in Southern Europe.

The results of the analysis show that some present-day rivers do not flow perpendicular to the strike of the mountain exit rather and make an unexpected pattern of entry into the plains. These conformal and non-conformal drainages were further investigated and compared based on their channel characteristics, flow dimensions and longitudinal profiles.

These variations in drainage directions can be explained through the variation of geomorphic settings and channel parameters of each river system; such as the control of an alluvial fan geomorphic setting for river Kosi in Bihar and high slope channel gradient for the river Gola. It is concluded that in the case of tectonically active landscapes the tectonics at times can control the flow direction of the rivers in the downstream.

A comprehensive subsurface study of basal part of Tura Formation in the areas of Upper Assam Basin: Insights from Petrography and Whole Rock Geochemistry

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The Upper Assam Basin is bounded by Mishmi Hills in northeast, Naga Hills to southeast and Shillong plateau and Mikir Hills basement uplift in southwest. It is divided into two distinct blocks viz North Assam shelf (NAS) and South Assam Shelf (SAS) on the basis of structural style, and hydrocarbon potentialities. The North Assam Shelf (NAS) is separated from the South Assam Shelf (SAS) by E –W trending Jorhat Fault System. Stratigraphically, the Tura Formation is considered to be of Early Eocene age. It is the oldest sedimentary sequence in the Assam shelf and unconformably overlies Precambrian granitic basement. The basal part of Tura Formation cosists of poorly consolidated whitish grey, light brown to reddish brown, coarse to medium grained, friable sandstone with scour base intermixed with ferruginous clay clast.

The present work deals with the petrography and geochemistry of a few borehole samples of Tura Formation belonging to both North Assam Shelf and South Assam Shelf of Upper Assam Basin to establish the provenance, tectonic setting, source area weathering and redox conditions of the formation. Based on the modal analysis, the Tura sandstones are classified as quartz arenite, sublitharenite and lithic greywacke types. Plots of the chemical composition of these sandstone samples in tectonic setting discrimination diagrams suggest derivation of these detritus from craton interior and recycled orogenic provenance. Geochemical classification of the sandstone samples shows mostly wacke type and provenance discrimination plots of sediments based on major oxides depict that the sandstone of Tura Formation was derived from quartzose sedimentary rock source. The tectonic discrimination diagrams suggest a passive continental marginal setting for the sandstone. The chondrite normalized REE pattern of the samples is equivalent to the upper continental crust, which reflects enriched LREE and depleted HREE with negative Eu anomaly. The Eu/Eu* (~ 0.69), La/Sc (~ 5.69), Th/Sc (~ 2.84), La/Co (~ 10.89), Th/Co (~ 5.26) and Cr/Th (~ 5.22) ratios indicate derivation of the Tura Sandstones from felsic rock source. Furthermore, La-Th-Sc ternary plot, Th/Sc-Zr/Sc and La/Sc-Th/Co binary plots also suggest felsic igneous source rock for the sandstone. Chemical Index Alteration (CIA), Chemical Index of Weathering (CIW), Plagioclase Index of Alteration (PIA) and A – CN – K plot suggest moderate weathering of source rocks under arid climatic conditions. The geochemical parameters such as U, authigenic U, U/Th, V/Cr, Ni/Co and Cu/Zn ratios support the deposition of these sandstones take place under an oxic environment.

Ichnofossil studies of the Upper Siwalik sequences exposed between Ghaggar and Markanda River Section

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Trace fossils are structures produced by organism behavior and can be used to interpret the depositional environment, sedimentation rate, oxygenation of bottom water and the depositional energy in the system. Continental (fluvial) strata of the Upper Siwalik Subgroup, Punjab Sub-Himalaya, India, contain an invertebrate trace fossil assemblage sporadically distributed, generally in suites of low abundance, although at places the bioturbation index is high. Three major ichnofacies, namely *Scoyenia*, *Mermia* and *Termitichnus*, have been found in different well exposed sections of Dhok Pathan, Pinjor and Tatrot formations of middle and Upper Siwaliks respectively. Sampling was done along the road section, along the Markanda river valley from Kala Amb section, comprising Middle and Upper Siwalik *Skolithos* bearing mudstones and siltstones. In Devni Khadri *Ophiomorpha nodusa* were collected from the weatherd surface as they were strewed in mudstone of Tatrot Formation. The traces are found in mottled red and yellow mudstone; red and orange variegated pedogenised mudstones with bioturbated siltstone, thick paleosol and interbanded friable grey multi-storey sandstone thick interval of alternating pinkish red siltstone, which is intercalated with mudstone, and thickly-bedded buff and greenish coloured sandstone. The findings of ichnofossils typical of continental (fluvial) affinity unequivocally establishes presence of floodplains, levee and channel-bars of fluvial environments and low-energy overbank floodplain deposits. They are not only of palaeoenvironmental significance, but they add to the growing ichnofossil database in facies of fluvial origin and should be an impetus to further ichnological studies of the Siwalik Group.

Discrimination of the Holocene subfamilies of the Family Naticidae: A geometric morphometrics approach

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The family Naticidae Guilding, 1834, characterizes a group of marine, carnivorous gastropods, inhabiting the shallow waters from tropics to poles, globally represented by more than 2500 extinct and extant species. However, despite this abundance and ecologic prominence, the taxonomic status of the members of this family is rife with uncertainty, mainly because naticid shells are morphologically nondescript (Das et al., 2019). The taxonomic status of even recent species is problematic, and can only be resolved confidently by genetic data (Huelsken et al., 2006, 2008). Here we implement shape analysis using geometric morphometrics of 42 recent species representing 20 genera of four extant naticid subfamilies - Naticinae, Polinicinae, Globisininae, and Sininae – to test whether naticid subfamilies are indeed difficult to separate based on their morphologies alone, or do they exhibit different subfamily-specific morphospace occupancy. Additionally, two species of family Neritinae are considered as outgroup. 16 morphologically and phylogenetically important anatomical points (landmarks) frequently used by previous workers (Aronowsky, 2003; Das et al., 2019 and references therein) in differentiating naticid taxa, are used for the shape analysis. We use Principle Components Analysis (PCA) as ordination method to visualize shape variation within naticids, and for discriminating among subfamilies.

The first three PCA axes summarise approximately 67% of all variation. PCA 1 represents shells with broad umbilical areas, PCA 2 represents shells with short spires and elongated apertures, and PCA 3 characterises shells with wide body whorls (Figs. 1a-1b). In terms of Raupian parameters (Raup, 1966), along PCA 1, D increases, along PCA 2, aperture lengthens with low T; along PCA 3 W increases. The results show that: (1) despite apparent differences in shape, different subfamilies are closely clustering (Figs. 1a-1b), although Sininae is dispersed mostly away from the rest with partial overlap; *Sinum bifasciatum* plots as an outlier; (2) the subfamily Naticinae is tightly clustered at the center of the morphospace, while Polinicinae and Sininae show relatively larger morphospace occupancy. The other subfamily, Globisininae, plots very close to Naticinae and Polinicinae.

Based on the analysis, we draw the following conclusions: 1) naticid morphology is overall conservative, indicated by the clumping of almost all species in the morphospace; 2) despite taxonomic differences, there is considerable overlap of species from different subfamilies in the morphospace, so they cannot be segregated using morphological attributes alone; 3) regardless of superficial shape similarity, neritids are indeed dissimilar from naticid gastropods, as they plot as outliers. This among-family morphological disparity is independent of the longevity of the subfamilies: Polinicinae, despite being the oldest clade (Jurassic-Recent), shows an overall morphospace occupancy equivalent to Naticinae (age range?). The youngest subfamily Globisininae (Paleocene-Recent) also falls within the area occupied by Naticinae and Polinicinae. This study suggests that, for Holocene species of naticid gastropods, there is substantial morphological convergence, and to properly resolve naticid taxonomy we may need to incorporate other important morphological characters, along with genetic data (see Das et al., 2019 for a similar argument; Huelsken et al., 2006, 2008; Aronowsky, 2003).

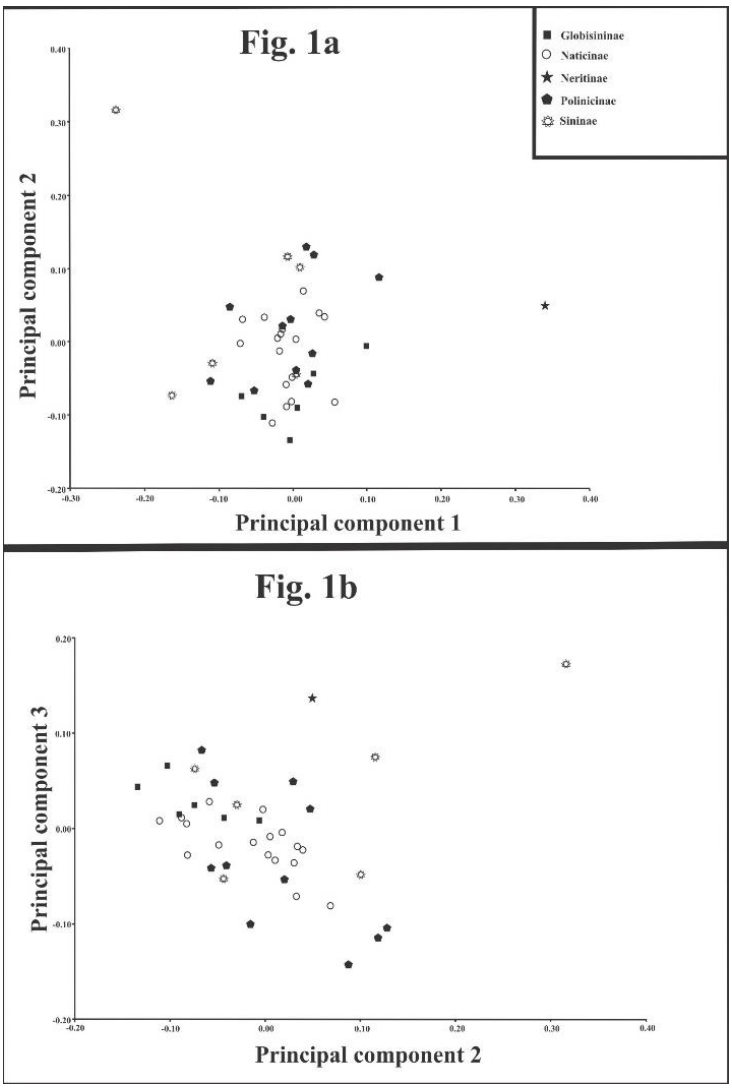

Fig. 1. Scatterplots of first three PC axes showing the relative positions of individual subfamilies. In both cases, subfamilies are closely clustered. 1a: the specimen at the top left is *Sinum bifasciatum*, and the two outgroup neritid species, *Nerita adenensis* and *Nerita antiquata*, plot together on the right end of the morphospace. 1b: *Sinum bifasciatum* still plots as an outlier at the extreme right, whereas the two outgroup neritids plot together high along the central region of the morphospace. Symbols for individual subfamilies are the same for both figures, as is indicated in the legend in figure 1a.

A new occurrence of *Deinothrium indicum* (mammalia, proboscidea, deinotheridae) from the Late Miocene of Kutch, India

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The Tappar beds from the Kutch basin, in western India are known for their rich mammalian and reptilian fossil assemblages. This section is thought to be from the Late Miocene age and consists of sandstone, siltstone and mudstone with intermittent conglomerate beds. During a recent field survey (2017-2018) of the Late Miocene deposits exposed around Tappar, an isolated right mandibular fourth premolar (P4) of *Deinotherium indicum* was recovered. South Asian deinotheres were first discovered on Perim (Piram) island in the Gulf of Cambay and described by Hugh Falconer in 1845. Since then, remains of deinotheres have been recovered from the Siwalik Group of India and Pakistan, the Dharmsala Group of India, the Manchars of Sind, the Gaj Series in the Bugti Hills of western Pakistan, Kutch in India, and in the Dang Valley in Nepal. The material under study is a large tooth with a tubercle on its outer border consistent with the morphology of *D. indicum*. The present specimen *D. Indicum* differs from *Prodeinotherium pentapotamiae* because the former is characterized by tubercles on the outer side of all the teeth of the lower series except the third premolar (P3), whereas no such tubercle can be traced in the latter species. We could not compare the present specimen with *D. orlovii*, since the hypodigm of the latter does not include a lower P4; only morphological characters of upper P3 and P4 are available. *Deinotherium indicum* is also known from Haritalyangar, where it occurs from 10-8 Ma. Given the presence of this species in the Tappar Beds helps refine the age estimates of the Tappar fauna to between 10 Ma and 8 Ma. *Deinotherium indicum* has sometimes been synonymized with *Deinotherium sindiense*. However, the holotype belongs to a small individual, and is metrically more similar to *Prodeinotherium pentapotamiae* than *D. indicum*. Indeed, the dimensions of the present specimen, and of other *D. indicum* specimens suggest that the two species are different.

Magnetostratigraphy of Deccan volcano-sedimentary sections from Jabalpur: implications for constraining age of lava flows

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The Deccan traps have been extensively studied during the last few decades as it coincide with K-Pg boundary and this has invited the attention of volcanologists, petrologists, geochemists and stratigraphers from various parts of the world. The basaltic volcanism occurred in three discrete pulses, the earliest one at ~67.5±1 Ma near the C30r/C30n transition and the following two at ~65±1 Ma, one entirely within C29r just before the K-Pg boundary and the other shortly afterward spanning the C29r/C29n reversal. The sedimentary successions associated with the Deccan lava flows are represented by Infra- and Inter-trappean beds. The infratrappean beds (Lameta Fm. in Jabalpur) occur below the local basal flows, whereas the intertrappeans, deposited during the dormant stages of the volcanic activity, occur intercalated within the lava flows.

Here we report the magnetostratigraphy of lava flows from different stratigraphic successions of Infra- and Inter-trappeans strata of Jabalpur and adjoining sections (Seonighat and Chui Hill Infratrappeans; Gaumukh, Mehadbani and Kohani Intertrappeans). This study is more vital as there are no paleomagnetic controls on the position of the intertrappean beds between the lava flows. The Seonighat infratrappeans comprises of limestone with burrows, mottled nodular and pebbly to granular limestone in ascending order overlain by lava flows of normal magnetic polarity with a mean ChRM of D=346°, I=-25°, a95=2.9 which corresponds to C30n chron. The Chui hill succession comprises of white-pinkish-violet kaolinitic clay layer which is fissile and splintery character, stratified fine to medium grained sandstone, mottled nodular limestone with burrows and nodules and granular to pebbly limestone in ascending order overlain by basaltic flows of normal magnetic polarity with a mean ChRM of D=339.2°, I=-19.8°, a95=5.5 (C30n). The Gaumukh succession comprises carbonaceous mud, fissile black shale and bioclastic limestone in ascending order overlain by basaltic flows of reverse magnetic polarity with a mean ChRM of D=168.3°, I=28.9°, a95=7.7, corresponding to C29r. The Mehadbani section displays a ~3 m intertrappean sediments (comprising chertified limestone) sandwiched between lower and upper basaltic flows. The paleomagnetic data revealed normal and reversal polarities for the lower (D=167.7°, I=54.9°, a95=5.0) and upper (D=348.4°, I=-37.7°, a95=2.1) lava flows respectively, which corresponds to both C30n and C29r chrons. The Kohani section displays a ~0.5 m intertrappean sediments (comprising chertified limestone) sandwiched between lower and upper basaltic flows and the paleomagnetic data revealed a polarity reversal for both the lower and upper flows with a mean ChRM corresponding to D=193.9°, I=64.3°, a95=8.8 (C29r). In summary, the magnetostratigraphic data of lava flows from Jabalpur sections encompass lower traps with magnetochron C30n (Deccan phase-1: ~6%; Mehadbani succession, late Maastrichtian) and upper traps with C29r (main Deccan phase-2: ~80%, end of Maastrichtian) straddling the K-Pg boundary coinciding with Bushe-Poladpur transition.

Mineralogy and Geochemistry of the Late Quaternary Palaeolakes sequences of the Ladakh region, NW India

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Ladakh is a high altitude region experiencing large diurnal temperature variation and receives scanty annual rainfall. This region comes under the Westerly's influence and in broad perspective differs from rest of the India, lying towards its South. The late Quaternary deposits of this region has witnessed various glacial (LGM, Dryas) and inter-glacial events (Holocene warming event). The palaeolake sedimentary sequences of this region preserve imprints of these climatic events. There are two schools of thought regarding the formation of palaeolakes in this region. While one favors the tectonic origin, the other held de-glaciation responsible for the formation of palaeolakes. The bulk mineralogy and geochemistry including the clay mineralogy of the lake sediments will be a handy tool to understand the earth surface processes including degree of weathering, palaeoclimate and provenance of the sediments. In my ongoing pursuit, few well date palaeolake sequences, ranging from LGM to Recent, will be studied to provide credible information on the processes and environmental condition operational in this region. This would help us to integrate geomorphological and tectonic framework along with the palaeoclimate and provenance to evolve a better picture understanding on this subject.

New Raoellidae (Artiodactyla) from the Subathu Group of Kalakot, Jammu and Kashmir, India and Their Palaeobiogeographic Implications

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The middle Eocene sequence of the Indian subcontinent is represented by Subathu Group of Kalakot J and K, Subathu —Dharampur, Himachal Pradesh, India and Kuldana Formation, Ganda Kas, Pakistan which are well known for its artiodactyls Raoellidae remains and reported by many palaeontologists. The main difference lie between the Pakistan and India faunas are predominance of Raoellids and perissodactlys in Kalakot area in comparison with the Dichobunids, artiodactyls of Pakistan. Outside Indian subcontinent there are some raoellids which are reported from the Middle Eocene Pondaung Formation of Myanmar and from Rencun, China. The Subathu Group of Kalakot area is most predominating by Raoellidae family which is divided into four genera we found a new raoellid genus and species on the basis of upper maxilla M1-M3 which totally differ from all known raoellids from the Indian subcontinent and from Myanmar and China by its smaller size, conical M1-M2 cusps, but low, bunodont M3 cusps and its bilophodont structure. The predominance of Raoellidae family from Kalakot area gives us fresh information about the taxonomic position of the new genus and alters our understanding of the origin, evolution, paleobiogeography and migration from the area in the past geological time. The study also throws light on the scope of gas, hydrocarbon and oil prospecting from the early Tertiary time.

Petrography of Siwalik sandstones from Kaladungi-Ramnagar area, Nainital district, Uttrakhand and its bearing on engineering properties

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The prime focus of this research is to study the petrography of sandstones from Siwalik subgroups of Kaladungi-Ramnagar area, Uttrakhand. These sandstones are fine to medium-grained and moderately sorted, and composed of quartz, rock fragments and feldspar as dominant mineral constituents. The accessory minerals include chlorite, zircon, epidote, rutile, illmenite, chromite, sphene, apatite and tourmaline. The groundmass matrix is less than 15% in general and also exceeds to more than 15%. The quartz and rock fragments are angular to subangular whereas those feldspar grains are sub-rounded. The Siwalik sandstones are classified as sub-lithic arenite and sub-lithic wacke. The relative abundance of mineral grains and textural parameters suggest that the Siwalik sandstones are immature to submature texturally as well as compositionally.

In order to assess the potential of constructing any civil structure on or within Siwalik sandstone, the physical and mechanical properties of similar rocks are determined viz. uniaxial compressive strength (25-60MP_a), were taken into account. On the basis of these compared results, sandstones of Siwalik Group are regarded as sufficiently moderate to strong and such sites are appropriate for construction purposes. Moreover, mineralogical and textural properties of Siwalik sandstones are also found to be suitable for construction material.

Theme II:
Geodynamics of the Fold Thrust Belts

Characterization of present day stress pattern in Himalayan-Tibetan collision province using Earthquake Data

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The Neotectonics of India-Eurasia collision zone is complex due to the active present day northward convergence of India, which leads to crustal shortening across Himalaya and crustal thickening of Tibetan terranes, followed by the reactivation of different structural features, manifested by large earthquakes all over the collision zone. In the present study, spatial distribution of contemporary stress field and stress regime in the Himalayan-Tibetan orogen, is addressed on the basis of earthquake fault plane solutions through stress inversion. To carry out the stress inversion for evaluating the regional stress field, we divided the study area into twenty nine seismotectonic sub volumes, along the trends of major active structures by carefully analyzing the seismicity, tectonics and faulting style of the region. Our results suggest that, the compressive stress dominates in subvolumes of Himalaya with low plunging N-S orientation, accompanied by a minor component of higher plunging E-W extension, which insights about the convergence of lithospheric plates and negative buoyancy of the slab; whereas Tibetan seismotectonic sub volumes experiences a low plunging E-W extension with a minor higher plunging N-S compression, exhibiting the signatures of wrench tectonics towards Eastern Tibet, induced by the resistance from East china block. The maximum compressive stress (SH_{max}) inferred in the present study is related to second and third order stresses, which is whole attributed towards the crust-mantle mechanical coupling undergoing in the Himalayan-Tibetan orogen.

Evidence of basalt-andesite-dacite-rhyolite (BADR) association in the Nubra-Shyok valley, NW Ladakh Himalaya, India: petrogenetic and tectonic implications for volcanic arc magmas.

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Coexistence of basalt-andesite-dacite-rhyolite (BADR) has been observed within the Khardung volcanics of the Nubra-Shyok valley, north-western Ladakh Himalaya, India. The interesting fact of this volcanic suite is the present geological position with the Shyok suture zone, which gives an attention to many geologists to understand whether they are a part of the Shyok ophiolitic sequence or Shyok volcanics. Over the past studies, it has revealed the subduction origin of these volcanics, but variable thoughts still lie regarding the magma source(s) and their genesis. The present study has made an attempt to understand the petrogenesis and magmatic process of BADR association and their relationship with each other based on their petrological and geochemical significance. None of the earlier works had studied the geochemistry of this BADR association of the Khardung. This study reveals that the felsic volcanics (dacite-rhyolite) show silica rich (64.75-79.11 wt. %) magma with relatively strong enrichment of LREE and LILE (Rb, Ba, K, Pb) elements, and higher depletion of HFSE elements (Nb, P, Ti) with pronounced Eu negative anomalies. The intermediate (andesite) with mafic (basalt) volcanics display silica low (53.39-62.05 wt. %, and 50.80-51.81 wt. %) magma with lower enrichment of LREE and LILE (Rb, Ba, K, Pb) and less depletion of HFSE (Nb, P, Ti) with feeble Eu depletion as compared to the felsic volcanics. Additionally, the geochemical studies constraint the petrogenesis of the BADR association indicating that the fractional crystallization combined with crustal assimilation were the dominant processes during their genesis, and they were generated contemporaneously in nature, on an active continental margin arc environment. The new study of zircon U-Pb ages of Khardung rhyolite and andesite (under review) samples yielded 66.55±0.42 Ma and 69.7±0.42 Ma along with earlier published zircon U-Pb ages 67 Ma and 60 Ma suggesting that the *eruption* of these BADR magmas *took place* within a *short time* period of ~10 Ma. Thus, the felsic volcanics (rhyolite) of the Khardung were crystallized in the early magmatic episodes followed by intermediate volcanics (andesite), and generated due to the fractional crystallization along with assimilation by continental crust on an active continental margin arc environment prior to the collision between India and Asia.

Geochemical and zircon U–Pb geochronological constraints on magmatic evolution of Karakoram batholith from eastern Karakoram, India

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Whole rock geochemical analyses along with laser ablation multicollector–inductively coupled plasma–mass spectrometry (LA-MC-ICPMS) U-Pb ages of the Karakoram Batholith sequence exposed along upper Shyok valley, NW India, have been carried out to understand its geochemical and magmatic evolution. The new isotopic dating results of granitoid and rhyolite rocks along with previously published records indicate that the Karakoram Batholith (KB) evolved during Albian (~110-100 Ma) period due to the subduction of Tethys oceanic lithosphere along the SSZ. The Karakoram block has witnessed a quiescent period of magmatism at ~99-85 Ma after which Kohistan-Ladakh and Karakoram were evolved as a single block in Late Cretaceous and early Paleogene. Our new results demonstrate that the Karakoram batholith evolved as a distinct unit in both the regions of eastern as well as the western Karakoram during ~110-100 Ma. Late cretaceous (~85 Ma) rhyolite intrusions within KB show calc-alkaline subduction-related signatures with highly peraluminous nature (A/CNK=1.42-1.81). This suggests that the volcanics have undergone crustal assimilation fractional crystallization (AFC) during ascent of the magma. This characteristic of rhyolitic magma was attained due to mantle wedge derived melts at the active continental margin of the Karakoram. Two granite samples from the contact of Shyok metamorphic complex (SMC) and KB indicate the post-collisional Miocene magmatism not only confined along the Karakoram Fault (KF) zone but extends beyond ~30 Km from Shyok-Muglib strand.

Geodynamics of Bimodal volcanic rocks from Betul Fold Belt, Central India

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The Meso-Proterozoic Betul Fold Belt (BFB) is one of the major supracrustal belt trending E-W in the Central Indian Tectonic zone with Mahakoshal belt in the north and Sausar belt in the south. It predominantly comprises of three distinct rock types- Baragaon group of supracrustal rocks, Padhar mafic-ultramfic suite, Syn-post kinematic granites. The present study deals with Baragaon group which comprises bimodal volcanic rocks of the supracrustal suite and their associated Volcanogenic Massive Sulphide Mineralisation. These bimodal volcanic rocks were also encountered at Sarni (part of Padhar intrusive complex), where shallow borehole drilling was done by NGRI. The bimodal volcanic rocks have undergone lower amphibolite facies metamorphism and mainly comprise of voluminous dacitic-rhyolitic rocks with minor subalkalic basalts-basaltic andesites. The basalts are both pillowed and non-pillowed while the rhyolites vary from grey to pink varieties. The meta-basalts exhibit intergranular to pophyritic textures while the meta-rhyolites display porphyritic texture with the phenocrysts of plagioclase, K-Feldspar and quartz with minor amount of biotite, chlorite, Fe-Ti oxides as accessory phases. The basalts are presumably formed from partial melting of enriched subcontinental lithospheric mantle where the melting could have intitiated in the stability field of spinel peridotite. The negative Eu anomaly in the basalts indicates that there is significant contribution of subduction zone sediments during magma generation. The felsic rocks are characterized by feebly negative Eu anomalies due to fractionation of amphiboles and titanites as the removal of Eu and Sr by plagioclase crystallization is delayed in water rich environment. The generation of silicic rocks is accounted by fractional crystallization of mafic magma and induced crustal anatexis. The magma generated is tholeiitic in nature. The rhyolites are classified as FII type based on their geochemical signatures which show moderate Zr/Y values ranging from 0.7 to 5.8; $(La/Yb)_N$ ranging from 2.9 to 34.0, along with strong subduction signatures indicating the they have been formed at shallow depths (~30 km) with amphibole and plagioclase residue. The basalts plot in Andean arc field which corroborates with the continental arc setting. The rhyolites host sulphide mineralization which includes pyrite, chalcopyrite, sphalerite and pyrrhoite with gangue of quartz, amphibole, biotite and chlorite. The sulphide mineralization is predominantly Cu-Zn type in this region. The current study shows that the Betul bimodal volcanic suite has been emplaced in the continental arc setting and a preliminary petrogenetic model is proposed.

Field character, petrography and petrogenesis of Pan-African granites in Coimbatore and erode districts of Tamilnadu, India

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A number of Pan-African granites are exposed in Northern Granulite Belt of central Tamil Nadu. These granite bodies run parallel to Moyar-Bhavani-Attur shear zone and intrude into hornblende biotite gneiss, charnockite and older basic / ultramafic rocks. Three types of granites have been demarcated viz., medium to coarse-grained granite, medium grained leuco-granite and pegmatoidal granite. Megascopically, these granites show almost similar character. It is emplaced as different stock for about 150 km in linear fashion from east to west. Their size varies from a few hundred metres to few kilometres in length and 5m to 250m in width and are massive to weakly foliated. It exhibits compositional variation *viz*., alkali-feldspar granite, syeno-granite, monzo-granite and grano-diorite. These are medium to coarse-grained, equigranular, leucocratic and essentially made up of quartz (40%), alkali feldspar (25–40%), plagioclase feldspar (10–40%) and biotite. Apatite, zircon and tourmaline are the accessory minerals. Quartz crystals show anhedral nature. Plagioclase is mostly sub-hedral (oligoclase-andesine). The alkali-feldspar represented by orthoclase and microcline. Chemically, these are calc-alkaline in nature, peraluminous to metaluminous and exhibit higher SiO_2 and total alkali. The Chondrite normalised REE pattern indicates enrichment of LREE. The geochemical attributes are comparable with S-type granites. The mechanism of emplacement of this granite is mostly passive type and is post-kinematic in nature. Most of the granites were generated by partial melting of older continental crust between 450 – 510 Ma. Significant crustal component was involved in the generation of these granites as indicated by high initial Sr ratio (0.71214).

Deformation rates and fault mapping of Surin Mastgarh Anticline, Jammu and Kashmir, India: evidences from field, tectonic geomorphology and Stream Length Gradient Index

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In the sub-Himalaya, strain release is mainly by major earthquakes that are caused by surface faulting along the Himalayan Frontal Thrust (HFT) or by out-of-sequence thrust. When earthquake fails to produce surface faulting, the strain is being accommodated in the form of fold scarp. Toward understanding the pattern of strain release rate, we studied Surin Mastgarh anticline (SMA) that marks the southern limit of non-emergent sub-Himalayan frontal fold belt of Jammu &Kashmir. SMA extends along its strike for ~200 km in length continuously, between Rivers Beas in the east and Munawar-Tawi in the west, without producing fault on its forelimb (i.e. southern limb).

We estimate geological shortening rate of SMA using fluvial strath terraces along River Chenab which flows across the growing anticline. The different levels of terraces were surveyed using high resolution RTK-GPS. The long profiles of terraces suggest that they have been progressively folded and uplifted above the current grade of Chenab River, with focused uplift along its fold axis. Considering the abandonment age of these terraces calculated using Optically Stimulated Luminescence, we infer geological shortening rate across the SMA as ~4-6 mm/yr with ~2 mm/yr vertical uplift rate at the hinge. Our results together with seismic data suggest that SMA is a through going simple detachment fold, without ramp structure beneath it. The SMA consumes ongoing shortening with active flexural slip faulting along either limb.

The stream length index (SL index) study was conducted along the seven major rivers that cut through SMA. The SL index results justify the field observations, suggesting the active growth of the anticline. Also, outboard of the mountain front in the alluvial plain, a continuous drainage anomaly is observed parallel to the regional structure indicating the subsurface deformation. The deformation pattern in this segment is higher in the hinterland whereas in central Himalaya deformation is focused along MFT.

Tectonic controls on river morphodynamics across Naga-Patkai thrust belt of Upper Assam foreland basin, India

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Dynamics of landscape variability is controlled by both surface and subsurface causes. The changes in surface topography are influenced by geomorphic features collectively or individually. The subsurface causes play very significant role in topography variation particularly in those areas which are tectonically active. The Upper Assam foreland basin is surrounded by the Himalayas and the Naga- Patkai ranges. Most of the prominent oil fields are located along the south bank of the Brahmaputra River having a well-established tectonically active margin, the Naga Patkai Thrust (NPT) belt. Some of the well preserved palaeo-channels are there on the valley relief showing avulsive trend of the major tributaries of the Brahmaputra in recent past. However, comparison of the plano-temporal variability of the tributaries belonging to the north bank and the south bank during the period 1915-2015 shows a comparative stability of the south bank rivers. Available literature shows that the topographic features are controlled by at least three major components- the aggradational processes, NPT induced lateral structural controls and of course the basement guided vertical component of movement. In the present work, four south bank tributary rivers of the Brahmaputra, namely, the Burhidihing, the Disang, the Dikhow and the Dhansiri, flowing across the thrust and over the foreland part of the valley are selected to take up some of the basic morphometric studies. Uniform corridors, each of 2.5 km width parallel to the NPT was chosen with the assumption that the thrust induced tectonic control is regional in scope and successive triggering influence all these rivers. Hence, a correlative measure can be taken up based on river morphology and the plano-temporal variability of a number of rivers flowing side by side at shorter intervals to take up a morpho-tectonic zonation of the foreland areas of a basin which can provide a handle to understand the tectonic controls and possibly the impact of those controlling elements on the mode of oil migration.

Platinum Group of Elements (PGE) geochemistry in mantle peridotites of the Indo-Myanamr Orogenic Belt ophiolites, Northeast India

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Platinum Group Elements (PGE: Os, Ir, Ru, Rh, Pt, Pd) in ophiolite suite of rocks provide important insights into the evolution of the mantle and crust-mantle interaction. They have similar geochemical behaviors during magmatic processes. PGE geochemistry can be used to obtain information on the genesis of the particular ophiolite complex, its geotectonic setting, and the chemical-physical conditions prevailing in the mantle during ophiolite formation. Three processes; that is, partial melting, crystal fractionation and alteration, possibly control the PGE in magmatic rocks. In this paper, we present the PGE data of mantle peridotites from the ophiolites of Indo-Myanmar Orogenic Belt, northeast India in order to understand PGE fractionation behaviours during magma evolution. The study area is predominantly consists of mantle-derived peridotites consisting of harzburgite, lherzolite, wehrlite, dunite with basic rocks and minor amount of chromitites. The investigated peridotites range from lherzolite to bearing harzburgites, and they are barren of any sulphides. Lherzolite, which is the dominant lithology, consists olivine (Ol; 30–49 modal %), orthopyroxene (Opx; 11–19 modal %), clinopyroxene (Cpx; 21–32 modal %) with 1–2 modal % Cr-spinel, whereas harzburgite contains 46–68 modal % Ol, 29–43 modal % Opx, 4–5 modal% Cpx and 2–3 modal % Cr-spinel. Both the rock types exhibit porphyroclastic texture and deformation features such as undulatory extinction, strain lamellae and kinking, indicating the rocks are tectonites. Kink bands and undulatory extinction are displayed by both clinopyroxene and orthopyroxene pophyrocrysts. At places, orthopyroxene grains are surrounded by olivine and clinopyroxene grains and are altered to greenish chlorite and serpentine. PGE with Au concentrations were determined by NiS fire-assay in combination with HR-ICP-MS technique. The peridotites shows lower concentration of PGE (Rh < 2 ppb; Pd < 25 ppb; Re < 16 ppb; Pt = < 10 ppb; Au < 28 ppb; Os < 9 ppb; Ir < 3 ppb; Ru = 5-11 ppb). The depletion of IPGE relative to PPGE observed is consistent with inter-element fractionation development in response to preferential retention of the IPGE in the magma source regions or co-precipitation with early fractionation ferromagnesian silicates. The constancy of the ratios Ir/Os, Ru/Os, Ru/Ir suggests that these elements were in thermodynamic equilibrium during the crystallization. Their variable mantle-normalised PGE patterns in conjunction with the Pd/Ir and Pt/Pt* values are affinity to the characteristic of residual mantle material. Thus, it is suggested the mantle peridotites from the ophiolite of Indo-Mynamar Orogenic Belt, northeast India might have derived by varying degree of partial melting rather than magmatic fractionation.

Morphotectonic investigations of Ganges-Brahmaputra river basins: Tectono-eustatic insights into the zonation of valleys

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The Himalayas represent one of the largest and the longest active continental collision orogenic belt which started forming about 50 million years ago and is still supposed to be at its youth at best. The orogen forming tectonics has great impacts in the formation and modification of the adjoining regions. Morphodynamics of the rivers originating in the belt of orogeny and draining the adjoining valleys and subsequently meeting the seas must be controlled by different principal *forcings* in different reaches. In the present work, we have hypothesised that Active Mountain fed big rivers flow across three major zones of valleys - *orogeny induced*, *eustasy controlled* and an intermediate *sedimentology controlled* transition zone. Morphology and plano-temporal variability of big river systems can act as effective proxies in the zonation of valleys in the light of tectono-sedimentary-eustatic processes. Morphometric studies help to understand the impact of tectonics in basin modification; flooding of rivers, dispersal of flood plain deposits and eustasy induced changes in the valley relief. In the present study, morphotectonic investigation for two big river systems, the Ganges and the Brahmaputra, originating from the identical source as well as terminating at the identical sink was taken up as a complementary means to differentiate valley relief based on the nature of principal controls.

Deformation patterns in the Main Central Thrust Zone (MCTZ), Bhagirathi valley, Uttarakhand Himalaya

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The Main Central Thrust Zone (MCTZ), a <2km to 15 km wide ductile shear zone, places the Higher Himalayan Crystallines (HHC) over the Lesser Himalaya (LH). This study revisits the geology and structures of the MCTZ by high resolution mapping at scale ranging from 1:10,000 to 1:50,000 and using structural analysis techniques along the Bhagirathi River from Sainj to Gangnani in Uttarakhand Himalaya.

The existing geological maps of the region, indicating the rock type and position of lower and upper MCT, are given by Valdiya, 1981, Jain et al., 2002, Srivastava and Tripathi, 2007 and others. In previous studies, the Vaikrita Thrust has been defined on the basis of change of grade of metamorphism and the evidences from the isotopic and geochronological studies. Whereas the Vaikrita Thrust outcrops distinctly in some sections, its delineation in other parts of the MCTZ is difficult. In this study, we delineate the Vaikrita Thrust on the basis of detailed geological mapping and structural analysis. Based on high resolution mapping we demonstrate the precise positions of Munsiari Thrust (MCT-I) and the Vaikrita Thrust (II) on the map. We report the occurrence of well-exposed imbricates of granite gneiss of the Munsiari Group and the psammo-pelitic schist of the Vaikrita Group in the MCTZ. A distinct 200-300 m thick phyllonite zone marks the Vaikrita Thrust zone in this section. Structural analysis reveals two common orientations of foliation planes, which show discordance with each other, one set dipping towards NE while the other towards NNW. Stretching/mineral lineations plunge about 55°-60° towards NE. Whether these two foliation sets represent S and C planes in the ductile shear zones remains uncertain and more field evidences need to be collected in order to ascertain our assumption. Thus, in combination with metamorphic grade, isotopic and geochronological criteria, detailed geological mapping and structural analysis of the MCTZ become additional criteria in the identification of the Vaikrita Thrust.

Petrogenesis of ultramafic cumulates and associated mafic intrusives from the Tuting-Tidding Suture Zone ophiolites, Eastern Himalaya, India: Implications for the presence of a fossil forearc regime

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Ophiolites are considered to be remnants of the oceanic crust which have obducted into the continental crust due to collisional orogeny. Study of ophiolites reveal that many of them have formed in a subduction related environment and many show geochemical signatures similar to modern-day forearc settings. In this study, we present the geochemical and mineral chemical data of ultramafic cumulates and mafic intrusives of the Tuting-Tidding Suture Zone (TTSZ) ophiolites of Eastern Himalaya which is extension of the Indus Tsangpo Suture Zone (ITSZ) to understand their petrogenesis and tectonic evolution. Dismembered outcrops of ophiolitic affinity are exposed along the Lohit and Dibang section of east Arunachal Pradesh. The rocks are highly altered and serpentinized with considerable deformation. They appear to have undergone up to lower amphibolite facies metamorphism and also exhibit evidences of deserpentinization. From the modal mineralogy, and chemical compositions like low CaO and Al_2O_3 values, high forsterite number ($Fo_{89.6-97.6}$) in olivine, Cr-spinel core compositions (Cr# - 0.90 and 1.0) and trough shaped REE patterns, it is suggested that the ultramafic cumulates of the TTSZ unit were generated by the partial melting of a spinel-lherzolite source to form boninitic magmas followed by interaction of the generated melt with the mantle wedge peridotite at the forearc region of the subduction zone. The mafic intrusives, on the other hand show similarity to the N-MORB with respect to REE patterns (almost flat with slight enrochment; La_N/Yb_N = 1.49 to 2.58) and low total REE (ΣREE = 23.34 to 59.12). These evidences combined with the trace element modelling and mineralogical assemblage suggests that the mafic rocks of TTSZ have formed probably due to moderate to high degrees of partial melting of a spinel lherzolite source with enrichment from the subducting fluids during spreading in the forearc region. Thus a two stage petrogenetic approach is suggested for the ultramafic and associated mafic rocks of the TTSZ ophiolite unit. The first stage incorporates derivation of substantially depleted peridotites from a possibly boninitic to high-Mg tholeiitic magma source in an intra-oceanic supra-subduction zone environment. The second stage saw the generation of mafic intrusives during fore-arc spreading by partial melting of a spinel mantle source with trace element enrichment from the subducting fluids.

Deformation of the Lower Gondwana rocks in and around Sessa, Kameng River Valley, Arunachal Himalaya

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The Lower Gondwana rocks of West Kameng District Arunachal Pradesh is the only example of Indian extra-penninsular continental Gondwana. These sequences in the hanging wall of Main Boundary Thrust (MBT) suggest the deformation due to strong N-S horizontal compression during Indo-Asia collision tectonics. Deformed metasedimentary rocks of Gondwana exhibit meso to micro scale structural features in response to and in conformity with the foreland propagating thrust sequence. The MBT separated the Gondwana Group from younger Siwalik Group. The Gondwana sequence is overridden by Bomdila Group of rocks along Bomdila Thrust (BT). Lower Gondwana rocks of the study area have been stratigraphically subdivided into Bhareli formation and Bichom formation. The Gondwana rocks are intensely deformed and also very weakly metamorphosed, which produce numerous deformation structures at micro scale and signatures are found in outcrop scale also. The continental Bhareli formation is lithologicaly, felsdpathic sand dominated, silt and coal bearing shale layers, but the marine Bichom formation is shale dominated with sand and silt layers. The outcrop to grain scale structural features indicate lots of ductile-brittle fabrics and ramp and flat geometry. The flexural folding both in outcrop and grain scale are ubiquitous. We construe the deformation pattern due to thrust loading and numerous brittle ductile shear zones are a Schuppen like structure.

Morphotectonic forcings in the foreland areas of the Eastern Himalayas and its impact on Dibru-Saikhoa window - A GIS based study using geological and geophysical data

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Geomorphic highs in tectonically controlled river basins are on occasions responsible for the formation of riverine relict islands. The principal feature of these islands is that at certain points of time, these used to represent much older flood plains which came within the folds of certain river systems showing a combination of anabranching, avulsions and bank line migration. Thus, these islands are older in age compared to the age of a river at a given location. The relict island of Dibru-Saikhowa is situated in the upstream reaches of the Brahmaputra River. The regional tectonic setting of the study area is constituted of the Eastern Himalayas to the north-west, Naga-Patkai hills to the south-east, Mishmi hills to the north-east and Mikir hills in the south west. The stratigraphy of the area suggests that the Himalayan foreland basin is constituted principally of Tertiary and Quaternary sediments and a thick repository of the recent alluvium. The Lohit river, which is a southern bank tributary of the river Brahmaputra, used to meet the river at a place near Bairagi Chapari till 1987, however the confluence point shifted about 20km downstream by 1997, during the flood of 1988 one small channel of the Lohit River captured the Dangori River and with time Lohit started flowing along the captured channel leading to the development of the Dibru-Saikhowa island. Our observations suggest that the structural forcings responsible for the formation of geomorphic highs in areas lying in and around the active convergent basin margins can broadly be classified into three categories; *basement controlled*, *peripheral thrust belt controlled* and *base-periphery combo control* types. This study is focused on the identification of the tectonic forcings acting on the Dibru-Saikhoa window based on analyzing plano-temporal changes during 1915-2015, lateral shallow subsurface variability based on seismic refraction data and basin scale study based on seismic reflection data. We have three major findings. First, major relict islands of the Brahmaputra valley are structurally controlled; secondly, valley topography and the basement topography in the Brahmaputra valley are having either positive correlation or negative correlation; thirdly, tectonic forcing characteristics for the Majuli and the Dibru-Saikhoa islands are different - the first one is basement controlled and the second one comes under base-periphery combo control category.

Imaging crustal structure beneath the Kumaon Himalaya based on receiver function modeling and CCP stacking

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Crustal structure beneath the Kumaon Himalaya has been studied based on *P*-wave Receiver Function (RF) analysis of teleseismic earthquakes recorded by a network consisting of 18 broadband seismological (BBS) stations. The locations of the BBS stations cover the major litho-tectonic boundaries of the northwest Himalaya starting from the Himalayan Frontal Thrust (HFT) to the Vaikrita Thrust (VT) passing mostly along the Kali River valley. The H-*k* stacking analysis has been applied to obtain average crustal thickness and Poisson's ratio (ν) beneath the stations. The study reveals low value in the Outer Lesser Himalaya and comparatively higher value of ν in the Inner Lesser Himalaya. The H-*k* stacking analysis and the RF inversion reveal that the crustal thickness is ~38 km near the HFT which increases to ~42 km near the VT suggesting a nearly flat geometry of the Moho. A Common Conversion Point (CCP) stacking image of the RFs along the Kali River valley has been constructed to trace the geometry of Moho as well as intra-crustal features. A prominent low velocity zone (LVZ) in the lower crust (at ~30-40 km depth) has been detected both in the inverted models and CCP image particularly in stations of the Inner Lesser Himalaya and Higher Himalaya. The seismicity in the region has been studied with the help of local earthquake data recorded during 2016-2018 by our network as well as data from ISC-EHB catalog (1950-2008). The presence of the LVL as well as high Poisson's ratio observed beneath stations of the Chiplakot Crystalline Belt (CCB) suggests presence of partial melt at lower crustal depth which is coincident with a large number of micro-to-moderate magnitude earthquakes forming a cluster at shallow to mid-crustal depths. The presence of fluids influences the rheological property and controls the mechanical and shear strength of crustal rocks producing the cluster of seismicity observed beneath the CCB.

Petrological characteristics of mafic plutonic rocks in Neo-Tethyan Naga Hills Ophiolite Sequences, NE India

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The ophiolite sequences of Naga hills, considered as a part of Indus Tsangpo Suture zone ophiolites, represent both, mantle section and crustal section. This ophiolite sequence is also comprised of variably altered oceanic rocks including marine sediments. Mantle section of Naga Hills Ophiolites (NHO) consists mostly of spinel Lherzolite and harzburgites with dunite and pyroxene bodies whereas thee crustal part, represents by mafic intrusives of gabbros affinity. From east to west, the ophiolite and associated rocks are broadly classified into three distinct tectono-stratigraphic units, viz., i) The Nimi formation consisting of low to medium-grade accretionary wedge metasediments of possible Mesozoic age, ii) ophiolitic suite of rocks and iii). Disang formation consisting of a thick pile of folded late Cretaceous-Eocene flysch-type sediments. This paper aims to provide an overview of the petrological characteristics of gabbroic rocks exposed in the NHO. The investigated mafic intrusive rocks are medium to coarse-grained, exhibit equigranular and sub-ophitic textures and are predominantly composed of plagioclase, clinopyroxene and Fe-Ti oxides. However, a few samples contain minor amount of hornblende. The average modal abundances of the constituting mineral phases are estimated to be 68-70 vol. % plagioclases, 23-32 vol. % clinopyroxene, 3-7 vol. % hornblende, 2-5 vol. % Fe-Ti oxides and chlorite, epidote and sericite are secondary components. Plagioclases occur mostly as tabular and laths and mostly un-zoned with corroded margins. Clinopyroxene occurs as euhedral to subhedral phenocrysts and either colorless or moderately pleochroic in green to yellowish purple. Euhedral hornblende crystals enclosed within a clinopyroxene phenocryst are observed. Based on petrographical characteristics the investigated mafic plutonic rocks have been identified as hornblende-barren mafic intrusive and hornblende-bearing mafic intrusive rocks. Geochemically, hornblende-barren mafic rocks are having mid-oceanic ridge basalt (MORB) composition characterized by comparatively higher values of TiO2 (<1.93 wt.%), K2O(<1.138 wt.%), P2O5 (<0.15 wt.%) and their SiO2content ranges from 42.73 to 50.22 wt.% with flat REE patterns (LaN/YbN= 0.76–1.51). Whereas the hornblende-bearing mafic rocks show distinct geochemical features of Supra-Subduction Zone (SSZ) type tholeiitic composition with low Ti content (TiO2 < 0.86 wt.%) and depleted LREE pattern with respect to HREE (LaN/YbN= 0.370.49). Thus, our field evidences in conjunction with the geochemical data, suggest that the MORB type mafic rocks of the study area represent the section of relatively older oceanic crust which was generated at mid-ocean ridge tectonic setting whereas the hornblende-bearing mafic rocks (SSZ-type) of the study area represent the younger oceanic crust, formed at the early stage subduction of the Indian plate beneath the Myanmar plate.

Shear sense indicators in the rocks of South Delhi Terrane near Sai-Pindwara region district Sirohi, Rajasthan

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The Mesoproterozoic period Delhi Supergroup (DSG) trending NE-SW is an important unit of Aravalli Mountain Range which flanks on the western edge of Indian shield and unconformably overlies the Aravalli Supergroup which has been dated between 1800-1500Ma. The rocks of Delhi Supergroup cover an area from southwestern, central and north-eastern Rajasthan. The deformation and metamorphism vary over the entire Delhi basin, where major part contain polyphase deformation (Roy and Jhakar, 2002). The DF1 produce isoclinal fold, DF2 having steep or vertical axial plane. Interference of second and third generation fold produce series dome and basin (Roy and Das, 1985)

DSG is divided into two major terrains in terms of their variation in litho assemblage, depositional environment, deformational pattern and grade of metamorphism. The group is divided into North Delhi Terrane (NDT) and South Delhi Terrane (SDT) on the basis of age constraint of the thermal event (Sinha-Roy, 1984). The North Delhi Terrane (NDT) of northern Rajasthan, encompasses E to W, from Bayana- Lalsot, Alwar and Khetri segment, and the South Delhi Terrane (SDT) runs as a linear segment from Pushkar lake in the north of Ajmer to northern Gujarat. The rocks of SDT is divided into two groups lower Gogunda Group which is arenaceous and correlated with Alwar Group and upper Kumbalgarh Group which is argillaceous and arenaceous correlated with Ajabgarh Group (Gupta et al., 1980). On the eastern part, SDT rest over the rock of Sandmata Complex and on the western side marked by Phulad Lineament.

The study area Sai-Pindwara is the part of SDT consist of granitoids (include massive leucogranite and granite gneiss), calcareous metasediment, quartzite, and Amphibolite. The area contains Basantgarh Formation of Kumbalgarh Group. The Regional Map of the study area has been prepared on the scale 1:50000 with the help of LANDSAT-8, Digital Elevation Model- SRTM, Google Earth imageries and Survey of India Toposheets (45H/1, 45H/2) along with regional field verification. Minor lineament (Geomorphic and Structural) has been manually extracted using Landsat imageries and processed in QGIS and rose diagram prepared in QGIS software for the orientation of the lineament, which is showing NE-SW direction similar to the Regional trend of SDT.

The minor lineaments are mostly concentrated in the eastern portion in granitoids and calc-silicates and may be related to the deformations preserved in the region. On the eastern side of the map near kayari on the macroscopic scale, upright folding, ptygmatic folding are present in calc-silicate rock while on the western part, near shear zones, dominating the region on macroscopic scale rotation of rhombohedral shaped boudin, pinch and swell structure and formation of δ type porphyroclast are shear sense indicator in the calc-silicate rocks and on microscopic scale highly sheared carbonate and sheared quartzite are observed. The lineaments and the megascopic and microscopic shear sense indicator are suggesting shearing along the lith-contacts.

Are the Rivers along drainage divide between the Ganga and the Narmada basins in Equilibrium?

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River networks are dynamic systems, which are sensitive to any kind of perturbations forced by tectonics or climate. Drainage divides of two adjacent river systems migrates, by the loss or capture of streams on both sides along a divide attaining equilibrium. In this scientific study, we are trying to investigate whether or not the drainage basins of the rivers of the Southern Ganga plains and adjoining Narmada river catchment are in equilibrium. To test our hypothesis, the chi (χ) profile analysis or the integral approach of river profile analysis is conducted, which is one of the robust techniques to analyze the variations in the local erosion rate along a stream. This method normalizes the longitudinal river profiles for drainage area, by integrating drainage area over flow distance for each and every channel, producing a transformed coordinate chi (χ). This chi value gives a direct estimate about the steepness of a river and in turn its erosive power. It has been observed from the results, that the rivers in the study area lack dynamic equilibrium. The results suggest that the tributaries of the Narmada River are aggressing towards the tributaries of the Ganga River and capturing their headwaters. These results are also supported by the field observations where slopes in relatively opposite direction (to the flow of a river) is observed. We surmise that the tectonic forcing is one of the major reason for the disequilibrium at the drainage divide.

Perthite microtexture from Koraput Alkaline Complex, Eastern Ghat, India

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Perthite is a common microtexture in alkali feldspar which forms exsolution of albite rich phases within orthoclase rich host. This microtexture is common in slowly cooled granulite facies rocks (Abart et. al., 2009). Koraput Alkaline Complex (KAC), Eastern Ghat, India, comprises of nepheline syenite, amphibolite, syenodiorite and granitic rocks and contain perthitic texture. These perthitic textures exhibit three types of exsolution lamellae, which develop within K-feldspar: 1) Spindle perthite 2) Patch perthite 3) Flame perthite. Spindle perthite comprises of 5-8 µm wide and 15-18 µm long albite lamellae; patch perthite comprises of 10-12 µm wide and 13-15 µm long albite patches; whereas, flame perthite comprises of 2-5 µm wide and 12-14 µm long flame like albite lamellae. In few cases, albite rich thick bands are observed along the periphery of orthoclase rich host. In general, lamellae are observed coarsening from rim towards the core. As the coarsening increases spindle-like precipitates evolve to more equant shape. There is a negative correlation between precipitate size and circularity (defined as 4π*area/perimeter^2, Tajc˘manova´ et al., 2012). Some authors suggest that shape change could also occur due to material redistribution by diffusion along the phase boundaries (Abart et. al., 2009). According to them this kind of phase transport is most efficient for small precipitates, rather than large ones, which is reflected by the negative correlation between precipitate size and circularity.

Some authors suggest that exsolution may occur by nucleation/growth and/or by spinodal decomposition (Abart et. al., 2009). On the other hand, Bhattacharya and Sengupta, (2014) argued that flame perthite may be formed from replacement of K-feldspar by albite through alkali exchange. Flame perthite differs from most other perthite morphologies in that it is generally found in deformed quartzo feldspathic rocks.

Equilibrium temperature of this microstructure is constrained by two feldspar thermometer using analysis of albite rich lamellae and orthoclase rich host, calculated temperature is 650-700°C (Elkins and Groove 1990). Metamorphic temperature and pressure of perthite bearing rocks is estimated to be 800-850°C and 7-8 kbar respectively using hornblende-plagioclase pair (Blundy & Holland 1990). At this condition sub solidus phase relation in albite-orthoclase two component system is also attempted as function of temperature and composition (T-X). It represents thermal maxima of the solvus at the 1033°C and the corresponding composition is Ab_{35} Or_{65}.

Deformation and tectonothermal history of Ambaji granulite, South Delhi terrane, Aravalli Delhi mobile belt, India

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Ambaji granulite, in the South Delhi terrane of Aravalli- Delhi mobile belt, NW India, comprises pelitic-calcareous-mafic granulites with several phases of granite, G_{0-3} that have been deformed by three phases of folding, $F_{1-3.}$ It is marked by a subhorizontal pervasive deformational-metamorphic-migmatitic fabric, S_1, axial planar to isoclinal-recumbent F_1 fold syntectonic with granulite facies metamorphism at a peak pressure-temperature of 5.5–6.8 kb/ ≥850° C. The S_1 was overprinted by discrete sets of mylonitic fabric, S_2, along subvertical sinistral retrograde shear zones which were developed axial planar to NE-SW striking upright F_2 fold and acted as channel for exhumation of the granulites to brittle-ductile transition zone. Further, NW-SE-F_3 folds affected the granulites producing several interference patterns. Brittle strike-slip and normal faults (S_3 fabric) overprinted the ductile structures. The present thesis portrays shear zone studies involving (i) shear kinematic, (ii) estimating temperature, flow stress and strain rate (iii) kinematic vorticity estimation. Further, I determined (iv) paleostress from brittle fault slip data and (v) magma fluid pressure from G_3 granite vein; Lastly, (vi) in situ EPMA Th-U-total Pb monazite geochronology has been done.

The S_2 shear zones carry the impression of an early stage of high temperature top to NW vergence thrusting. This was overprinted by low temperature top to NW strike slip sinistral shearing. The microstructural study of mylonite, which is interbanded with pseudotachylites, indicates that high temperature thrust slip shearing is characterized by GBM and low temperature strike slip shearing is characterized by BLG-SGR recrystallization. Textural study and grain size analysis on dynamically recrystallized quartz grains estimated likely range of deformation temperature and differential flow stress as 490 °C-600 °C and 390 °C-490 °C and 12-15 MPa and 18-26 MPa for high and low to medium temperature shearing respectively. The deformation occurred by climb assisted dislocation creep and strain rate was between 10^{-12} and 10^{-15}/s.

Mean kinematic vorticity number (*Wm*), estimated by Rigid Grain Net (*RGN)* and strain ratio/orientation (*Rs/ϴ)* techniques suggest the high temperature shearing had *Wm* values of 0.32-0.40 and 0.60, indicating pure shear dominated transpression leading to horizontal shortening and vertical displacement of the granulite to upper crustal levels. The low temperature retrograde shearing event yielded *Wm* estimates of 0.64-0.87 and ~ 1.0 suggesting that the second shearing event was general non-coaxial deformation first, followed by a simple shearing, implying lateral flow.

Paleostresses analysis suggest that strike-slip faulting is due to N-S compression and E-W extension, and normal faulting is due to NW-SE extension. Orientation of G_3 granite veins, which is syntectonic to normal faulting, show girdle distribution in stereoplot implying magma pressure- $Pm > \sigma_2$, compression- σ_1 was vertical and extension- σ_3 was NW-SE horizontal, stress ration, $\Phi = 0.81$, driving pressure $R' = 0.92$, suggesting extensional tectonics.

EPMA in situ Th-U-total Pb monazite geochronology yielded three sets of ages as ca. 875-857 Ma, 838-764 Ma and 761-663 Ma for S_1, S_2 and S_3 strain respectively suggesting that the South Delhi orogeny occurred during ca. 875-663 Ma, synchronizing with early phase of Pan-African orogeny.

Dimensionality analysis of MT impedances of Tso- Morari Dimensionality analysis of MT impedances of Tso- Morari Dome: Implication for structural interpretation

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The Tso-Morari Crystalline (TMC) is a significant litho-unit between the north Indian continental margin and the south of the ISZ. In the northern region, the TMC dips towards NE while in the southern region it dips towards SW and therefore this region is referred as Tso-Morari dome. It has been observed that high pressure eclogite facies metamorphism of TMC suggests a deep subduction of the Indian Plate underneath the Eurasian Plate . The TMC and the ophiolites are well exposed in the Mahe valley as well as in the adjacent Nidar valley of the study area and are separated by Zildat Ophiolitic Melange.

The Magneto telluric (MT) method utilizes natural electromagnetic signals in order to estimate subsurface resistivity variations. Resistivities of rocks are sensitive to their rheological properties and therefore can be used a proxy to infer about the structural, geometrical information of the subsurface. Before modelling impedances for resistivity variations, MT tensors are subject to dimensionality and decomposition analysis. It essentially means estimations of MT tensor in regional geoelectric co-ordinate system, if subsurface resistivity variations are two dimensional. Regional geoelectrical co-ordinate system in that case broadly overlaps with regional structural strike. In this paper, we present dimensionality analysis of MT impedance tensors calculated for TMC and discuss about the decomposition parameters, especially strike, the poorly resolved parameter, in the background of structural information available in the region from literature.

Crustal thickness and poisson's ratio variations in the northeast India–Asia collision zone (Tidding Suture)

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The northeast India-Asia collision zone (Tidding Suture) is a significant tectonic unit of the Eastern Himalayan Syntaxis (EHS) where the ENE-WSW oriented major tectonic units of the Himalaya show a southward bend connecting the Indo-Burma ranges (IBR) to form the EHS. We carried out receiver function (RF) analysis at 11 broadband seismological stations (BBS) established in a profile along the Lohit river valley of Arunachal Pradesh passing across the Tidding Suture Zone (TSZ). The study profile is significant as it cuts across the mega thrust zones and suture related withevolution of EHS. The average crustal thickness (H) and Poisson's ratios (σ) were estimated with the help of H-*k* stacking analysis of RF's at each station. The study reveals a thickening of crust from ~46km beneath the Brahmaputra valley in the west to ~55 km in the TSZ and the western part of Lohit Plutonic Complex (LPC). In the eastern part of the LPC, the Moho shows marginal uplift with average depth of about ~50 km. The estimated Poisson's ratio in the Brahmaputra valley is low (0.23), suggesting felsic composition of the crust. The Poisson's ratio is intermediate in the Mishmi Thrust zone (0.249-0.261) and in some parts of the LPC. High Poisson's ratio (0.277-0.293) is observed beneath the TSZ and western part of the LPC, indicating the effect of aqueous fluid/partial melt present in the crust. The seismicity in the study area has been investigated based on data recorded by our network and data obtained from reviewed catalog of International Seismological Center (ISC) bulletin. Seismicity is observed to be distributed mainly at a shallow depth range ~1-15 km. However, earthquakes of M > 4.0 are primarily concentrated at ~25-35 km depths. This bimodal distribution of seismicity has significant role in understanding subsurface configuration beneath the profile.

Growth of ilmenite rod and (hydro) andradite in serpentinised peridotites of Western Ladakh-Implication for deep origin and alteration

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The ophiolitic rocks in western Ladakh are sandwiched between platform carbonates in south and intra oceanic volcanics in the north. The Shergul serpentinised peridotite is considered as a dismembered ophiolitic slice along Indus Suture Zone. Rock samples were collected from Shergul serpentinite hill, are variably serpentinised harzbergite, lherzolite and dunite, with relict chrome spinel. Here in this study we observed several rods of disoriented ilmenite having 0.2-4 µm width and 20-50 µm length, found in the mesh cores as well as secondary hydro garnet and diopside Lizardite is found as in mesh centres as well as forming veins. Fibrous chrysotile manifests different pleochroic colours, with width of each strip varying micron scale. The vein centres are characterised by the presence of magnetite, in precipitated form along channels or surrounding major chromite grains in the form of atolls. Hydro andradite is found as spherical aggregates as well as veins. Both type of andradite is found to contain magnetite inclusions. Secondary diopside, subhedral with clear boundaries found at one end of veins, in these samples. The Raman spectra of andradite are collected in two regions of 200-1200 cm^{-1} and 3000-4000 cm^{-1}. The first order region shows characteristic peaks of 370, 516 cm^{-1} Ag bands, 878 cm^{-1} Eg band and several F_2g bands with second order region peaks of OH substitution at 3500-3700 cm^{-1}. By applying MIRAGEM method(Bersani,2009), we calculated the composition of garnets as Alm:10%, Py: <1%; Spes: <1%; And: 91%; Gross: <1%, the vein type garnet shows relatively more grossular content (And: 82%, Gross: 8%), may formed during increased mobility of Cr. From the petrographic observation the andradite may formed after magnetite in High Ca, low fO_2, low silica aqueous geochemical environments. This is further supported by the formation of calcite in serpentine veins as well as the formation secondary diopside in veins. The experimental studies suggest the stability of andradite at very low temperature (<280^0C). Diopside also found coexist with garnet at this narrow lower PT range (Plumper et al., 2014). Hence these alterations occur near surface at the late stage.

Ilmenite exsolution needles are found in mesh cores, left after several even episodes of fluid activity. Exsolved Ilmenite is identified from the mixed Raman bands of 683 cm^{-1}, 450 cm^{-1} and 368 cm^{-1}. These needles type ilmenite reported here shows similar occurrence as reported earlier in Alps, formed by decomposition of olivine solid solution phase while decreasing of pressure (Dobrzhinetskaya et al, 1996).

Hence the deep origin can be attributed to peridotite rock, which might have followed decompression path with the development of ilmenite in the host minerals, which later serpentinised due to excess inflow of fluids near subsurface.

Evolution of Tholeiitic and Alkaline mafic intrusions in the Siang Window, Eastern Himalaya Northeast India: constraints from geochemistry and U-Pb geochronology

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Petrological and geochemical studies of mafic intrusions are of major interest worldwide since 1) they act as a mantle window, II) recognized as a signature of mantle plume activity, III) associated continental break-up or recurrent crustal extension episode during which large quantities of mafic magma are formed and transported from the mantle to crust. The age and genesis of mafic intrusives in the Siang Window of Eastern Himalaya remains unclear. Therefore, U-Pb isotopic and whole-rock geochemical data for these rocks have been studied in order to understand their petrogenesis and tectono-magmatic evolution. Based on field evidence, mineralogical and geochemical characteristics, mafic intrusive rocks of Siang window are classified into Type-I (Tholeiitic) and Type-II (alkaline). The Type-I is characterized by medium to coarse-grained gabbros comprising of clinopyroxene (~40-50%) and plagioclase (~50-60%) as the major phases with minor amounts of amphibole, sericite, chlorite and Fe-Ti opaque minerals. They exhibit equigranular, subophitic to ophitic texture. Clinopyroxene is euhedral to subhedral in shape, has high relief and imperfect cleavages. Plagioclase grains are subhedral to anhedral and short columnar to granular in shape. They appear platy and transparent and seem to have suffered extensive alteration. The type-II rocks are porphyritic diabases which have intruded only in the Miri quartzite. The mineral composition is marked by phenocrystic plagioclase and clinopyroxene in a fine-grained groundmass of plagioclase, pyroxene and opaque minerals. Plagioclase phenocrysts are subhedral in shape and occur as clusters of laths, which are saussuritized at some places and show intergranular and vitrophyric texture. The Type-I exhibit two distinct geochemical features and further identified as type-Ia (TiO_2 < 2 wt.% and HREE depletion- Yb_N < ~12) and type-Ib (TiO_2 >2 wt.% and negative HREE depletion - Yb_N > ~15). Type-I samples, however, display E-MORB features and were derived from peridotite-bearing garnet with no signature of contamination. In contrast, the Type-II mafic intrusive samples are enriched in LREE, LILE and HFSE contents, but depleted in HREE with slightly positive Eu anomalies, pertaining to OIB affinity. This type might have originated from an enriched mantle source.

HFSE-REE systematics of both the rock types also invoke heterogeneous mantle sources comprising enriched MORB type components combined with plume type melts. Rift-controlled intraplate setting associated with an ocean-continent transition zone (OCTZ) marked the tectonic environment for the Siang mafic intrusions. Zircons from the Type-I samples yield 521±3.25 Ma to 567.66 ± 2.09 Ma, suggesting Late Neoproterozoic to early Cambrian magmatic activity in the eastern part of the Himalayan. This is the oldest magmatic age reported so far in the region.

Gravitational Potential Energy gradient and GPS measured Geodetic deformation across the Nahan Salient and the Dehradun re-entrant

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Study of surface deformation and the stress/strain estimates from satellite geodetic method is an important area of geoscience research particularly in a seismically active region like Himalaya. Geodetic methods can be used to study the stress/strain accumulation in plate interiors as well as at plate boundaries. These type of studies in the Himalayan region would help us to understand the rate of deformation and will figure out which faults are most likely to produce another big earthquake.

In this work, we attempted to study the surface deformation across two profiles using the Global Positioning System (GPS) data and the Gravitational Potential Energy (GPE) change. One linear profile along the Nahan Salient and another along the Dehradun re-entrant towards MCT are considered. GPS data from 33 continuously operating stations, both from IGS and Wadia institute local network for a span of 8 years from 2010 to 2017 has been used in this study. The data were processed using the GAMIT/GLOBK software and the velocities were estimated in the ITRF as well as in the Indian Reference Frame. For computing the Gravitational potential Energy (GPE), we have used crustal thickness and the topographic data of the study region. We computed the horizontal stress from the Gravitational potential energy by modelling the vertical density contrast for the case of a two-layer crust-lithospheric model having a standard thickness of L = 120 km.

Results from GPS data show all the Himalayan stations have surface velocities varying from 40-50 mm/yr toward Northeast direction in ITRF. But with respect to the India Pole the frontal stations are showing velocities towards Southeast direction. However, the magnitudes of these movements are different which increases towards east from the Nahan station. It is also observed that movement along the frontal Himalayan arc is prominent than across the arc movement. But beyond the locking zone towards north in the Lesser and Higher Himalaya the scenario is different, there we can clearly observe the expected perpendicular to the arc movement. The analysis of GPE and its gradient results across the Nahan salient were compared with respect to the case of Dehradun re-entrant. Our results show that across the Nahan salient the GPE gradient is quite erratic, especially within the Lesser Himalayan region. Here the negative gradient shows the region is under compressive stress. However, in the sub-Himalayan section between the HFT and the MBT the positive gradient shows that the region is under dilatational flow, which we observed as a regime of much topographic erosion. However, in the Dehradun re-entrant the GPE gradient is quite steady which increases from the sub, lesser and to the Higher Himalaya.

Evaluating emplacement and exhumation of the Chiplakot Crystalline Belt, Kumaun Himalaya: A geochemical and structural approach

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The granite gneisses of Chiplakot Crystalline Belt (CCB) is well exposed along the Kali River of the Kumaun Himalaya, Uttarakhand. The northern and southern tectonic boundaries of the CCB are demarcated by the North Chiplakot Thrust (NCT) and South Chiplakot Thrust (SCT) and they separate the CCB from the siliciclastics and carbonates of the Lesser Himalayan Sequence. The central part of the CCB is marked by the Central Chiplakot Thrust (CCT). We carried out zircon U-Pb geochronology and bulk rock geochemistry of CCB to reveal its age and petrogenetic history. The bulk rock geochemistry suggests shoshonitic composition. In addition to that, depletion in Nb, Sr, P and Ti suggest volcanic/continental arc tectonic setting. Zircon U-Pb geochronological study of the three samples collected from different structural levels of the CCB reveals crystallization ages ranging from 1970-1860 Ma. It is interpreted that the CCB belongs to the Inner Lesser Himalayan Sequence and is equivalent to the Munsiari Formation. Therefore, it is an *in situ* litho-unit rather than a Greater Himalayan Klippe, as previously believed. We also carried out mesoscopic, magnetic fabric, quartz piezometric and fractal dimension analyses to understand the strain variation in relation to syn-Himalayan deformation and the mechanism of exhumation of CCB. Mesoscopic and magnetic fabric concordantly dip towards NW, parallel to all major thrust zones such as the Munsiari Thrust, Main Central Thrust etc. Microstructural observation suggests that the samples from CCT possess high temperature dynamic recrystallization textures such as Grain Boundary Migration (GBM) and progressively this texture is replaced by Sub Grain Rotation (SGR) towards the north nearing the NCT and Grain Boundary Bulging (BLG) and Sub Grain Rotation (SGR) at the SCT. Differential flow stress (σ) is highest within CCT zone and decreases towards south with increase in quartz grain sizes. Similarly, σ decreases towards the north with sudden increment within the NCT zone. The area-perimeter fractal dimension is also highest within the CCT zone. We infer that the intensity of brittle-ductile shearing is more prominent along the CCT compared to NCT during exhumation. We envisage a 'critical taper wedge' scenario in relation to internal deformation and forward propagation of thrusts. We suggest that the CCT is an out of sequence thrust formed due to internal deformation and has played a pivotal role in the exhumation of the Chiplakot Crystalline Belt during the Himalayan Orogeny.

Field and petrographic studies of the granitoid rocks from the Hyderabad area part of Eastern Dharwar Craton South India

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The granitoids from the Hyderabad area of the Telangana state are confined to Precambrian gneissic complex of the northern-eastern part of Eastern Dharwar Craton. They cover 7,760 sq km represents Hyderabad and Rangareddy districts. The study area and fall between Latitudes. 16° 52'- 17°42'N and between East longitudes 77° 21'- 77°51'E. The granitoids are mainly classified into grey and pink granites, granodiorites and aplites. They occasionally contain older mafic enclaves in the form of lensoid bodies and thin bands and cut by younger dolerite dykes, pegmatite and quartz veins. Granitoids form batholithic domes, pointed hillocks, small mounds and sheeted outcrops in the study area. They are characterized by massive interlocking granular structure with coarse grained phaneritic texture fabric in hand-specimen. Under the microscope they show varied textural features such as intergrowth perthitic texture between alkali feldspar and plagioclase feldspar and symplectic myrmekitic texture between plagioclase, quartz at the margin of K-feldspar. They are mainly composed of feldspar (microcline and plagioclase) and quartz as essential minerals. Biotite and hornblende form minor minerals, and epidote, chlorite, apatite and iron oxide occur as traces amounts. They have been plotted in restricted field of syeno granite, monzo- granite and granodiorite on QAP diagram of Streckeisen (1974) and Le Maitre et al. (1989). These granitoids are described as subsolvus in character due presence of two feldspars that are formed at below solvus (<400^{0}C) temperature with wet conditions.

Mid-oceanic ridges and supra-subduction zone geochemical signature in mantle peridotite and chromitite from southern Manipur Ophiolite Complex (MOC), Northeast India: Significance of mantle melting processes

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The fragments of oceanic lithosphere were emplaced in the southern part of Manipur Ophiolite Complex (MOC) during the closure of Neotethys Ocean and are composed of well-preserved mantle sequence (peridotites) with podiform chromitite bodies along with upper crustal gabbro, mafic dykes and basaltic lavas. The peridotites consist chiefly of harzburgite with a lesser amount of lherzolite and dunite whereas podiform chromitite bodies of variable sizes are hosted in the serpentinized harzburgite-lherzolite. The peridotites are mainly characterised by Mg (89.25-90.48), high Al_2O_3 (45.59-50.85) and low Cr (19.66 - 23.56) in chromian spinel (Cr-spinel) collectively suggest a typical abyssal peridotite derived from fertile mantle at mid-oceanic ridges (MOR) tectonic setting. Whereas, the composition of chromites in chromitites has changed drastically showing low Al_2O_3 (14.35 to 19.68) and high Cr (65.5 to 71.83) that suggests they were crystallized from boninitic magma series in the supra-subduction zone. Our petrological and geochemical evidences reveal that two stages of magmatism evolved during the formation of NMO. In the initial stage, magma was generated at the mid - oceanic spreading centre (MOR) by a small degree of partial melting (8–10 %) resulting high Al-rich and low Cr-rich chromian spinel bearing peridotites essentially of lherzolitic composition. At the second stage, high Cr-rich and low Al-rich magma evolved by high degree of partial melting intruded the earlier formed lherzolitic mantle exhibit harzburgite with high Cr chromitite that formed at the fore-arc related setting above supra-subduction zone. It has been concluded from the present study that the magmatism in the mid-oceanic ridges environment followed by supra-subduction tectonic process were responsible for the evolution of the Nagaland-Manipur Ophiolites that were emplaced along the Eastern plate margin of Indian subcontinent.

Central India tectonics, the shear zone and sedimentary formations: Results from MT studies from Rewa-Shahdol region, India

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Magnetotelluric (MT) studies in eastern segment of central India tectonic zone unravels Gondwana and Vindhyan sediments with the resistivity range of 30-150 ohm-m. The thickness of both basins increase towards the Narmada-Son Lineament (NSL) zone. It indicates fault controlled sediment deposition in this area. Given the Gondwana sediment thickness and tectonic setting in the northern part of the Graben is more hydrocarbon prospecting than the southern segment. The present study together with geochemical studies over the Proterozoic Vindhyan basin in central India suggest the occurrence of elevated concentrations of light hydrocarbon gases that migrate through faults and lineaments in the region. The 2-D inversion model of (shallow) MT data images undulation in the basement topography below the Gondwana sediments which indicates the complex tectonic activity in the central India. High resistivity structure near the CIS represents the upliftment of Bastar and Bhundelkhand craton during the collision. The present study also reveals clear signature of major tectonic boundaries such as Central India Shear zone (characterized with the MT phase beyond 90 degrees), Narmada-Son South Fault, Shahdol lineament with low to moderate resistivity (3-100 ohm-m). Further, The MT study suggests the reactivation of Narmada Son south fault during the Deccan volcanism bringing out the mafic material to near surface as well as the mafic material intruded along the intra basinal faults of sedimentary basin. Narmada Son north fault was not active during the Deccan volcanism thus, we do not image high conductivity features in north of NSL.

The new classification diagram for juvenile Archean felsic Granitoids: Tonalite-Trondhjemite- Granodiorite (TTGs) and Sanukitoids

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We present a new geochemical plot Na_2O/K_2O*100 Vs Ni+Cr+V (ppm) to use as a parameter to discriminate the dominant Archean felsic lithologies namely Tonalite-Trondhjemite-Granodiorite (TTG) (3300Ma – 2500Ma) and Sanukitoids (2700Ma – 2500Ma), which encompasses nearly 35-40 % by the rock record in granite-greenstone association of the Archean cratons globally. Data from the Archean cratons of Dharwar, Amazonian and North China Craton emphasizing on TTGs and Sanukitoids are basis to instrument this plot. The geochemical database comprises Major elements: Na_2O and K_2O, trace elements: Ba, Sr and transitional elements Ni, Cr and V, which plays vital proxies for identification of the source reservoirs of TTGs as wet basaltic crust and sanukitoids as enriched mantle or metasomatized mantle are fundamental entities in this plot. The existing Na_2O/K_2O vs Ba+Sr (ppm) play a significant role in discriminating these lithologies, but it undergoes a greater degree of overlap, while the designed Na_2O/K_2O*100 Vs Ni+Cr+V (ppm) have a greater precision in demarcating and hence useful in the regard of its functionality in petrological and geochemical studies. The average value (n=110) TTGs: Na_2O/K_2O*100 = >120 Ni+Cr+V ≤100; (Low-HREE and High-HREE TTGs); Sanukitoids (n=96): Na_2O/K_2O*100 = 150; Ni+Cr+V = 350 ppm. A total value of n=196 for TTGs and sanukitoids defines a trend line y= 0.4286x+54.20 which demarcates Tonalite-Trondhjemite-Granodiorite (TTG) and Sanukitoids with a high degree of precision and accuracy.

Seismically induced soft sediment deformation structures in an active tectonic setting along the Trans Yamuna Fault in Doon valley, North Western Himalaya

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Himalaya is one of the youngest folded mountains in the world and also the region of large magnitude earthquakes. Documented active faults in northwest Himalaya provide evidences of continuous strain release in between faulted zone of Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT). Active tectonic signatures in this segment are recognized through deformed and/or newly created tectonic landforms such as uplifted and faulted river terraces and alluvial fans, stream off sets, dislocated ridges, sag ponds, triangular facets, pressure ridges and abandoned/controlled drainage pattern etc.In the present study an attempt has been made to correlate paleoearthquakes and active tectonics along the Trans Yamuna Active Fault (TYAF) systems in NW Himalaya.TYAF system recognised in between MBT and HFT is a ~ 13km long NE-SW trending fault trace which has three main segments and can be clearly recognisable on the satellite image. The subdued expression of TYAF can be further extended on either direction. Two trenches were excavated on the NE end (at Bharli) and at SW end (at Sirmuri Tal) towards paleoseismological investigations. The trenches at Bharli Active Fault (BAF) and Sirmuri Tal Fault (STF) occupy dissimilar lithological units including the Quaternary deposits. It has been observed in both the trenches that there are prominent deformation features in the soft sediments. The phenomenon that involved in the deformation of soft sediment deposits has been attributed mainly due to the increase in pore-pressure by liquefaction process and fluidization mechanism. The various induced deformation features (also known as Seismites) are mainly in the form of sand boils, clastic dykes, flame structures, clay burst sand water escape structures etc. The deformation in soft sediments will only possible due to strong ground shaking, generally because of an earthquake (>5.5M) indicating a tectonic activity in the Quaternary period. Since the above soft sediment structures are not syn-sedimentary in origin, they must have genetic link with the ancient earthquakes. The deformation recognised in the soft sediments suggests in the TYAF also suggest its reactivation of in the recent past.

Does Dharwar Craton exposes a tilted section of crust along its N-S expanse? insights from P-T pseudosection and fluid inclusion studies

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The granite-greenstone ensembles in Dharwar Craton (DC) has long drawn the attention of geologists. For over half a century the DC is known to expose progressively deeper levels of paleocrust (from ~10 to 25 km) from N to S, along its expanse of >400 km. In DC, the mineral isograds cross-cutting the N-S trending schist belts define the metamorphic zonation, dividing the craton into greenschist, amphibolite and granulite zones from N to S. Metamorphic facies transition zones separate each of these zones and the idea of northwardly tilted Dharwar crust hinges on the validity of these transition zones. This study assesses this long-standing postulation by means of geothermobarometric estimates based on metamorphic mineral equilibria and fluid inclusion studies on greenstone rocks (metabasaites) in parts of the Eastern Dharwar Craton (EDC). In addition to this, new P-T constraints are put on the magmatic emplacement conditions of granitoids around Kavital in Hutti region.

Metabasite rocks in Hutti, Ramagiri, Penakacherla, and Kolar comprise amphibole, plagioclase, quartz, and ilmenite as stable metamorphic mineral assemblages. This corresponds well with the stable mineral assemblages deduced through PT pseudosection analysis using Perple_X suite. Magnesiohornblende and andesine are the common varieties of amphibole and plagioclase. The exposed metabasites throughout the N-S stretch of study area yield peak metamorphic conditions mostly in the range of 650-750 °C. The isochores for aqueous carbonic fluid inclusions hosted in matrix quartz (within metabasaites) define fields that overlap with the P-T field of stable mineral assemblage in P-T pseudosection. This method furnishes pressure values of ~4 to 6 kbar and infers paleocrustal depths in the range of ~15 to 20 km corresponding to amphibolite facies conditions. This agrees well with the consistent presence of magnesiohornblende, andesine, and ilmenite in metabasaites.

The deduced peak metamorphic P-T conditions for greenstone rocks compare well with the crystallization conditions of surrounding late Archean granitoids. In the northern reaches of EDC, P-T estimates (674 – 729 C/4.2 – 5.7 kbar) on granitoids around Kavital region imply ~15 to 19 km of depths for magma emplacement. Further south, recent studies suggest roughly similar estimates (~14-19 km) for vast tracts of granitoids along the N-S stretch of ~250 km (from Ramanagaram to Nagasamudrum). On this basis, the notion that granite-greenstone rocks in the purported 'greenschist facies zone' (in northern reaches of craton) expose shallower crustal depths up to as low as ~10 km, seems conjectural. We surmise that the granite-greenstone terrain exposes ~15 to 20 km of paleocrustal depths from Hutti in the north to amphibolite-granulite transition zone in the south; the latter is best observed in transects along Kolar-Shevaroy hills and Kabbaldurga-B.R. Hills by means of incipient charnockitisation. Perhaps, the expanse of Dharwar craton that exposes an oblique panel of the crust is limited to less than ~100-120 km across amphibolite-granulite transition zone near the southern margin of DC.

Fate of the subducted continental gneiss in the Himalayan Orogeny

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The Tso Moriri gneissic dome in the NW Himalaya has been documented as a UHP terrain through the occurrence of coesite inclusions within the garnet in Eclogite, which occurs as boudins in the High grade Puga gneiss. The deep subduction of the Indian plate (Mukherjee et al 2003) has been documented from the occurrence of this UHP mineral in the metabasics. According to the existing Foreign vs Insitu model proposed for this area, metabasics are the foreign material that are intruded into the gneisses during the last exhumation event (which was coeval) and only the metabasics have undergone UHP metamorphism and not the gneisses, as they show only mid- crustal level metamorphism. The Puga gneiss which occupies the core part of the dome has undergone severe retrogression due to which the HP signatures may have been erased. So the accessory minerals (Zircon, Rutile, Monazite, Apatite), which are chemically inert and stable over long periods of geological time needs to be targeted to test the existing model for this area. Thus, the slightest morphological changes in the accessory minerals is a important signature of a geological event undergone by it. Thus through the growth of these heavy minerals we can try to understand their role on the crustal growth with time if we can unfold the successive growth stages (Magmatic/hydrothermal-Prograde-Peak-Retrograde-exhumation). For correct interpretation of the domains the most important parameters are internal structures, external morphology, mineral inclusion composition and trace element distribution pattern of the zircon grain concerned. The different rock types (Ortho-gneiss/Para-gneiss/White-schist) in the area contains varied modal dominance of accessories within them. Since our main focus is in understanding the role of the continental gneisses in the subduction environment and its relation with the UHP metabasics the zircons of our prime interest are the metamorphic ones formed during prograde-peak metamorphic episodes and the ones that has a igneous core and overgrowth of metamorphic growth rims. To study the retrogression and exhumation history of the region we intend to take minerals with low closure temperature (Rutile, Apatite and Monazite). Magmatic zircons shows general trend of increasing trace element abundances and typical oscillatory zoning, whereas metamorphic zircon shows dissolution, cloudy zoning. The variation in the optical resolution of the obtained CL images can be directly correlated with the variation in the trace elemental concentration (U/Th ratios). So it is necessary to classify broadly the type of metamorphic zircons available in the area. The parameters chosen for this classification is the i) Shape of the Zircon grain (Anhedral/Euhedral/Subhedral), ii) Distribution of inclusions in the core, mantle and rim part of the zircon, iii) Deformation features (fractures/alterations) present within the zircon, iv) Type of zoning seen in the grain (oscillatory/patchy/sector/dissolution zoning), v) Degree of transparency/opacity of the grains. We can conclude that there is a distinct difference in the internal and external structures of the Zircon grains which indicates that the paragneiss and orthogneiss might have followed a different subduction path.

Micropetrographic study of Chromiferous ultramafics and their role in crustal building processes: A study from Boula-Nuasahi area, Odisha

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The ultramafic rocks play a vital role in revealing many geological processes associated with the deep crust-mantle domain. These rocks preserve a record of thermal gradients associated with partial melting, cooling, fractional crystallization, magmatic differentiation and emplacement that are useful in reconstructing tectonic histories (Windley, 1994). These ultramafic rocks are the repository of platinum group elements [PGEs]. The ultramafic intrusive bodies in occurrence on the surface of the earth to a specific segment in a specified set up. Appearance of leuco Gabbros mostly occur in layered complexes. The magmatic stratigraphy of these intrusions is more or less similar to the layered intrusions. The present communication is petrological analysis, structural analysis and tectonic setting of ultramafic suits and their altered product of the Nuasahi ultramafic complex. To identify different ultramafic suits in the complex and identify their interrelationship in them to understand petrogenesis of these ultramafics and their role in crustal formation and petrochemistry and mineral geochemistry of selective sample to characterize the ultramafic suites lava and elucidate their source composition.

Odishan Bauxite from two Geo-Environments - a comparative study

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Bauxite capping over Eastern Ghat Group (EGG) and Iron Ore Group (IOG) in Odisha, eastern India show contrasting physical, mineralogical and compositional characteristics. Bauxite over EGG appears as extensive plateau blankets at higher altitude while IOG bauxite occurs as small tabular low-level platforms. The IOG bauxite shows thicker vegetation in contrast to the sparse growth in the other type. The EGG bauxite exhibits spongy texture contrary to pisolitic / oolitic texture shown by IOG bauxite.

Gibbsite is present in both bauxite, but boehmite and minor diaspore are recorded in IOG bauxite. Relict garnet, sillimanite and kaolinite / illite are noticed in EGG bauxite only. Hematite in EGG bauxite is present as discrete grains, while these are mostly acicular in the other set up. Goethite appears as secondary filling in both the set up. Ilmenite is present in EGG setup in contrast to anatase in IOG bauxite. Compositional fingerprint of selective phases indicates the IOG bauxite to be largely of boehmite type while EGG bauxite is gibbsitic. EGG bauxite is metallurgical grade and IOG bauxite of refractory grade. Relatively higher concentration of trace and LRE elements is observed in EGG bauxite. The bauxite of two set-ups exhibits different chondrite normalized pattern.

In EGG province, alternate acid and alkali leaching was followed by partial recrystallization while in IOG province, alkali leaching was followed by multistage precipitation. It is established that the bauxite ore bodies in different parts of India have formed under different geo-environmental conditions.

Interlinking deformation, metamorphism and magmatism in the Greater Himalayan sequence from Bhagirathi Valley, Garhwal Himalaya

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Geothermobarometry together with micro- and macro-structural data indicate ductile flow in the metamorphic core of the Himalaya in the Bhagirathi valley, Garhwal region of India. An almost continuous cross-section exposes the Lesser Himalayan Sequence to the Tethyan Himalayan Sequence through the medium to high grade Greater Himalayan Sequence (GHS) in between. The Lesser Himalayan greenschist facies rocks are juxtaposed by the amphibolite facies GHS rocks through a 2-3 km thick high strain zone, having distributed ductile deformation, i.e., the Main Central Thrust (MCT) zone. Mapping of the isograds provide an inverted field gradient with first appearance of garnet and kyanite index minerals coincident with the high strain zone. Garnet zoning profiles, petrography and elemental compositional maps exhibit prograde assemblages for the Lesser Himalayan Crystalline Sequence (LHCS) and MCT zone, whereas GHS shows retrograde equilibration. Within the GHS unit, two populations of extensional conjugate fractures overprints the ductile structures; and these fractures crosscut the major tectonic boundaries of MCT zone and the South Tibetan Detachment (STD). In a MnNKCFMASHT system, pseudosections were derived using Perple_X software along with geothermobarometric calculations so as to understand the Pressure-Temperature paths. Across the MCT, P and T increase rapidly from ~6 kbar and ~550°C in the LHCS to ~15 kbar and ~850°C at ~3 km above the MCT in the Greater Himalayan Sequence (GHS). Pressure and temperature increase almost upto K-feldspar + aluminosilicate field. There is a sudden decrease in pressure (~8 kbar) within the GHS while temperatures remain nearly constant at ~700-750°C up to the structurally overlying South Tibetan Detachment (STD). Different P–T evolution paths and well-developed tectonic boundaries are characterized by these units. The distribution of peak assemblages, might be a result of post-metamorphic ductile thrusting in a downward propagating shear zone. The thermobarometric and metamorphic observations are consistent with a form of channel flow. However, channel flow does not account for exhumation structures that formed above the brittle-ductile transition. To generate a proper model for the genesis and exhumation of the GHS, both the channel flow and critical taper theories must be taken into account.

New evidences of piedmont fault to the south of western Nepalese Himalayas

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The mountain front of Himalaya is migrating southward since the time of its inception. The migration of mountain front has occurred from the Main Central Thrust (MCT) to the Main Boundary Thrust (MBT) further to the present day Main Frontal Thrust (MFT). Yeats and Thakur (2008) identified a new mountain front - which they termed 'Piedmont fault' - to the south of the MFT; they suggested that it extends from the western to the central Himalaya. However, since the first reporting no study has been carried out on this fault and barely anything is known about it. The present study aims at investigating this fault in the south of the western Nepal Himalayas. Multi-disciplinary approach is adopted, such as integrated use of satellite image data, digital elevation model (DEM), and geomorphic markers along with grain size investigation, to investigate the presence of the fault or fault related deformation. Furthermore, field investigations are also carried out along the Sharda and the Ghaghara rivers to fortify the above data. Presence of unpaired terraces and paleochannels in the field suggest northward shifting of the rivers in response to the uplift along the deformation zone (related to piedmont fault). Variation in river width, sinuosity, braiding bar index, break-in-slope, and sediment grain size across the fault collectively substantiate that there exists a deformation zone related to the piedmont fault in front of the western Nepalese Himalaya.

Modeling of Strong Ground Motions of 1991 Uttarkashi and 1999 Chamoli Earthquakes using a Modified Hybrid Technique

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The 1991 Uttarkashi (M 7) and 1999 Chamoli (M 6.6) occurred in the Western part of Central Seismic Gap (CSG) of Himalaya. The CSG a segment of about 1400 km between the rupture zones of 1905 Kangra and 1934 Bihar-Nepal earthquakes of Himalaya. Recently 2015 Gorkha Nepal earthquake occurred in the Eastern part of CSG. The probability of occurrence of the great earthquake in CSG has been estimated to be like 52% in a hundred-year time window and 31% in a fifty-year time window (Khattri, 1999). This implies the severe seismic hazard in the region. The earthquake strong ground motions play a significant role in the assessment of seismic hazard of a region. In the absence of adequate recorded accelerograms in a region, the simulated accelerograms using different techniques become important for the evaluation of seismic hazard. A number of techniques including theoretical, empirical and hybrid techniques have been developed for simulating the earthquake strong ground motions.

In the present study, a hybrid technique has been modified and used to model the empirical accelerograms of 1991 Uttarkashi and 1999 Chamoli earthquakes. The technique involves the generation of envelope function of target earthquake by the superposition of envelope functions from a suitable number of small events (sub-events). The sub-events of varying size have been distributed randomly, instead of uniform distribution of same size sub-events, on the fault plane of target earthquake. The best locations of the random distribution of sub-events have been found using a genetic algorithm. The envelope function thus obtained has been combined with the white noise to generate the accelerogram at a site. The parameters required for the hybrid technique include fault area and orientation, stress drop, Q-relation, rupture velocity, duration, PGA-attenuation regression. In order to simulate the accelerograms at the surface, the empirical transfer function (site effects) and high-frequency decay parameter have been estimated and incorporated in the hybrid technique. Figure 1 shows the comparison between the accelerograms simulated using a modified hybrid technique with those of recorded ones for both the earthquakes modeled here.

The simulated accelerograms have been compared with the observed accelerograms in terms of peak ground acceleration (PGA), duration, Fourier and response spectra. The simulated accelerograms have been found to be in agreement with those of recorded ones for most of the sites. The modified hybrid technique is suitable for predicting the accelerograms of future similar earthquakes in the region and therefore useful of the evaluation of seismic hazard.

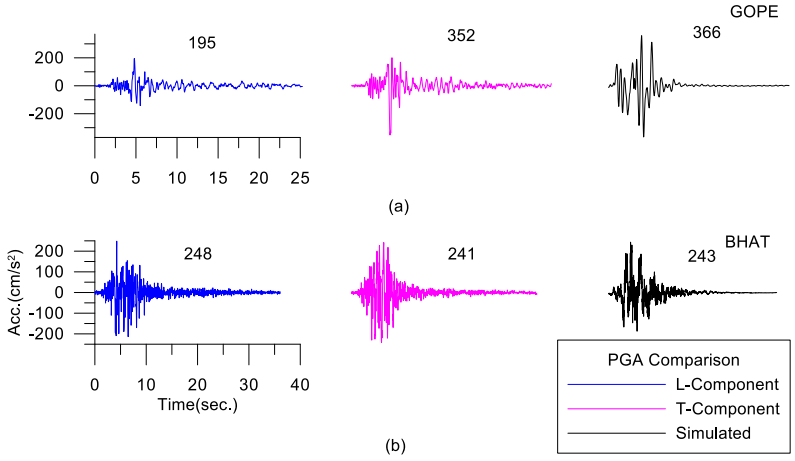

Fig.1: Comparison of Observed and Simulated accelerograms at (a) Gopeshwar (GOPE)recording station (Chamoli earthquake, 1999) (b) Bhatwari recording station(BHAT) (Uttarkashi earthquake, 1991).

Lu-Hf isotopic systematics of Migmatites, upper Satluj valley, India: Implication for Paleo-tectonic reconstruction

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Uranium–lead and Lu–Hf signatures of zircon from migmatite of upper Satluj valley, India provides information on the temporal evolution of metamorphism, migmatization, and magmatism, but also on the protoliths of migmatite.The migmatite are mainly dominated by mesoproterozoic to Palaeozoic zircon with εHf values from +13.01 to –17.47. The proximal source for zircon derived from Meso to neo-proterozoic rocks that were reworked during the Pan-African Orogeny. The average Th/U ratios of 0.16859 shows igneous origin except some grains which are having Th/U ratio<0.1reveals metamorphic origin. The youngest zircon (23.8 ma) have lowest epsilon Hf value of -17.47. REE pattern of zircon shows igneous origin expressing positive Cerium anomaly and negative Europium anomaly, the magnitude of anomalies are shown as Ce/Ce* and Eu/Eu* ratio where Ce* and Eu* are value for a smooth normalized pattern. Zircon crystallised at the time of supercontinent assembly shows positive to negative epsilon the Hf(t) values, by this we inferred that involvement of juvenile and ancient crust, negative epsilon Hf value indicate more evolved crustal sources and highly positive epsilon value suggest participation of juvenile crust. Correlation of U-Pb age, epsilon Hf value and tectonic events specify a conjugate position for India with Arabia Nubian shield, Africa in west and Antarctica in east at the time of Rodinia supercontinent, subsequent the earliest deposition of Greater Himalayan Sequence, Bhimpedian orogeny took place at 520-480my it is correlated with the emplacement age of Higher Himalaya crystalline sequence.

Geophysical study of Indo-Myanmar Range using Gravity and Seismic data

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Indo-Myanmar Range (IMR), also known as Indo-Burman Range (IBR) is located at the extreme north-eastern part of India. Geologically, it is a folded and faulted mountain belt located between the Bengal basin and Central Myanmar basin. The major phase of folding took place during Oligocene and Miocene. Churchandpur Mao Thrust (CMT) is one of the major thrusts in this region and it is considered to be the most active plate boundary thrust. Seismicity in this region is related to underlying nature of the crust and present geodynamics of the region. Due to its rugged topographic features and remoteness of the area, many parts of this region are not yet explored. Detail exploration in this region is a challenging task for all geoscientists. The present study aims to explore this region using geophysical data like Bouguer gravity anomaly (BGA) and seismic data. The study area is characterised by negative gravity anomaly (-60 to -135 mgal along the profile) which decreases towards east. Seismicity data shows both shallow and intermediate earthquakes (i.e. focal depth less than 300 km).

Earliest Neoarchean arc-back arc subduction system in the Indian Peninsula: evidence from mafic magmatic suite in the Shimoga Greenstone Belt, Western Dharwar Craton

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The Neoarchean Shimoga Greenstone Belt (SGB) of western Dharwar Craton is dominated by ultramafic-mafic-felsic magmatic suite and sedimentary rocks. Here we investigate the mineral chemistry and whole-rock geochemistry of the Koppa-Herambapura mafic magmatic rocks (tholeiitic metagabbro and metabasalt) from the southern SGB to understand their petrogenesis and geodynamic implication. The geochemical features classify the Shimoga rocks as basaltic-basaltic andesite with a sub-alkaline tholeiitic signature. Trace element compositions of both rock types display uniform depletion in HFSE relative to LILE-LREE, higher LILE/HFSE and LREE/HFSE ratios (La/Nb =1.30-8.07, Nb/Ta =11.58-16.19, Zr/Sm =10.24-29.77) and negative Nb-Ta, Zr-Hf and Ti anomalies in multielement patterns, corresponding to magmatic arc rocks generated within an intraoceanic subduction environment. The Nb/Th (2-15), Zr/Sm (10-29) and Zr/Hf (44-233) ratios indicate a depleted to enriched mantle source. The parental magma of the Shimoga mafic rock suite were generated by medium to higher degrees (~20-50%) of mantle melting at depths corresponding to spinel to garnet peridotite fields of arc-back arc setting. The tholeiitic metagabbros were derived from depleted subduction unmodified mantle source generated in an arc environment, whereas the metabasalts had a mantle source attributed to: (i) development of juvenile back-arc rift close to a subduction zone; (ii) upwelling of MORB-like mantle; (iii) metasomatism through influx of hydrous fluids and sediments derived from subduction; and (iv) flux-induced melting in the compositional domain of spinel-garnet peridotite. Based on these results, we conclude that the mafic rock suite from the southern SGB marks one of the earliest Neoarchean arc-back arc subduction in the western Dharwar Craton (WDC).

Analysis of Seismicity in the Central Seismic Gap in Himalaya, India

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The region in Himalaya, between the great earthquakes of Kangra (1905) and Bihar- Nepal (1934), termed as Central Seismic Gap (CSG), is a potential zone for future great earthquakes. A broad band seismic network is continuously recording the earthquake events in Garhwal and adjoining Shimla Hills of Himachal Pradesh since 2007. This study region lies in the CSG. The data analysis for more than 3000 local events (2007 to 2018) indicate that majority of earthquakes are occurring in a narrow zone, south of MCT in the magnitude range between 1.8 to 5.7 with focal depths of 12 to 25 km . The events have low stress drop values and one of the reasons could be that the crust of the region is not able to sustain accumulated energy and is being released regularly in the form of micro earthquakes. Earlier studies on this data set has been carried out for waveform modelling, seismic precursors, velocity model and b-value analysis. The waveform modeling indicates low angle thrust fault earthquakes continue to occur in this region with a small area of fault, actually participating in releasing the large portion of energy. A low frictional coefficient has been obtained, suggesting the presence of fluids near detachment below the Chamoli region. Swarm as a seismic precursor has been observed but the other precursors (Vp/Vs) has not shown any significant changes. A four layer velocity model has been obtained for this region. Body wave attenuation properties worked out for the first time for this region indicated random and high degree of heterogeneities. The inferences based on the spatial and temporal variation in b-value indicate a relative increase in recent seismic activity in the northwest Garhwal and Kumaun regions compared to the region of southeast Garhwal which probably indicate accumulation of high stresses in the region. A new data set for the period 2015 – 2018 has been added. The source characteristics and source mechanisms of events are evaluated. This is for the first time that seismicity of the region has been looked from the perspective of migration. The events when plotted year wise reveals that the events near Chamoli region are becoming more pronounced as a cluster. Interestingly this is the region exhibiting fluids at depth and consequently low frictional coefficient as described in previous studies.

Significance of Kullu-Larji-Rampur tectonic window developed at base of root zone of Lesser Himalayan Crystalline nappe in Sutlej River valley, NW Himalaya

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In the Sutlej River valley, the SE end of NW-SE trending anticlinal Kullu-Larji-Rampur (KLR) window is surrounded by the Chail and Jutogh crystalline thrust sheets. Towards norththe NE-dipping limb of the KLR window, comprising of quartzite-metabasic sequence of the inner Lesser Himalaya is thrust over by the Jeori Gneisses of the root zone of the Lesser Himalayan Crystallines along the SW-verging Jutogh Thrust. At base of the Jutogh Thrust, brittle thrust faults have rotated foliations and increased their dip from 45° to 72°. Similarly, at top of the footwall block, the normal faults have rotated bedding foliations and reduced their dip from 52° to 14°. A younger normal fault splay of the Jutogh Thrust is recognized, across which dip of foliation is variable from 70°/E in the footwall block to 48°/NE at base of the hanging wall block. Trend of surface traces of brittle thrust and normal fault imbricationcoincides with the narrow and deeply incised and gorged perennial tributary that indicates the tectonic forcing of channel along the Jutogh Thrust. Development of a number of linear series of slip-circles of mass movements, and closely spaced gullies and spurs in the valley-slopes indicatesactive nature of fault zone along tributary.

The KLR window has developed towards south, adjacent to the Jutogh Thrust. It implies that the earlier deformation front associated with the movement of rocks along the leading edge of Jutogh Thrust had shifted toward south to participate in the formation of the KLR window. Presence of multiple high-angle thrust faults and shear zones, particularly along the northern limb of the KLR window, suggests that these faults may represent the signature of earthquakes that rocked the area as the epicentres of the Main Himalayan Seismic Belt lies on the KLR window. The published literature shows location of focii of seismic events at 5-10 km beneath surface trace of the Jutogh Thrust. It is interpreted that the presence of seismically active shallow-level blind thrusts related to that tectonic horses associated with the duplex system within the northern flank of KLR window.

Role of Halogens (Cl & F) in formation of Karakorum migmatites, Ladakh, Trans-Himalaya: Constraints for fluid chemistry of migmatitization process

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The partial melting in the continental crust is one of the major feature of convergent zones generally observed in syn-collision migmatite outcrops in active collision zones of Himalaya and Trans-Himalaya. In south Karakorum (the western prolongation of the Lhasa block), Neogene migmatites and granites have been recognized, in Shyok and Tangtse valley of Ladakh region. A rare magma accumulation within anatectic rocks presumed to be a part of the magma source region for the leucogranitic Karakoram batholith (20–15 Ma) i.e, I-type granite (Weinberg et al., 2000). These anatectic rocks are exposed as Karakorum Migmatite of about 7 km wide, along the dextral-transpressive Karakoram shear zone, in Ladakh, NW India (Weinberg and Mark, 2008).

The Karakorum migmatite in Tangtse vally dominated by amphibole, biotite, feldspar, quartz and accessories minerals (mainly apatite, zircon, titanite, allanite, epidote). The amphibole is categorized into ferro-pargasite and ferro-hornblende. The geochemical classification suggest the occurrence of primary and requilibrated biotite in the studied samples. The chemical composition of biotite and amphibole may be influenced by halogens (Cl and F) because OH^- of hydrous minerals (mainly amphibole, biotite and apatite) replace by F and Cl present in the circulating fluid. The Cl content in amphibole range in between 0 to 0.11wt%, whereas F varies in between 0 to 0.40 w t%. The biotite is also Cl –poor but rich in F (i.e. 0.1 to 0.6 wt %). The higher fluorine contents in biotite and amphibole in comparison to Cl suggest fluorine-enriched magmatic source and also reveal that it may be derived from partial molten crustal igneous rocks of tonalitic to granodiorite composition.

Theme III:
Climate Change and Geological processes

Tectono-geomorphic assessment in the Barak River Basin of Western Hills of Manipur, using GIS techniques

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Tectonic geomorphology is considered as an important field of study because the results of regional neo-tectonic studies are essential for evaluation of natural hazards, land use development and management in populated areas. The geomorphic indices act as important indicators in the studies of tectonic geomorphology which are capable of deciphering landform responses to active deformation processes and have been widely used as a reconnaissance tool to demarcate areas which have suffered active neo-tectonics. In regions with active tectonics the drainage pattern response well to active processes such as folding and faulting which contribute to accelerated river incision, basin asymmetries, drainage geometry and complexity and deflections in river courses. Barak river basin lies in the western hills of Manipur which is a part of the young fold mountain belts of Indo Myanmar range (IMR). The study area has high structural complexity and are seismically and lithologically unstable consisting of tertiary sedimentary rocks. Landslides are common, causing several social and economic problems. In order to evaluate and understand the tectonic activity of the study area, the basin was divided into seven sub-basins. Geomorphic indices such as linear, areal and relief parameters, Hypsometric integral (HI) and Valley floor width to valley floor height (Vf) ratio have been analyzed for each basin using GIS techniques. The analyzed results have been compiled and expressed by applying the concept of relative active tectonic index (Iat) which we classified into four classes such as relatively low, moderate, high and very high tectonic activity with S/n values >2.5, 2-2.5, 1.5-2 and 1-1.5 respectively and it showed that there is relatively high to very high tectonic activity taking place in the study area. The earthquake and landslide data plotted for the study area are found to be consistent with the result indicated by the relative active tectonic index (Iat). It has been inferred that the geomorphic parameters computed using GIS techniques proved to be a competent tool in the assessment of tectonic activity in the Barak river basin.

Felsic magma emplacement and its interaction with the host rocks: a study from Sirsilla granite pluton, southern India

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The Sirsilla granite pluton consists of two variants (pink to grey granite) confined to the central part of the pluton, with subordinate minor hybrid facies restricted to the periphery. The hybrid-facies consists of assimilated country rocks belonging to tonalite-trondhjemite-granodiorite (TTG) suite, mafic magmatic enclaves (MMEs), dikes, banding, and late magmatic pegmatites or aplites. The MMEs shows sub rounded to stretched enclaves or layered enclaves. The layered enclaves are characterized by disaggregating units progressing to schlieren, with tip streaming from host granite to mafic enclaves. The syn plutonic dikes and fragmented dikes are abundant at the margins when compared to core regions. The rhythmic layers with deformation observed mainly towards margins. This deformed layers and rhythmic layers occur due to magma pressure, rheological discontinuities, regional stress field and degree of supercooling. Late magmatic pegmatites and aplite layers were also observed in the peripheral regions of the pluton. The solidification of highly differentiated granitic melts gives rise to late magmatic pegmatites and aplites produce from the undercooling of residual magma. The above features can be described by differentiated magmatic pluses, mechanical and chemical hybridization of mafic magma, local hydrodynamic sorting and segregation of residual melt.

Retreating rate of Chaturangi glacier, Garhwal Himalaya, India derived from kinematic GPS survey and satellite data

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Different climatic conditions are seems to be responsible for varying retreating rate of the glaciers in the Indian Himalayan region. The regular monitoring of the glaciers is important to determine their retreating rate and mass balance for overall glacier health. Chaturangi glacier, a major inactive tributary of the Gangotri glacier system was selected for the present study due to its dynamic nature and also because there are no previous records of its retreating rates. In order to reconstruct past retreating rates, total area loss, volume change and shift in snout position were measured through multi-temporal satellite data from 1989 to 2016 and kinematic GPS survey from 2015 to 2016. The results obtained from satellite data indicate that in the last 27 years Chaturangi glacier snout has retreated 1172.57 ± 38.3 m (average = 45.07 ± 4.31 m/year) with a total area and volume loss of 0.626 ± 0.001 sq. km and 0.139 km^3 respectively. The field measurements through differential global positioning system survey revealed that the annual retreating rate was 22.84 ±0.05 m/year. The large variations in results derived from both the methods are probably because of higher difference in their accuracy. Nevertheless, the results derived from both the methods are in agreement that Chaturangi glacier is retreating at a considerable rate.

Shreds of evidence from southeastern Mikir Hills, NE India: Biostratigraphic, Paleogeographic and Paleoenvironmental implications

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In India, Tertiary rocks are best exposed in northeast India. They are differentiated into two facies: basinal and shelfal sediments. This differentiation is mainly marked in the Eocene strata of the succession. The Paleogene Shelfal sediments are well developed in Garo Hills, Khasi and Jaintia Hills along the southern margins of Shillong Plateau in Meghalaya, southeastern parts of Mikir and North Cachar Hills of Assam and of Dhansiri and Upper Assam Valleys. These sediments represent diverse depositional environments from marine, lagoonal, tidal flat to fluvio–deltaic displaying the effects of differential tectonic movements in basin floors, changes in shorelines, sediment source and varying degree of energy conditions of the transporting media. The Shillong Plateau and Mikir Hills are known as the pop-up structure of the Precambrian basement of the Indian Craton. Our area of interest falls in the Dillai Parbat in southeastern Mikir Hills (situated inside CCI mines, Assam) which exposes a part of the Eocene Sylhet limestone succession. Our main focus in the Dillai Parbat where the limestone is exposed in a quarry is due to the abundances of fossil occurrences. Field-based lithofacies analysis in conjunction with paleontological data of the region indicates the broad depositional environment of the region. Facies association indicates that along with major transgressions and regressions, there were short phases of transgressions and regressions. The presence of foraminifera (both larger and smaller), ostracods, corals and other faunas indicates a connection between the enclosed water bodies with the sea either through storm cuts or tidal inlets. The size of the larger foraminifera indicates its association with algal symbionts. The lower Limestone formation of the succession contains a few fossils as compared to the upper Limestone Formation, which indicates that more basinal condition exist in the upper limestone formation and due to transgression, limestones becomes more muddy. In between the 2 phases of limestone successions, there is a presence of sandstone beds with coal and carbonaceous matter. The sandstone beds represents a supply of clastic sediments input to the basin, changing the regime from carbonate to the clastic deposition. The association of coal with sandstone documents regression and seem to have been deposited in an environment of the lagoonal coastal swampy condition. The larger foraminifera inhabits well-lit, clear waters of shallow seas to benefit from algal symbionts, characterize the oligotrophic environment. The δ13C value of the organic carbon shows negative carbon excursion which may be correlated with MECO (Middle Eocene Climatic Optimum) or any other hyperthermal events. For climatic studies, Middle Eocene Climatic Optimum (MECO) represents a significant climatic reversal in the midst of the long term cooling which may be identified in this succession. The foraminiferal zones which will be refined in the present study will be calibrated with the global standard larger foraminiferal zonation of Serra-Kiel et al., 1998. The Middle Eocene warming may be caused by enhanced degassing of CO_2 from magmatic sources or due to extensive metamorphic decarbonation which occurred during Himalayan orogeny. Overall, these studies will be helpful in establishing a global biostratigraphic correlation, paleoenvironmental changes and paleogeographic reconstructions of the region.

Topographically controlled vulnerability under torrential rainfall along major rivers in Uttarakhand Himalaya

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The Himalayan-Tibetan orogen plays a critical role in controlling the global climate (Molnar et al., 1993; Ramstein et al., 1997; Harrison et al., 1998; Yin and Harrison, 2000) and the landscape in the tectonically active areas results from a complex integration of the effects of vertical and horizontal motions of crustal blocks and resultant erosion or deposition by surface processes (Burbank and Anderson, 2001). The mass wasting often leads by the combined effect of tectonic and climate processes and has not only resulted in human casualties on large scale but has also ruined agricultural land and disrupted hydro power projects and other governmental as well as private property. In present attempt, we investigate the flood events along major rivers of Kumaun Himalaya, Uttarakhand as most of rivers are criss-crossed by various thrusts/faults, which makes the region more prone to disasters. Various geomorphic features e.g., immature topography, deflecting river courses, ponding of ancient drainage, development of cascades, formation of unpaired fluvial terraces and series of triangular fault facets suggested the tectonic modification along the thrusts/faults of the valleys. Moreover, the Uttarakhand Himalaya is frequently rocked by cloud burst/heavy rainfall induced floods during monsoon period. The resultants of events are not only loss of million dollar properties but also toll of local inhabitant as well as pilgrimage, as the state has various shrines. The region has several holy rivers which provide the drinking water to millions of people of India. In other hands, the rivers seem to be very precarious due to excessive rainfall and carry floods in downstream region. Thus, the fragile lithology, torrential rainfall, accelerating erosion and incision with higher uplift due to tectonic upheaval along the active faults play a significant role in destabilizing of the river valleys and responsible for rainfall induced catastrophes in the region. So far, the anthropogenic disturbance as well as ignorance and poor understanding of geological structures and increased pressure of urbanisation also are pulverizing the river dynamics. We, Suggest that the impact and human causality can be minimized through proper guidelines to sustainable development along these valleys and awareness of processes of landslides/cloudburst induced floods. Further, it needs to relocate the people to safer side on the flat and gentler slopes without waiting for next disaster as relocation is much better than rehabilitation.

Decoding the relationship of tectonism and climate in the Himalayas- A case study from the Eastern Kumaun region

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The interplay of tectonics and the climate (erosional processes) perform a dominant role in designing the landscape of an area and the change in any of the variables affect the topography in a complex manner. Previous studies reveal that the rainfall pattern shows non-uniform distinctive patterns across the strike of the Himalayas, which is exhibited by the erosional/depositional landscapes and the carrying load of the rivers. The complex interaction between these two variables, precipitation and landform is investigated in the Kali River Basin of eastern Kumaun Himalayas, up to river-exit. In the present study the topographic and/or orographic barriers are demarcated by draping the Tropical Rainfall Measuring Mission (TRMM) data over the longitudinal profiles derived using the SRTM and ASTER (30m resolution) data. The results indicated that the major thrust boundaries, i.e. Trans Himadri Fault (THF), Main Central Thrust (MCT), Main Boundary Thrust (MBT), Himalayan Frontal Fault (HFF) from north to south, served as the orographic barriers. Thus, the erosional processes are dominant in the vicinity of these margins, which in turn result in the exhumation of the region and this process works in a cyclic and intermingled manner to shape the landscape of the area.

Geochemical analysis of Paleochannel present in alluvial plain area in Kurukshetra, Haryana

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The present paper deals with the Major elements, Trace elements and Rare Earth elemental analyses of the Quaternary sediments exposed at paleochannel present in alluvial plains of Haryana at Bhor-Sayindan village towards Pehowa, Kurukshetra. The exposed section is 6.5 m thick and comprised of sand, silt and clay in their ascending order of stratigraphy, however, the base is not exposed. Major elemental composition is used to study the assessment of the amount of physical and chemical weathering of the paleochannel to size up inter- elemental relationship and geochemical processes operating on the paleochannel.

The Chemical Index of Alteration (CIA), the samples has given values ranging between to 53-77 which reflects weak to intermediate weathering at the source.

Major oxides like TiO_2, Fe_2O_3, K_2O, MgO show the positive correlation with Al_2O_3, while SiO_2 and Na_2O show negative correlation with Al_2O_3 indicates sediments of mature continental provenance and relative enrichment of K_2O and depletion of Na_2O and CaO reflects highly mature and recycled sediments.

The tectonic discrimination diagram between K_2O/Na_2O vs SiO_2 of the sediments shows that the sediments lies in the passive margin region reflecting the sediments are from stable continental areas and deposited in sites away from active plate boundaries.

Source Rock Characteristics and Clay Mineralogical Study of the Rocks of Yinkiong Group, East Siang District, Arunachal Pradesh

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The Paleocene-Eocene Yinkiong Group of rocks of Arunachal Pradesh is geologically very unique from the other parts of Lesser Himalayan sedimentary units of the eastern Himalaya. This Group preserves sedimentary rocks, composed mainly of sandstone, shale (pale green shale, grey shale and purple shale) and carbonate rocks (limestone and marlstone). There is, however, no available work on the source rock characterization and clay mineralogical study of this unit. Therefore, the present study aims to evaluate the source rock potential of the shales as well as the qualitative analysis of the clay minerals of Yinkiong Group of rocks occurring along Siang and Yamne river valley in East Siang district of Arunachal Pradesh. The calculated rock-eval parameters infer very low TOC (0.02% to 0.46% with an average of 0.19%), S1 and S2 values indicating low amount of organic matter. Tmax vs hydrogen indices and hydrogen vs oxygen indices of kerogen refer to the mature and type III organic matter, suggesting poor source rock quality. To identify the clay mineral compositions X-ray diffraction (XRD) and Fourier transform infrared (FTIR) spectral analysis have been carried out and the minerals such as quartz, feldspar (albite, microcline and orthoclase), calcite, hematite, dolomite, kaolinite, chlorite, illite, montmorillonite, palygorskite and aragonite are identified.

Understanding the timing and dynamics of the India-Asia collision using sequence stratigraphic analysis of the Tethyan sedimentary sequence

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The timing of the India-Asia collision remains debated even after more than half a century of intense research because various methods that have been employed by the geoscientists to date the collision resulted in variety of different ages (varying between ~65 Ma and ~42 Ma). This discrepancy has sustained because these methods used some indirect proxies which rely upon the (1) past convergence/subduction rate, (2) past subduction angle and (3) various other geodynamic parameters which have been continuously re-evaluated with new data. Even the most accepted and direct collisional age estimation using sedimentological analysis did not account for the complex response of the expected sea-level change, due to interplay between subsidence (tectonics) and global eustatic sea-level rise during the collision. The north-western Indian passive margin (Tethyan) sediment deposited during the India Asia collision consist of Stumpata Quartzarenite, Dibling Limestone, and Kong Slate Formations in order of superposition. Sedimentological evidence of a marine to continental transition, due to sea-level fall, across the Kong Slate and overlying Chulung-La Formation has been put forward in support for a ~50 Ma collisional age. Following this model, subsequent workers have argued that India Asia collision occurred at ~52 Ma, based on the fact that Kong slates (~52 Ma depositional age) record the earliest arrival of Asian derived detritus on northern Indian passive margin sequence. In contrast to the basic sedimentological model of a sea-level fall during the collision, sequence stratigraphic rationale suggests a subsidence induced sea-level rise just at the onset of collision due to flexural bending of the subducting Indian lithosphere. It is therefore hypothesized in the present study that the last stage of subsidence induced sea-level rise before the onset of the Asian detritus to the passive margin sequence should demarcate the India-Asia collision. Sedimentological analysis of the Tethyan succession suggests that Stumpata Quartzarenite deposited in a fluvial to shoreface environment. Since, overlying Dibling Limestone and Kong Slate Formation deposited in a shallow marine setting, the shoreface to shallow marine transition indicates last phase of sea-level rise before the arrival of Asian derived detritus in Kong Slate Formation. Presence of index fossils for Shallow Benthic Zone-6 (SBZ-6), *Alveolina ellipsoidalis*, *Alveolina daniensis*, *Alveolina pasticillata*, *Alveolina solida*, and *Nummulites minervensis*, constraints the depositional age of middle part of the overlying Dibling Limestone at ~55 Ma. Based on these evidences, it has been proposed that India-Asia collision must have occurred before ~55 Ma.

Reconstruction of Upper Calabrian to Holocene Sea ice extent in the Japan Sea – A multiproxy approach

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The melting of Sea-ice has significant influence on climate and ecological conditions in Japan Sea. Sediment core samples of IODP site U1423 from north-eastern Japan Sea, have been quantitatively analyzed for angular and faceted surface Ice Rafted Debris (IRD), foraminifera and detrital fragments to reconstruct Upper Calabrian (Upper early Pleistocene) to Holocene sea-ice extent history in the northern Japan Sea. The terrigenous sediments were locked within the glaciers and deposited on the sea floor, when these glaciers melted on the sea. This analysis suggest that the sea-ice was expanded southward in the end Calabrian and beginning of middle Pleistocene in response to enhanced cooling, which is evident from the high abundance of IRD between 880 to 450 ka. The cooler sea surface temperature and reduced salinity caused dominance of extremely low temperature tolerant species, *Neogloboquadrina pachyderma* (sinistral) and also indicate deeper carbonate compensation depth (CCD). The detrital material present is linked to the seasonal sea-ice associated with East Asian Winter Monsoon strength and Tsushima Warm Current inflow towards the studied site. The abundance of detrital fragment and nearly absence of foraminifera between 450 and 150 ka suggests influence of seasonal sea ice in the Japan Sea that shoaled the CCD. The modern conditions of Japan sea initiated at 150 ka marked by significant decrease in IRD and detrital fragments and increase abundance of foraminifera. The extent of sea ice and CCD fluctuations in northern Japan Sea responds to 100 kyr variability, which is attributed to ice sheet dynamics and global ice volume changes.

Landscape Painting – A pictorial archive of landforms

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In geosciences, landscape evolution studies are often carried out on a thousand or tens of thousands year scale due to interests at the regional scale. However, in the last decade, several studies have shown that extreme events have the capacity to modify low order landforms on a decadal and century scale. Such, geomorphic changes can be described by using the aerial photographs (since 1900), satellite imageries (since late 1970; but have limited usage due to the temporal availability and spatial resolution of imageries), thousand-year scale changes are often described on the basis of geological studies, i.e., of numerical dating and modelling. What about the geomorphic changes on a century scale? The regions which have old maps and photographs are preferred to be studied for geomorphic changes on a century scale. Though, unavailability of such suitable datasets leads to undocumented geomorphic changes and geological methods like dating techniques cannot be straightaway applied to such regions. Sometimes these maps do not even highlight geomorphic changes occurring at a local scale.

Landscape painting is one of the unconventional methods to study such local scale geomorphic changes and has been successfully used in several areas to detect geomorphic changes at century scale. The main characteristic of a landscape painting is a pictorial representation of an artist's visual unification of the landforms which falls in his spectrum. Hence, the observation may vary from a layperson to a geoscientist. A detailed comparison between landscape painting with the present day photograph has been successfully attempted in the past to analyze geomorphic changes. (e.g., Shepard, 1957; Nordstrom and Jackson, 2001). In the present study, I will initially present a brief review of the usage of landscape painting in the field of geomorphology. Furthermore, I will present a Himalayan test case study from the Srinagar valley (along the Alaknanda River) using a landscape painting (~ 1790) and photograph (2012) to detect geomorphic changes on a century scale. The results show that the formation of a terrace in two centuries is due to a rapid rate of erosion and incision in the region. Further, a southward shifting of the Alaknanda River was detected, which is in agreement with the long-term shifting pattern of the river. The results indicate the significance of the landscape painting to study the geomorphic change on a century scale. So, in order to understand the geomorphic changes on a smaller time scale, we need to test more unorthodox methods.

Geomorphic response to an extreme hydrological event in a Himalayan River: Analysis of landscape change and paleohydrology

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Extreme hydrological events have recently been recognized as one of the most prominent mechanisms for landscape evolution/modification in the Himalayan river basins. Triggered by cloud bursts, glacial and landslide lake outburst floods; these events are capable of eroding, transport and deposit vast amounts of sediments with profound landscape changes. The Himalayan river basin frequently experiences such events during the monsoon, but there are very few morphological and hydrological data for the same event, an analysis of such events in the Himalaya is challenging. Hence, we studied a high magnitude low-frequency flash flood event which occurred in the upper reach of the Asiganga River basin (a small tributary basin of the Bhagirathi River, which in turn is a headwater tributary of the Ganga River) on 3 August 2012.

In this study, we attempted to address the geomorphic response of the mountain river to extreme floods with the aim of (i) detect the landscape modification/change during this event and (ii) calculated the paleohydrology of the event. The pre and post geomorphic mapping was carried out using satellite imageries (Google Earth), field data, and published literature to analyze landscape modification/change. Paleohydrology of the event was calculated using dimensions of 440 mobilized stream boulders at 11 location in the Asiganga River basin. Our results suggest that during the event, the Asiganaga River's reaches encountered sediment deposition and erosion on a massive scale; especially in the lower terrace levels. Channel shifting and widening was also a dominating geomorphic response, and it occurred in different magnitude along the course of the Asiganga River. A significant alteration trend is observed in sediment bars, especially in the reaches which were exceedingly influenced by morphological and hydraulic parameters. The peak discharge was calculated using D95, D90, D85, and D80 of the mobilized stream boulders. Overall, the measured highest peak discharge was around 4500 m^3s^{-1}. Interestingly, the peak discharge of D90 yielded the value of 2661 m^3s^{-1} that corresponds with the peak discharge (i.e., 2665 m^3s^{-1}) measured using an instrument in a previous study.

In the Himalayan River basins, documentation of geomorphic response coming from such extreme hydrological events is crucial. Such studies will provide a unique database, from which river sensitivity on geomorphic adjustment towards such extreme hydrological events can be predicted in future studies.

Carbon isotope variations in sediments from Rann of Kachchh: implications to Holocene palaeoclimate

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The evolutionary history of Rann of Kachchh through Holocene is enigmatic due to the presence of several archaeological sites, representing advanced human habitation, in this desert region. Previous researches conjectured the Rann to be a marine Gulf until around 500 years B.P., while other studies implicated the changing summer monsoon intensities for the rise and abandonment of human settlements in this region. To retrieve palaeoclimatic conditions during the Holocene, sediment cores have been raised at few places in Rann of Kachchh. Stable carbon isotopic ($\delta^{13}C$) measurements and Total Organic Carbon (TOC) from the core sediments have been used as a first hand proxy to understand the contemporary vegetational conditions because organic matter content in sediment preserves the mean stable carbon isotopic composition ($\delta^{13}C$) of the extant vegetation with little or no fractionation. Our study indicates mixed marine-terrestrial signatures in the recent past and a possible change in organic matter source around 7-9 ka. Future compound specific studies will be attempted to quantify the extent of vegetation change through the Holocene.

Understanding control on diverse behavior of the Bara Shigri and Samudra Tapu glaciers, western Himalaya

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Climate determines the glacier evolution. An unprecedented temperature rise over the last century has led to significant glacier decline worldwide. However, glaciers with similar climatic settings may also behave in disparate ways. The inter- and intra-region heterogeneity in the glacier response is widely reported across the Himalayan mountain ranges. These variations can largely be explained by the local topography and surface conditions of the glaciers. In present study, an attempt has been made to investigate the response of two largest glaciers of the Chandra basin, Himachal Himalaya namely Bara Shigri (BS: 127.78 ±2.22 km^2) and Samudra Tapu (ST: 82.19 ±1.19 Km^2). Multi-temporal data from Landsat-TM/ETM+/OLI, Terra-ASTER and SRTM, acquired between 1992 and 2017 have been utilized to estimate the vital glacier parameters (length, area, snowline altitude (SLA), surface ice velocity (SIV) and surface elevation changes (SEC) as well as influencing factors (debris cover, slope, aspect, altitude, and area accumulation ratio (AAR)).

Results reveal that both the studied glaciers are degenerating; however, the rates of change are significantly different. Though the deglaciation was of similar order (BS: 3.85 ±0.06%; ST: 3.90 ±0.09%), the terminus retreat was much higher in ST (24.03 ±2.11 m/y) than BS (17.93 ±2.11 m/) during 1993-2016. Also, initially (1992/93) the ST moved with much faster pace (38.23 ±3.29 m/y) and continued to move faster with negligible slowdown (7.92%) during 1992/93 and 2015/16. Conversely, the BS moved with slower rate (28.29 ±5.12 m/y) and registered substantial decrease in SIV (29.52%). Both the glaciers also downwasted significantly but with different rates (BS: −1.45 ±0.05 m/y; ST: −1.63 ±0.05 m/y) during 2000-2017. The overall higher degeneration of SC may be due to several reasons. First, the higher retreat of ST may be attributed to lake-induced calving. Second, slightly higher downwasting of ST is due to lower extent of debris cover (8.56%) as compared to BS (15.19%). Nevertheless, both the glaciers registered almost identical debris growth (BS: 1.61 ±0.01%/y; ST: 1.72 ±0.01%/y) during 1993-2016. In turn, despite similar debris forming capacities (combination of steep and gentle slopes), the lower debris mantle (dimension as well as thickness) on ST can be linked to its efficient debris-transfer mechanism evident by continuous higher SIVs, which also restricted supraglacial lake (SGL) and ice-cliff formation on it. Contrarily, progressive slowdown in BS favored large debris accumulation on it. The lower ablation zone of BS has thick debris (~30 cm), which probably posed an insulating effect leading to lesser terminus retreat, but coupled with slowdown facilitated SGLs and ice-cliffs development. These surface conditions further dragged down the SIV of BS. Moreover, the higher SIV of ST may also be driven by continuous higher mass supply which is evident by much lesser SLA upshift (83 m) and lesser AAR decrease (6.81%) as compared to BS which witnessed prominent SLA increase (215 m) and decline in AAR (19.85%) during 1993-2016. The orientation of these glaciers (north-facing BS & east-facing ST) may have also contributed towards the observed disparity in their respective response. Thus, the present study demonstrates the possible role of factors which guide varying evolutionary paths of glaciers existing in similar geographical regime.

Spatio-temporal variability in the ice flow velocity of the Kangriz glacier, J & K

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Fluctuations in glacier surface ice velocity (SIV) regulates its mass budget and vice versa, making SIV a crucial parameter for ascertaining the glacier's health. Also, being ambiguous indicators, the frontal changes and shrinkage rates do not give a comprehensive picture of the glacier response, thereby necessitating the evaluation of glacier SIV. Conventional measurement of glacier velocity using ground based techniques pose several problems including frequent loss of stakes, rugged terrain and harsh climatic conditions, which limit their assessment. Under such conditions, remote sensing can be used as a best tool owing to their large geographical coverage. The existing work on Kangriz glacier, Suru Sub-basin, Jammu and Kashmir mainly focuses on dimensional changes, inadequate enough to ascertain the glacier health. Therefore, this study evaluates the SIV of the Kangriz glacier using sub-pixel correlation of multi-temporal optical images for the period 1993/94-2017/18. Results reveal an overall slowdown in mean glacier velocity by ~13% during the period 1993-2018. The registered decline in SIV was more pronounced during 1993/94 to 1999/2000 (10%), followed by an insignificant slowdown (3%) during 1999/2000 to 2017/18. The slowdown in SIV during the study period is synchronous with continuous increase in the supraglacial debris (16%) and snow line altitude (SLA) (113 m). Meanwhile, the maximum and minimum temperature has also increased by 0.15 & 0.32°C, respectively in the study region during 1993-2018. Zonal analysis reveals a decrease in mean velocity in the accumulation zone by 5.14 ±3.68 ma^{-1} (16%) during 1993-2018. However, mean velocity in the upper ablation zone increased by 9.26 ±3.68 ma^{-1} (4.9%) while there has been a pronounced decrease in the lower ablation zone by 7.91 ±3.68 ma^{-1} (20%). The observed slowdown can be ascribed to negative mass balance conditions driven by prevailing climate and concomitant growth in debris coverage.

Triple oxygen isotopic measurement of chert samples from India to understand the evolution of ocean

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The oxygen isotope composition of sedimentary minerals have been used in the past to understand the evolution of earth surface processes. Initially, this was done using the $^{18}O/^{16}O$ ratio. However, during the last decade both $^{17}O/^{16}O$ and $^{18}O/^{16}O$ ratios are being used with certain distinct advantages. Normally, the $\delta^{17}O$ changes are about half the $\delta^{18}O$ changes displaying a feature known as mass-dependent fractionation (Craig, 1957). However, it is now known that there is deviation from this rule and the departure from mass dependence (measured by $\Delta^{17}O=\delta^{17}O-0.516*\delta^{18}O$), depends on the temperature of formation (Pack and Herwartz, 2014). The measurement of $^{17}O/^{16}O$ is difficult due to low abundance of ^{17}O and interference from the contaminants become serious. We have used a commercially available Laser Fluorination system (Sharp, 1990) to generate O_2 from silicates by reaction with BrF_5. The product O_2 is purified from contaminants by passing through a molecular sieve column by cryogenic means under vacuum. The accuracy and precision of the system were checked by analysis of NBS-28 ($\delta^{18}O$:9.6±0.1‰, $\delta^{17}O$: 5.0±0.1‰ and $\delta^{17}O$: -100±8 ppm). We also analysed chert samples collected from various sedimentary basins of India (Mahakoshal, Maihar etc.). The $\delta^{18}O$ and $\delta^{17}O$ values of these samples fall in the expected range corresponding to their ages reported by other workers from elsewhere. Details of the system and available results will be presented.

Microfacies analysis of Upper Krol Formation, Kumaun Lesser Himalaya, Nainital Area

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The upper Krol Formation exposed in the vicinity of Nainital district, Uttarakhand state formulates the southern part of Kumaun Himalaya. Microfacies is defined as the compositional feature or appearance of rock or mineral in thin section under the microscope. In the present study, I investigated different facies within different part of upper Krol. Detailed microfacies investigations was carried out to unravel the depositional environment, which are depicted in the form of microphotographs. Total 26 microfacies are recognizable, of these three from Barapatthar Member, 9 from Pashandevi Member, 7 from Bisht College Member, 7 from Sherwood Member. In the view of the microfacies investigations, it is concluded that Geologically the Krol Formation represent a tidal flat evidenced by various facies belonging to typical subtidal, intertidal and supratidal environments. Overall, the Krol Formation appears to display features of a shoaling upward or prograding sequence.

Role of Palaeolithic Archaeology to understand Pleistocene history of the Upper Krishna basin

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Archaeology is a discipline which studies human cultures with the help of material remains. River valleys have been occupied by the humans since the earliest times. Acheulian culture comprising of large flake-based tools is the earliest known and well spread culture in India. This is the longest surviving culture commencing from the Early Pleistocene and continuing till about end of the Middle Pleistocene period. Until 2014, except a few stray artefacts, the Deccan Trap region of the Upper Krishna basin had not yielded convincing Acheulian artefacts. It was suggested that the basalt was not a suitable raw material for such artefact production, or the artefacts have not survived due to heavy weathering.

Earlier studies in the Upper Krishna basin had suggested that the channel gravels and sediments exposed on the banks of the rivers were of a Late Pleistocene age. A few uncalibrated carbon 14 dates also showed that the sediments were younger than 100 ka. Considering this background, the present work focused on explorations in the Krishna River, Urmodi River and Bavdhan *nala*, in the Satara district, Maharashtra. These field surveys lead to a discovery of 9 new convincing Acheulian sites namely Menavali (Krishna River), Shahapur, Vechale, Valse, Majgaon, Atit and Nisrale (Urmodi River), and Bavdhan and Pandhrewadi (Bavdhan *nala*). The Acheulian artefacts ($n > 300$), made from locally available basalt cobbles and boulders, were collected from varied geomorphic contexts such as loose coarse channel gravels, cobbly-rubble and breccio-conglomerate. The different contexts of these artefacts are a result of role played by different formation processes.

The source region of the Krishna River, Urmodi River and Bavdhan *nala* have laterite capping, and thus the channel gravel also comprises of laterite clasts apart from basalt, and siliceous clasts. Surprisingly at Menavali, situated on the left bank of Krishna River the lowermost artefact-bearing conglomerate is devoid of true laterite clasts. This was verified by applying mineral magnetic method apart from visual observation. It has been hypothesized that this conglomerate was deposited by a drainage (currently named Kamandal River) originating from the non-lateritic area. This implies that during the Middle Pleistocene period when early hominin activity was going on, the drainage of Kamandal River was stronger than the Krishna River. This hypothesis needs further confirmation applying more scientific methods.

As the bedrock is high on the banks, the coarser gravels were deposited within the channel bed and were re-worked. The artefact-bearing sediments are usually non-calcretised while the capping sediments are rich in varieties of calcretes, pedogenic or groundwater types. It can be thus inferred that the climate during the post-Acheulian activity phase was broadly dry semi-arid, probably of Late Pleistocene period.

The typo-technological study of the artefacts and geomorphological observations are fairly convincing to suggest a Middle Pleistocene age for early hominin adaptation in this region. In the absence of typical fossils, absolute dates, and other proxies like pollen data, archaeology may play an important role in understanding the Pleistocene history of Bedrock Rivers in Upland Deccan.

Determination of lava flow direction and possible fissure locale by Anisotropy of magnetic susceptibility study of Rajmahal Trap basalts, India

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We are reporting for the first time the results of Anisotropy of magnetic susceptibility (AMS) study from the Rajmahal trap basalts (~117 Ma) obtained from 18 locations distributed in areas of Sahibganj and Pakur districts of Jharkhand, India. The AMS study is undertaken to understand the petrofabric orientations, lava flow directions, and the shape anisotropy. The results show normal flow fabrics with horizontal foliation planes. The typical ratios of the principal AMS axes are 1.018 for the magnetic lineation (*L*) and 1.017 for the magnetic foliation (*F*). From the AMS results, we tried to uncover the best-fit fissure locations for the existence of RT basalts and which we concluded as the Son-Narmada-Tapti Lineament (SNTL). This might have provided the pathway for the lava to erupt from the Kerguelen hotspot (mantle plume), which gave rise to the Rajmahal traps (RT), seeing that, the K_{max} trends are observed parallel (observed flow directions) with the general trend of SNTL i.e., NE-SW. The source area is situated Northeast of the RT and which is a triple junction point of SNTL, Dauki fault. Magnetic susceptibility (K), and combined Rock magnetic study including, Isothermal Remanent Magnetization (IRM) acquisition curves, hysteresis loops, backfield (coercivity remanence) demagnetization and k-T (Susceptibility vs. Temperature) suggests Single domain (SD) Low Ti-Titanomagnetite [$Fe^{2+}(Fe^{3+}Ti)_2O_4$] may be the dominant mineral in these samples with Magnetite [Fe_3O_4] in an accessory form.

Grain-size distribution of Rewalsar Lake sediments, Himachal Pradesh

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Grain Size analysis can be used as a powerful proxy to decipher the depositional environment and hydrological changes that occurred within the lake basin and the catchment area. A sediment core of 647cm in length was recovered by the living stone corer from a tectonically formed Lake Rewalsar (76°50'E, 31°33'N). The Lake is situated in Mandi district of Himachal Pradesh. The results of Grain Size analysis show the dominance of clayey silt throughout the core except for few intercalations of sandy silt and silty clay. Excessive silt fraction can be related to high precipitation in the catchment. The statistical parameters such as mean grain size, sorting, kurtosis and skewness were calculated by the Gradistat software (Blott and Pye). The range of variation in mean grain size data are not moderately wide suggesting homogeneity of the source material. The dominance of silt and clay sized particles tend to low disturbance and low energy condition. The standard deviation and skewness values of core indicate that the sediments are moderately to poorly sorted and symmetrical to finely skewed. The kurtosis values fall between mesokurtic to leptokurtic. The core sediments exhibit unimodal-trimodal distribution, which indicates that the lake sediments were transported by various agencies.

High-resolution millennial to centennial scale ISM variability in the north Ganga Plain

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The unequivocal and unprecedented climate change (global warming) has been attributed to a progressive increase in the atmospheric concentration of greenhouse gases (IPCC, 2014). The climate change is expected to have a significant impact on the freshwater resources, biodiversity, ecosystems and human well-being (Myers et al., 2000; Chaudhary and Bawa, 2011; Chand et al., 2019). The major concern of the ongoing changes is to understand its effects on the global/regional climate systems like the monsoon. The effects of these changes on the Indian Summer Monsoon (ISM), a fundamental component of our agrarian based socio-economy are yet to be understood. The partial understanding may be attributed to the paucity of high resolution terrestrial data sets that often suffer from age uncertainties (Sinha et al., 2007; Prasad et al., 2014; Ghosh et al., 2015; Ali et al., 2018 and ref. therein). Although variation in monsoon in term of wind speed is fairly recorded in marine core sediment, however the resultant ISMR (Indian summer monsoon rainfall) from the terrestrial archives is inadequate. In order to develop future climate model simulations, it is crucial to understand the palaeo variability of ISMR from terrestrial archives. Towards this, we aim at reconstructing high resolution centennial-scale ISM variability from lake sediments in northern Ganga Plain. We have used stable isotopic ($\delta^{13}C_{org}$) values, TOC, TN, and TOC/TN of the sediment organic matter. To understand the modern vegetation-climate relationship, we have developed a modern isotope based analogue. For this, we have used 108 surface sediment samples that have been collected in a pre-planned gridded pattern. The $\delta^{13}C$ value of the surface samples range between –25.2 and –20.7‰, with an average of –23.5‰. The TOC values range from 0.48% to 15.23% (average 3.11%). It has been observed that the lake experiences a heterogeneous water level (annually). Using seasonal remote sensing data, we have observed that the south-eastern sector of lake remains filled with water throughout the year, however the north-western part remains dry except for the monsoon period. This seems to have a significant effect on the $\delta^{13}C$ values and is manifested by lower values of $\delta^{13}C$ (average -23.1‰) in waterlogged sector and relatively higher values (average -22.6‰) towards the drier part (north-west). The frequency curve shows the maximum values falls in the range of -22.5‰ to -21.4‰ suggesting mix source of organic matter (C3 and aquatics). Significant variations of $\delta^{13}C$ values in the ~3.5m core advocate for fluctuating climate during the Holocene.

Petrogenesis of acid magmatic rocks from Riwasa and Nigana areas of Neoproterozoic Malani Igneous Suite, Northwestern peninsular India: Petro-mineralogical, geochemical, and tectonic approaches to reconstruct Malani Supercontinent

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The petrographical, geochemical and radioactive characteristics with tectonic modeling of Riwasa and Nigana areas of Tusham Ring Complex (TRC) in Malani Igneous Suite (MIS) have proposed that these magmatic suites are A-type, Within-plate and highly mineralized granitoids. The phase petrology of the investigated areas established phase relationships among all magmatic suites and they are classified as volcanic phase (rhyolites and quartz porphyry), plutonic phase (granites of different grain sized) and dyke phase (both granites and rhyolites). These acidic rocks consisting various shades of colors show hypidomorphic, granophyric, porphyritic, glomeroporphyritic, aphyritic, spherulitic, perlitic and microgranophyric textures. Geochemically, these acid volcano-plutonic rocks of peraluminous nature display significant enrichment of SiO_2, Na_2O+K_2O, Fe/ Mg, Rb, Th, U, Cu, Ga, Zn, Sn, W, Zr, Y and REE (except Eu); typically A-type affinity in extensional environment of MIS. The enrichment of trace elements and negative anomalies of Sr, Eu, P & Eu in the multi-element spider diagrams suggest that the emplacement of these granitoids were controlled by fractional crystallization and crustal contamination of protolith magma. Tectomagmatic relationships (Quartz-Albite-Orthoclase compositional diagram) suggested that these granitoids are emplaced from 15-30 km depth, 2-7 kb pressure, 450-900^{0}C temperature ranges, through hot-spot magmatic activity. The high heat production nature of the granitoids indicates high ore-forming ability through active circulation of hydrothermal solutions which affected the concentration of incompatible elements also (case of metallogeny). The relative enrichment of Ce, Zr, Ga and Y are indicative of their compatibility with a sub-crustal magmatic composition (crustal component is dominant). Magmatic temperatures calculated from the zirconium solubility model are higher (typically range of 450-900^{0}C) with elevated F and Cl abundances, will result in a higher zirconium solubility at a given temperature. Field observations, petrographical study, geochemical characteristics and tectonic modeling suggest that the investigating magmatic rocks (rhyolite and granite) were formed from different degree of partial melting. Hence, the present contribution focuses on the petro-chemistry and geochemical data bank of both volcanic and plutonic suite to determine their petrogenesis and tectonic settings with reference to the geodynamic evolution of MIS (an understanding approach to reconstruct Malani Supercontinent before 732±41 Ma ago).

Palaeoclimatic Reconstructions from Late Cretaceous dinosaur fossil bearing mottled Nodular Bed of the Lameta Formation (Central India)

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Palaeoclimatic reconstructions from Late Cretaceous dinosaur fossil bearing strata have been reported widely worldwide. Though micromorphology is a robust proxy tool for palaeoclimate and palaeoenvironment reconstructions, only limited researchers carried out detailed micromorphology of these strata. Some researchers interpreted these dinosaur fossil bearing strata in Korea, Romania, France, Spain, Argentina and Mongolia, as palaeosols on the basis of detailed micromorphology. Palaeosol micromorphological studies serves as one of the best proxy tools for palaeoclimate and palaeoenvironment reconstructions, thereby signifies the need for as many such studies as possible at various spatio-temporal scale. In view of this, micromorphological studies have been carried out in the Late Cretaceous dinosaur egg bearing mudstone strata exposed in the Jabalpur area of central India. These red brown mudstone strata are commonly known as Mottled Nodular Beds and are famous for dinosaur eggs; however less number of dinosaur egg clutches compared to immediate older stratigraphic Lower Limestone unit. These show significant degree of pedogenesis and therefore preserve Late Cretaceous dinosaur fossil bearing palaeosols in India. These palaeosols are extensively bioturbated and show abundant development of rhizoliths, rhizocretions, segregations and nodules. Abundant ferruginous and carbonate textural coatings along-with some silt to clay coatings have been observed. Abundant matrix and intrusive pedofeatures indicate formation of these palaeosols in tropical warm-wet to dry climate cycle under well-drained conditions.

Climate record of the last three millennium from a high altitude wetland of Ladakh (Northwest Himalaya), India: A multi proxy approach

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The Himalayan region is characterised by subtle changes of climate (monsoon), which affects the social economy and poses certain challenges leading to the destruction of life and properties the region by extreme events like the flash floods of Leh 2010 and Kedarnath 2013. It is therefore important to conduct high resolution climate reconstructions to understand the frequency of changes of monsoon intensity of the region through suitable archives. The Himalayan peatlands are good archives that records paleoenvironmental conditions and associated changes of the past. For this we present a ~2600 years past climate record inferred from multiproxy study of a wetland in north-west Himalayas, which is situated in the transition zone of the mid latitude westerlies and the Indian summer monsoon. The record is established using a 122 cm long sediment section sampled from Shakti (Ladakh) constrained by three ^{14}C AMS dates. We measured total organic carbon (TOC), total nitrogen (TN), their isotopes and geochemistry of Rb/Sr from the sequence. An age depth model for the peat deposits is created to know the sedimentation rate (0.97 to 0.20 mm yr^{-1}). TOC and TN depth- profiles of the studied-sequence have a significant correlation (r^2=0.82) indicating that both TOC and TN are derived from similar sources. However, the increasing trend of TOC/TN with depth from surface indicates climate amelioration, favourable for the organic productivity. The results suggests that period from ~100 to ~800 BP, the TOC/TN ratio becomes <10 which indicates that OM comes from aquatic plants. Further, continuous highest TOC/TN ratio (>10) is observed ~1000- ~2600 BP), which suggests that the organic matter (OM) is derived from terrestrial plants. TOC/TN ratios of the OM hints that peat sediments are sharply affected by the input of terrestrial plant materials. However higher or lower TOC /TN ratio can reflect changes in relative contribution of the two sources of OM. The multiproxy investigation suggest that periodically warmer and colder phases of monsoon intensification. Additionally, the Indian sub-continent is mostly influenced by ITCZ, mid latitude westerlies and atmospheric-ocean circulation.

Cell parametric and interatomic study on illite and chlorite lattices for palaeoclimatic reconstruction of Holocene-Late Pleistocene (8-130 ka) loess-palaeosols, Dilpur Formation, Kashmir, India

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Previously well-constrained aeolian-palaeosols (archived glacial and inter-glacial climate), revealed pedogenesis induced ionic substitutions caused end-member compositional deviations in illite and chlorite linked to widespread climatic changes with time. However, micro-level resolution is needed. Thus, layer-wise X-ray diffraction analyses of clay separates followed by Rietveld refinement, revealed varied cell parametric and interatomic distances. Obtained values for detrital and pedogenic illite and chlorite when plotted against stratigraphic succession recognized notable changes in the crystallographic axes. Inadequately pedogenized palaeosol illite altered to illite/smectite mixed layers, but, chlorite shows expansion of a-, b- and contraction of c-axes with more lattice distortions under warm-humid and acidic environment. Detrital 48, 44 and 83, 74 bonded illite and chlorite (with 2 sub-types each) when pedogenized retain 48, 44 and 34; and 83 and 74 bonds in their neo-formed 3 and 2 sub-types, respectively. Al-O bond length shows expansion, but, unchanged Si-O and decreased Si-K and K-O bonds show Al loss and Si and K retention in illite lattices. Illite with 32 atoms and 48 bonds represent K-O, Si-K, Al-O and Si-O bonds contraction, caused bond reinforcement; however, Al^{3+} loss reflects all-out illite alteration. Owing to Al-O and K-O bond expansion, major K^{+} and Al^{3+} ionic loss occurred during LGM, however, further ionic loss depends upon the magnitude of the loess-palaeosol weathering that they have suffered. Climate sensitive Fe, Mg and Al ionic losses for Fe-O, Mg-O and Al_{11}-O_9 bond length expansions were recognized in chlorite lattices. Such ionic losses are common, but, complete distortion is attributed to Al, Si, Fe and Mg ionic losses, followed by weakening of Al-O, Si-O, Fe-O and Mg-O bonds. Though, Si-O_4 and Fe_1-O_4 bonds, and Si and Fe_{1st} ions remain intact.

Thus, three major glacial episodes of ~5 ka duration each occurred under alkaline environment, but, intervened by two successive cycles of 55 ka each, encompassing three alternate warm and cold climatic sub-cycles of 12-15 ka. However, coldness increased with each warm-cold sub-cycles that attained glacial maxima. Further, these events correlate well with the deep sea records of the North Atlantic (MIS-1 to MIS-5e) and CLP loess-palaeosols (~127 ka).

Role of Elevation and Slope in Snow Distribution in Upper Ganga River Basin (UGRB), central Himalaya

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The Himalaya has one of the largest concentration of snow and ice outside the polar region. It is called third pole because its ice cover reserve the largest fresh water outside the polar region. All the major river in the south Asia originate from the Himalaya and their upper catchment is covered with snow and glacier. Snow cover areas (SCA) are important to monitor the water availability in low land area. In snow covered area, snow melt runoff is predominant during summer, improper management lead to inadequate fresh water supply in mountainous region and cause downstream flooding. It also plays an important role in hydroelectricity production using the stream runoff in mountainous regions. Exact knowledge of the SCA is essential for water resource management**.** The elevation and slope of the terrain also play a vital role for snow accumulation, snow-melt and climate control.The present study has been carried out to find the relation of SCA with elevation and slope in Upper Ganga River Basin (UGRB), central Himalaya using MODIS terra data (MOD10A2) during 2005-2016. Snow cover is derived using the Normalized Difference Snow Index (NDSI). Aster DEM is also used to delineate the basin boundary, and to classify the basin into 15-elevation zone upto Devprayag with 500 m interval and slope maps. The zone wise thematic elevation map was intersected with snow cover thematic images to determine the distribution of snow cover over different elevation zones. Elevation zone 14 and 15 (6500 to 7000 and > 7000 meters) has the highest snow cover area among all the zones during April to September, if averaged over a 12 year period. On the other hand, zones 7 to 13 have higher SCA during winter months. This is mainly because the winter snowfall decreases with increasing altitude towards the Great Himalayan range. For almost every month a very high polynomial regression coefficient (R^2) of 0.9 was obtained. It is also observed that a maximum SCA of 45.24 % is observed in the 0-10 degree slope class. This may be due to the fact that area between 0-10 degrees characterized by a low ablation rate.The decreasing trend of SCA in higher slope classes above 20 degree to 50 degree in which significant geographical area is lies may be due to gravity induced force and sliding of snow occurs. It is observed that SCA is estimated to be 9.34 % (August) to 53.3% (February) in UGRB to the total basin area of 18719 sq. km.

Sedimentological and Geochemical study of the Quarternery sediments of the western part of the Bengal basin at Garhbeta, West Bengal with a special reference to laterite characterisation

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The study area Garhbeta situated in West Medinipur district of West Bengal, India is known for its unique topography and magnificent lateritic cover and is a part of the stable shelf province of the Bengal basin. The present study is to understand the depositional environment of the lower pliestocene sedimentary succession exposed at Garhbeta which is debatable. Further, as laterisation of sedimentary layers are not so well studied like laterisation of an igneous and metamorphic rock bodies, so special emphasis has been given to the characterisation of the laterite. Facies analysis of the sedimentary sequence suggests that the sediments were deposited in a fluvial environment. On the other hand the tropical humid climate of this area may cause intense and prolonged chemical weathering which is responsible for the laterisation of the fluvial sediments. Major elemental concentrations analysed by XRF method suggests that the laterite is formed dominantly by downward leaching of mobile elements and residual enrichment of immobile elements. Detailed future studies about the trace element concentrations and clay minerology of the lateritic layers can broaden the view of their formation process.

Volcanism induced regional fire incidences through KPB transition: Evidence of pyrolitic PAH compounds from Mahadeo – Cherrapunji Section, Meghalaya, India

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Well-established continuous KPB bearing late Maastrichtian-early Danian Um-Sohryngkew River succession (USR) represents shallow marine environment, but, rare data is available on adjacently (~25 km direction) located similar Mahadeo-Cherrapunji road succession (MCR) deposited in the shelf environment. Regional fire incidences together with the paleoenvironmental distress effected biota during KPB transition as evidenced by Polycyclic Aromatic Hydrocarbon (PAH) compounds in the layer (biozone CF3) immediately below KPB of the USR succession. However, inadequate details on MCR succession are available, thus, necessitated to study such affects on biota and to trace out lateral continuity of the KPB layer in the shelf environment. In this scenario, PAH records were traced out across the MCR section and presented in this paper.

PAH data revealed sudden ~2-4 fold rise in high molecular weight (HMW) pyrolitic benzo(a)anthracene, pyrene, fluoranthene and chrysene in thin clayey KPB layer that lies between CF1 and P0 biozones. Moreover benzo(a)pyrene, benzo(e)pyrene, ind (1,2,3,4-cd), pyrene, benzo(ghi)pyrelene, pyrelene peak out immediately below the KPB layer. Abundant low molecular weight (3-ring) phenanthrene, anthracene and fluorine noticed in this layer. These compounds peaks out in biozone CF3 of USR succession and the layer constrained by biozones CF1 and P0 of MCR succession are analogous to reported anomalous concentrations from the El-Kef, Stevns Klint, Gubbio and Woodside Creek KPB sections. Moreover, incidence of these peaks attendant with the Deccan volcanism and convergence of the Indian plate with the Eurasian and Burmese plate causative for severe disturbances in the ocean as reflected by eustatic and related depositional environmental changes, including retreat of the Tethys. Obtained high pyrolitic PAH content is independent of the total organic carbon content; suggest their transportation by atmospheric input. In USR succession, pyrolitic compounds are coincidental with the reported Ce anomaly layer, but, preceding planktonic foraminiferal break. Downwardly thrown USR bearing Therriaghat block causative for early accumulation of PAH compounds. Although, in MCR succession, pyrolitic PAH compound anomalies correlate well with the high shell fragmentation and dissolution effects in the planktic foraminifera, thus, suggestive of equivalent changes in the marine biodiversity and distress to biota. Thus, HMW PAH compounds of both the sections represent significant excursions in KPB layer itself or immediately below or above the KPB layer. Incidence of regional fire due to the heat supplied by late Maastrichtian Deccan extrusions is perhaps linked to transition event initiated ~300 ka prior to the KPB, thus, Deccan volcanism contributed largely to the latest Cretaceous environmental crisis and biotic turnover that culminated in the mass extinctions.

Understanding the Extreme Flood Events and Erosional Hotspot of North East Himalaya

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Paleo-flood hydrology, which is the study of floods beyond the instrumental records not only preserves the reliable signature of climate variability but also tectonics and surface process relationship. Floods in the Brahmaputra basin of India are characterized by their extremely large magnitude, high frequency and extensive devastation. The frequency of such event will increase or decrease has important bearing on paleo-flood history and what kind of climatic phenomenon controls their occurrence. The phenomena of paleo-floods specially the extreme events are often preserved in the form of Massive sand deposits and/or sand-silt couplets called as slack water deposits at geomorphologically suitable locations in river valleys. In the Siang valley, Arunachal Himalaya along the banks of the river such massive sands deposits are mapped and studied at 7 locations between Pasighat (at mountain front) and Tuting (Suture zone). Sedimentological and petrographic data is generated on these deposits to understand the depositional environment and provenance of the flood sediments. Provenance study of these flood deposits can give information on hotspots of erosion and its controlling factors. The Optically Stimulated Luminescence (OSL) dating technique is utilized to establish the chronology of the flood events.

The chronology indicated that the Siang River experienced atleast 7 mega-floods between 8 and 2 ka under the influence of warm and wet climatic conditions. Different grain size parameters implied high energy turbulent depositional conditions. The petrographic details indicated that the eastern Himalayan syntaxis which has the highest uplift and exhumation rate just beneath Tsangpo Gorge produced most of the sediment during these extreme events while few floods were possibly generated in Tibetan plateau due to the glacial lake outburst flood. So the study has focused on different parameters that might be causing these extreme events and controlling factors of erosion during these flooding events.

Evolution of Badlands in the Marginal Gangatic Alluvial Plain Manifests Peripheral Bulge Upliftment

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Tectonic activity of any area characterized by landforms developed upon them. The Marginal Gangetic Alluvial Plain (MGAP), the part of the peripheral bulge, have evolved due to collision of Indian plate with Tibetan plate during Cenozoic Period. MGAP lies where Peninsular Indian Rivers debouch in Gangatic plain. Rivers deposited their thick alluviums in MGAP in course of time. Peripheral bulge region are continuously being uplifted to compensate isostaticaly for Himalayan thrust load. Due to peripheral bulge upliftment of MGAP, base level of erosion of rivers are lowering with respect to topographic elevation of the region. This lowering of base level of erosion caused for increase in the intensity and depth of erosion in the region, consequently badlands have been developed in many parts of the alluviums of MGAP. In this paper, we attempt to demarcate the badlands of the region through field investigations and maps produced from CartoDEM-1 in ArcGIS platform. We also tried to find out a relation between badland development and peripheral bulge upliftment. This study will contribute for the research in the field of tectonic geomorphology in the study area that will be useful to reduce land degradation.

A paleocurrent and sedimentary environmental appraisal from the Lower Gondwana rocks using AMS analysis

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Oriented cylindrical cores of rock samples were collected from the Lower Gondwana basins exposed in and around Maithon and Jitpur areas. The Gondwana Basin of the Damodar valley overlies the Chotanagpur Granite Gneissic Complex. Here the rocks of Raniganj Basin display a concordant relationship with the Gneissic basement. The rocks of the Talchir formation consists of tillite, boulder bed, conglomerate, sandstone, shale and varve deposits along with coarse clastic pebble, cobble and granules that are immature and arkosic in composition and consists of abundant of feldspars, rock fragments with an assemblage of accessory minerals. The Barakar Formation consists of pebbly sandstone, sandstone, black and grey shales which are sometimes carbonaceous. Mineralogically matured sandstones and the abundance of clay minerals reveal the change of glacial environment to a temperate humid climate. Anisotropy of Magnetic Susceptibility (AMS) has been widely used as a tool in the analysis of Petro-fabric and it has successfully been used to investigate the spatial and geometrical configuration of the rock components for qualitative estimation of fabric development. AMS in the oriented cores were studied to determine the nature of magnetic fabrics, correlate it with the paleocurrent patterns. Another factor which can contribute towards the development of primary magnetic fabric in sedimentary rock is the nature of depositional surface: inclined or horizontal. The nature of the depositional surface is negligible in current free environments but important in the moderate and strong current environments. The value of q-factor (0.042 which is less than 0.7) shows that the shapes of the susceptibility ellipsoids and directional data of the AMS indicate primary magnetic fabrics. The orientation of the maximum and the minimum susceptibility axes are aligned towards the paleocurrent and the stereographic projection of the same are the paleocurrent directions. The orientation of the principal susceptibility axes on the equal area diagram is along the periphery (horizontal plane) indicating the fabric to be depositional (primary). The random distribution observed in the Rose diagram is due to the influence of moderate to high energy environment of deposition of the sediments in the studied units. Also, the magnetic foliation (average value = 1.42) exceeds the magnetic lineation (average value =1.01) and the shape parameter exceeds 0 in most cases pointing towards an oblate fabric. The paleocurrent in the present study as indicated by the K_1 axis imbrication is towards the SW direction. The surges of glacial events along with the disordered depositional environment changes within the basin can be a major reason of influence on the direction of dispersed nature of paleo-current patterns. It can thus be strongly recommended that AMS is a powerful supporting tool in understanding the depositional environments and paleocurrent patterns in basin analysis.

Treeline Transposition of Tungnath, Garhwal Himalaya: Climatic or Geo-edaphic Influence?

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Treeline is the edge of the habitat at which trees are capable of growing and used as an important ecosystem dynamics of Mountain regions. Himalayan treeline show different response to recent climate change including substantial upward shifting, moderate expansion, almost stationary position and even the possibility of retreating in case of warming induced drought stress. Besides this spatio-temporal distribution and pattern, treeline reflects the paramount influences of geological history, lithology, structure, geomorphic processes and landforms. However, little is known about the control of geo-edaphic characteristics and treeline species in a Himalayan region. Large portion of the past and current literature was dealing with the global distribution of high-altitude forests, with the question of what environmental factors limit tree occurrence at upper limit around the world. Therefore, the present study aim to address the influence of geo-edaphic characteristics and climate on treeline dynamics. The Chopta-Tungnath section of the Chamoli district in western Himalaya has been selected for dendroecological & geo-edaphic analysis. Dendroecology is the most efficient method to estimate the tree age using tree rings and its growth response to climate. Accordingly, based on tree ring data of *Abies spectabilis*, treeline shift rate for Chopta-Tungnath transect is estimated as 1.37 m/yr. It indicates that climate as well as other internal factors (topography, slope, geological structures, soil type, etc.) might have significant role in the growth and tree line dynamics of *Abies spectabilis* at the Tungnath area for past 300 years. The occurrence of fir trees younger than 100 years within the forest ecotone limit might be the result of observed increasing trend in the winter temperature during the 20th century. Furthermore, linking these finding with geo-edaphic factors would be helpful in better understanding of treeline dynamics in future.

Upwelling intensity in the Somali Basin coincidental with African climate variability and Hominid evolution during the Pleistocene: A planktic foraminiferal approach from DSDP Site 241, Somali Basin

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Marine records of continental margin largely document shifts in east African climate as well as vegetation and faunal assemblages during the Pleistocene. The monsoonal activity and east African climate are observed since 2.2 Ma using abundances of planktic foraminiferal assemblages from 40 core sediment samples at DSDP Site 241 in the Somali basin. *Globigerina bulloides*, a coastal upwelling indicator, shows high abundances with an average of 20% from 1.9 to 1.6 Ma and an average of 8% in the late Pleistocene. *Globigerinita glutinata*, an open ocean upwelling species, also shows a similar trend but less in abundance relative to *Globigerina bulloides*. A step-wise increase in abundances is noticed in *Globigerina bulloides* population from 1.9 to 1.8 Ma, whereas at the same period *Neogloboquadrina dutertrei*, a thermocline dweller, had a sharp decline in abundance because of intense upwelling induced mixing between surface and thermocline waters. In addition, mixed layer species like *Globigerinoides ruber*, *Globigerinoides sacculifer*, *Pulleniatina obliquiloculata*, etc. dominated in the early Pleistocene and then thermocline shoaling occurred after 1.7 Ma. The abundance of deep dweller species like *Globorotalia crassaformis*, *Globorotalia truncatulinoides* began to increase after 1.5 Ma. The observations from Site 241 suggest that African climate was warmer and wetter in the early Pleistocene, turned to cooler and dryer condition after 1.7 Ma. The intense upwelling during 1.9 to 1.8 Ma coincides with the expansion of early Hominid in eastern Africa.

Water and Sediment Discharge from Small Mountainous Rivers of Western Ghats: Variations and controls

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The 1600 km Western Ghats escarpment created numerous small and medium scale coastal rivers. 70 such rivers from Kanyakumari to Surat were selected for water and sediment export to the Arabian Sea. Detailed analysis of discharge and sediment load from 32 gauge discharge (GD) locations over the past 20-35 years is calculated. Water discharge is higher in the middle block (western dharwar craton), whereas sediment flux is higher in northern block (Deccan Traps) of the region. The water discharge from the region is comparatively higher than east flowing major and minor rivers of peninsular India. The sediment yield (area normalized flux) is higher than all major rivers of peninsular India. The Deccan Trap Rivers have high sediment yield, which is comparable with the Himalayan Rivers and other high eroding Asia and Oceania rivers. A statistical Man-Kendel test is applied to find the temporal changes in water and sediment loads over the region. In addition, the erosion related geomorphic indices of the same basins were also derived. The high prediction and accuracy rate of geomorphologically active basins with the measured sediment load provides the role of uplift and erosional stage of the basins over the regions.

Demarcating the Maximum Flooding Surface in late Proterozoic shallow marine sequence using carbon isotopic composition of the bulk organic matter

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Intra-basinal correlation of sedimentary packages using the sequence stratigraphic rationale provides the basis to develop a complete and accurate model of basin fill history in space–time framework. However, in absence of fossil records, intra-basinal correlation for Precambrian sedimentary succession becomes extremely cryptic. Use of Subaerial Unconformity (SU) in demarcating the Sequence Boundary (SB) has proven to be unsuccessful because of highly time-diachronous nature of the SU in low gradient Precambrian large Shallow 'platformal' sea setting. In contrast to SU, Maximum Flooding Surface (MFS) is the least time-diachronous surface among all other sequence bounding surfaces therefore can be used as sequence boundary. However the difficulty in demarcating the exact position of the MFS in Proterozoic fine grained (silt to fine sand) system restricts its use as Sequence Boundary (SB) in many cases. This ambiguity in pin-pointing the position of MFS arises because (1) absence of vascular land plants and associated 'clay factory' during Proterozoic which resulted in scarcity of finest grain facies (clay), (2) low organic content in the MFS associated condense section, and (3) Shallow 'platformal' sea in Proterozoic experienced intense wave-tide reworking of the sediments. In this context, as a case study, we have explored the possibility of using carbon isotopic composition ($\delta^{13}C$) of the sediment associated organic matter from platformal sediment to demarcate the MFS, with the premise that $\delta^{13}C$ values of the marine OM would be different from their terrestrial counterpart. The results of the present case study, from the Proterozoic Upper Vindhyan Shirbu Shale Member (~650 Ma), shows that carbon isotopic composition ($\delta^{13}C$) of the bulk Organic Matter (OM) can help to demarcate the exact position of the MFS in the sections which was only tentatively proposed in earlier sedimentology based studies. The present work thus suggests that $\delta^{13}C$ values of the sediment hosted OM can be a useful tool to find out the exact position of the MFS in silt to fine sand dominated Late Proterozoic shallow marine deposits and may help in building a comprehensive basin scale sequence stratigraphic framework.

Variation in groundwater level due to projected rainfall in Chennai region, India

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Climate change as well as rapid growth in population and agricultural production is likely to affect the groundwater resources in several parts of the world. The objective of this study is to understand the effect of climate change induced rainfall variation on groundwater level in Chennai, India. The complex geological setup of the aquifer system was discretized into thirteen layers. Projected rainfall in GCM was downscaled by Met Office Hadley Centre regional climate model PRECIS, using HadCM3Q model under A1B scenario which indicated a decrease in rainfall. Projected was bias corrected by linear scaling method before using it. It was observed that the average annual rainfall could reduce up to 12% by 2050. Using this projected rainfall, groundwater level until the year 2050 was predicted by groundwater modeling. A finite element groundwater modeling approach was used to carry out this study. The numerical model was calibrated with the monthly observed groundwater level data of over 10 years in about 36 wells. The calibrated and validated model simulated the regional and temporal variation in groundwater level with reasonable level of accuracy, which was verified by statistical methods. The results indicate decline in groundwater level in most of the observation wells throughout the study area. Based on the predicted result the study area was divided in to different zones for groundwater availability.

A Comprehensive Study on Biomarkers, Palyno and Megafloral assemblages along a rivulet section near Kumunda Village, Angul District, Talcher Basin, Odisha, India

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Palaeofloristics, palynology and organic geochemistry of a fossiliferous horizon have been carried out thoroughly along Singda rivulet near Kumunda Village of Talcher Basin, Angul district, Odisha, India. The area is located at 20° 58' 32" N latitude and 85° 01' 45" E longitude. The megafloral assemblage of the investigated section comprises *Glossopteris, Gangamopteris, Vertebraria indica* (Glossopteridales); *Trizygia speciosa* (Sphenophyllales); *Schizoneura gondwanensis,* Equicetaceous stems (Equisetales) and *Neomariopteris hughesii* (Filicales) along with stem casts. The genus *Glossopteris* dominates the assemblage with 20 different species and more than 60% in occurrence. The specimens are preserved as both impressions and compressions on compact, fine-grained carbonaceous shales of the present locality. Based on the megafloral assemblages, the reported section of Talcher Basin is assigned to the Early Permian Barakar Formation. On the basis of the palynofloral evidence two distinct palynoassemblages has been recognized in this section. Palynoassemblage-I is characterized by the predominance of *Striatopodocarpites* spp., *Faunipollenites* spp. and Palynoassemblage-II is distinguished by the dominance of *Striatopodocarpites* spp., *Faunipollenites* spp. along with *Densipollenites* spp. The Palynoassemblage-I and II correlate with *Striatopodocarpites–Faunipollenites–Gondisporites* assemblage zone and *Striatopodocarpites-Densipollenites* assemblage zone of Tiwari and Tripathi (1992) respectively of the Late Permian (Lopingian) Raniganj Formation in Damodar Basin. The presence of key species viz., *Densipollenites magnicorpus, Falcisporites nuthallensis, Strotersporites* spp., *Lunatisporites pellucidus, Guttulapollenites hannonicus, Corisaccites alutus, Weylandites lucifer* and *Hamiapollenites bifurcates* in these palynoassemblages assign their affinity to the Late Permian. The rich diversity of *Glossopteris* leaves in the fine sediments infers seasonal falling and favourable conditions for plant growth with warm, humid, temperate climate during the Permian in Talcher Basin. The organic geochemistry study indicates that high bacterial activity was dominating in the studied sediments with high input of aquatic macrophytes and higher plant organic matter.

High Resolution Laser Based Isotopic Sclerochronology on Biogenic Carbonates

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High resolution Laser-based carbonate analysis technique for determining sclerochronological variation in stable isotopic composition of accretionary carbonate is a relatively newer technique. Instantaneous gas generation with a short burst time minimises the laser induced fractionation and the interaction of gas generated by burning the inherent organic matter can be eliminated by vacuum roasting of the sample. Solving these associated problems, this technique allows a resolution as high as 125 microns and a precision up to 0.2‰, when measured in an attached Continuous flow Isotope Ratio Mass Spectrometer via Gasbench. Stable isotopic composition (mainly $\delta^{18}O$) of modern and fossil fish otoliths are being widely used as a good proxy for the ambient water environmental conditions, as these are metabolically inert unlike bones and teeth, and remains unaltered by its unidirectional growth. The $\delta^{13}C$ values of otoliths to be used as a good Dissolved Inorganic Carbon proxy, is still controversial. Conventional methods, comprising of micro drilling small portions across the growth rings followed by acid digestion of powdered samples is well established, but could not attain higher resolution like this technique. To understand whether this method could be reliably applied upon otoliths to use it as a proxy, otoliths of different species of Arid catfish from western coast of India near Gulf of Kachchh have been analysed. The results suggest the importance of roasting to remove the binding organic matter. The organic matters incorporation is found to be more in the juvenile part due to higher metabolic activities and is reflected on the difference of $\delta^{18}O$ between untreated and roasted portions. The available SST (Sea Surface Temperature) and water isotopic composition of the particular area in Arabian sea (Gulf of Kachchh) is used to calculate the expected oxygen isotopic composition of equilibrium otolith carbonate. The Laser based analyses of these otoliths yielded acceptable results and an annual variation in each otolith falls within the envelope of the range of expected isotopic composition of otolith carbonates. Stable isotopes in *Arius sp.* Otoliths, thus hold a promise as a viable paleoclimatic proxy and can be used in varied settings from geological to archaeological samples.

Temporal variability and time series trend analysis of temperature in Asan watershed, Doon valley, Uttarakhand

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Variation in quantities such as rainfall and temperature is often assessed by detecting and characterising trends in available meteorological data. In the present study, a daily gridded temperature dataset with the spatial resolution of 1°x1° for 1975-2013 were obtained from Indian Meteorological Department portal to evaluate the trend and variability pattern. Data is processed using an Excel macro named MAKESENS. The integration, processing and assessment of data source is also presented. The 39-years period of daily gridded temperature dataset were assessed to see how the daily mean temperature have changed over time and space. From the temperature dataset (based on daily time series), annual maximum, minimum and mean derived to find out the possible changes in temperature of the watershed. The prime objective of the study is to determine a yearly variation in temperature series and to identify the warmest and coldest phases. The linear regression method as well the temperature anomaly method was used to analyse the behaviour of annual maximum, minimum and annual average temperature for the last four decades. The monthly statistics reveals that the mean temperature of the study area ranges from 12.04 °C (minimum) for the month of January to 28.90 °C (maximum) for the month of June with annual average temperature is 21.90 °C. The warmest year with annual mean temperature of 22.81°C was 2010 and the coolest year with annual mean temperature of 20.91°C was 1983. The regression of annual mean temperature demonstrated positive trends and it was found statistically significant. The long range temperature anomaly of mean annual temperature showed inter-annual variability while the trend after 1997 has been continuously higher till 2013. This finding duly supports the speculations that temperature variation in the watershed which may lead to change in hydrological cycle and decrease in agriculture productivity in the watershed.

High resolution climate record of the last ~3 ka from a multi proxy analysis of an organic rich sediment deposit (Ladakh-NW Himalaya)

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An organic rich sediment section from Upshi (Ladakh) is studied employing multiple proxies (palynology, $\delta^{13}C_{org}$, $\delta^{15}N$, TOC, TN and environmental magnetic parameters). The record is constrained by five AMS ages spanning from ~2.7 ka BP to present with no erosional discontinuity having a temporal resolution of ~43 years. The temporal dynamics of several processes (biotic and abiotic) which are influenced by climate are studied such as carbon sequestration, denitrification, magnetic mineral concentration, biomass accumulation and vegetation changes. Rising $\delta^{13}C$, $\delta^{15}N$, χlf are indicative of increased carbon sequestration, higher denitrification, and higher magnetic mineral input respectively. These are in phase with increased flux of aquatic pollen, arboreal pollen (AP), and decreased Chenopodiaceae/Amarantheceae (indicator of stressed climate) suggesting warming phase whereas the reverse is true for cold phases. Two warm and wet phases (~2.7 to 1.8 ka BP and ~1.1 ka BP to present) and one dry phase (~1.8 to 1.1 ka) is identified. The two warm phases overlaps with the Roman Warm Period (RWP) and Medieval Warm Perioid (MWP) respectively. Comparison of the present record with residual $\Delta^{14}C$ suggest the oscillation of monsoon even in the rain shadow zone of the Himalaya is still controlled by solar changes. TOC, TN and $\delta^{15}N$ appear responding to solar oscillations. $\delta^{13}C_{org}$, χlf and pollen record respond on a much coarser scale (probably millennial). The climate record is also comparable to historical the events of India, China, South East Asia and Europe. This can perhaps be inferred as the climate has been an important factor which modulated the anthropogenic changes and developments of the Late Holocene.

Magnetic proxy data for the past climate variability in the Central Himalaya

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High resolution magnetic proxy data were used to reconstruct the past climate of the Central Himalayan region using sediments (sample collected at every 1cm from 4m pit) of a pro-glacial lake of Kalla glacier valley. The parameters that we studied for inferring the past climates are concentration of magnetic minerals present in the sample, their grain size and their mineralogy. The magnetic concentration of minerals can be inferred using low field susceptibility (χ_{lf}) and Saturated Induced Remnant Magnetization (SIRM). Higher concentration value indicates more magnetic material input to pro- glacial lake by the erosion or weathering activity in and around the glacial area. The grain size parameters inferred from ARM, χARM/SIRM, χARM/χ_{lf}, SIRM/χ_{lf} (ARM stands for anhysteretic remnant magnetization) has a similar trend with the concentration (χ_{lf}) parameters. The magnetic mineralogical parameter, S-ratio > 0.9 (magnetite *vs* hematite) indicate the dominance of magnetite and if the value is in between 0.4 - 0.9, then it is dominated by hematite. Presence of magnetite implies a cool and dry phase of climate while warm and humid condition can be inferred from the presence of hematite. On the basis of these magnetic properties, the palaeoclimatic conditions can be divided into the following eight phases with the corresponding high or low values of χ_{lf}, SIRM and χ_{ARM} correlating to wet or dry climates: 16.5–16.0 ka with extremely wet climate conditions; 16.0–15.0 ka with dry climate conditions; 15–14.3 ka with wet climate conditions; 14.3–11.2 ka with drier phase; 11.2–8.0 ka show fluctuating (transitional) zone between wet and dry conditions; 8.0–5.0 ka with overall dry climate conditions; 5.0–3.0 ka with wet climates; 3.0–1.0 with dry climate; and 1.0 ka–present with wet conditions. This is an ongoing research where geochemical proxies of stable isotope and major oxides will also be used to infer the palaeoclimatic variability.

Multiproxy approach to understand tipping elements of the Indian summer Monsoon in the central Ganga Basin

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High resolution proxy records from the continental deposits such as lakes and speleothems during the Holocene have provided important clues to abrupt changes in the past climatic conditions across the Indian subcontinent. During the early Holocene, in Ganga Basin numerous lakes were formed due to the channel relinquishment because of changes in course of major river channels and the tectonic activities (Srivastava 2003; Singh 2004; Singh 2015; Saxena 2017). These lakes in the region preserve the prominent record sacks to understand the Holocene climate history, tectonic activity, and channel shifts.

To understand this climate variability of the central Ganga Basin, we present a multi proxy record from Lilour Lake (28.44°N and 79.04°E; Bareilly, Uttar Pradesh) based on grain size and geochemical proxies ($\delta^{13}C$, TOC). The region is rich in Quaternary deposits constituting of alternate bands of clay and sand with inter-beds of calc- concretions. Climatically, the region is characterized by humid subtropical climate with hot summer and cold winters.

The record based on the grain size variability and isotope study suggests that the period from ~3919 to 3077 cal yr BP is marked by an increase in precipitation whereas from ~3430 to 3077 cal yr BP and ~3919 – 3670 cal yr BP the reduced precipitation owing to weakening in the Indian summer monsoon. Furthermore, the climate variability in the region is established as the manifestation of solar radiation and decoupling of various other climate controlling factors are studied.

Role of northward voyage of Indian Plate on the Paleocene – Eocene sedimentary sequence development

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Cenozoic Era was the turning point, both tectonically and paleoclimatically, in the geological history of the Indian subcontinent when Indian plate experienced maximum isolation, several extreme thermal phases before it collided with Asia and there occurred a great mountain building activity shaping the Himalaya. In the Cenozoic Era, the sedimentation commenced in the late Paleocene in the pericontinental basins of the western India as well as the foreland basins of the Himalaya that mark the beginning of a major transgression on the Indian subcontinent. The early Paleogene sedimentary record of these pericontinental and foreland basins of India deciphers development of Oxisol (lateritic bauxite), Histosol (coal), Calcisol (Aridisol/calcrete/nodular limestone/biochemically precipitated fossiliferous limestone) and Gypsisol (evaporites) in the stratigraphically younging/upward manner. Development of these facies in a hierarchical manner corresponds to larger coverage of latitudinal or climatic belts during the northward voyage of Indian plate, prior to its collision with Asian subcontinent. Oxisol, occurring in crudely bedded, laminated and blanket forms, shows mineral association of gibbsite-goethite-kaolinite. Additionally, it exhibits chemical index of alteration (CIA) values close to 98. The formation of Oxisol was possible in warm and humid climatic conditions of the equatorial region when northern part of the Indian subcontinent was close to the equator. The horizontally bedded Histosol is interpreted as having originated from an undisturbed peat developed in a swamp of high tree density under wet tropical climatic conditions above the intertropical convergence zone, while the pedogenic calcrete in the Himalayan foreland basin and middle Eocene Calcisol and/or Gypsisol in the pericratonic Kachchh and Jaisalmer basins formed once the sub-tropical semi-arid/arid climatic zone was reached. The development of such Calcisol/Gypsisol horizons on western Indian Subcontinent was associated with regression driven by global cooling during the latest middle Eocene/late Eocene possibly associated with the nucleation of the Antarctica ice-sheets coupled with the initial upliftment of the Himalaya.

Depositional model for the first report of late middle Eocene dolostone succession of Kachchh Basin, western India

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The present study focuses on the processes of dolomite formation of the recently reported 16.5 –m – thick massive dolostone succession exposed in the NW region of the Kachchh district, western India. This dolostone succession shows a sharp contact with the underlying middle Eocene Fulra Limestone Formation and can be considered as a new facies/succession. The petrographic study, inclusive of stained thin-sections, exhibits a dominance of unimodal, planar-euhedral idiotopic mosaics of dolomite rhombs along with replacement texture. The X-ray diffraction patterns confirms it as non-stoichiometric type dolomites (average molar% $MgCO_3$ = 47.19). SEM-EDS study deciphers perfectly developed zoned planar-e dolomite rhombs (40 µm-60 µm) with minor variation in the concentrations of elemental Mg (47.67 to 43.33%) and Ca (52.33 to 56.67%). Among the major oxides, CaO and MgO are the dominant components, indicating that the major mineral phase is dolomite. The positive correlation of CaO with SiO_2, Al_2O_3, and Fe_2O_3, and a negative correlation of MgO and ∑REE with them suggest that the CaO was mainly contributed from the rivers as a result of the weathering of carbonates, alongwith the siliciclastic, while the MgO was contributed from the lagoonal brine/seawater. Among the trace elements, Sr is the chief constituent (144 - 234 ppm) that exhibits negative correlation with CaO and positive correlation with MgO that suggests formation of a strontium mineral in the dolostone. The ∑REE content in the dolostones is comparatively lower (18.22 ppm) than the average value of typical marine carbonates (28 ppm) thus suggesting meteoric mixing conditions. The superchondritic Y/Ho values (35.21 – 100) and Post-Archean Australian Shale (PAAS)-normalized REY patterns of the dolostone facies exhibit typical shallow (bathymetry < 50 m) seawater-like patterns. A strong positive correlation between ΣREE and Y, and low Er/Nd ratios (~0.1) in the dolostone facies indicate incorporation of minor terrigenous influx during dolomitization in a meteoric – marine mixing condition. The authigenic uranium (0.4 - 1.7) and slightly negative Ce anomaly suggest that the dolostone succession was precipitated in oxic to dysoxic conditions. The prevalence of planar (euhedral and subhedral) dolomite texture indicates that the dolomitization occurred in a shallow marine environment under low salinity and temperature conditions. Thus, absence of evaporitic association and physical compaction or deep burial features, presence of large channelized vugs, mouldic pores alongwith partially replaced shallow marine fossils, anhydrite cement and marginal-marine values of Sr, Na, Ba, Mn and Fe, supports the meteoric-marine mixing model of dolomitization under shallow marine condition to this dolostone succession.

Soft sediment deformation structures in the Late Quaternary sediments in Ladakh sector implication to reoccurrence of palaeoearthquakes

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Ladakh Himalaya lies in the Trans- Himalayan region, and is bounded by the NE-SW trending Karakoram Fault towards the north and Ladakh range is bounded by the Karakoram range in the northen part and Indus Suture Zone in the South. The trend of that fault in the NE-SW direction.

The study area is exposed on the left bank of the River Indus. The exposed Quaternary sections of Ladakh show evidence of seismicity during the Late Quaternary. Seismites are formed during or shortly after deposition of horizontal sedimentary layers and are important diagnostic features of palaeoseismic studies. Some levels of soft-sediment deformation structures (seismites) are recorded from the Quaternary sediments of Spituk-Leh, along Indus Suture Zone (ISZ), along Shyok Suture Zone (SSZ) and Karakoram Fault (KF). Nine levels of seismites from Spituk-Leh and seven levels from Tangste sections are recorded. The deformed sediments comprise of clay, silts and sand and are restricted to a single stratigraphic layers bounded by undeformed beds suggesting synsedimenatry deformation. The various deformational structures identified are simple and convolutes, pinch and swell bedding, microfolds and microfaults, flame like structures, pseudonodules, clay diapirs, ball and pillow structures, pillar structures, sedimentary dykes and mud lenses. The release of stress along the ISZ, SSZ and KF, may have been responsible for inducing seismicity in the area during the late Quatenary times which may have caused liquefaction as a direct consequence of permanent deformation of ground surface due to earthquakes of large magnitudes (>5 intensity).

Oriented specimens were taken from localities mostly in metavolcanic rocks. In each locality oriented samples were taken and standard specimens were selected for measurements of the anisotropy of magnetic susceptibility. To understand the kinematics and dynamics of seismites, we evaluate the anisotropy of magnetic susceptibility (AMS) of various seismite types, which have formed during palaeoseismic activity along the Karakoram Fault (KF). The deformations structures are thus interpreted as resulting from earthquake induced liquefaction that happened were associated with the tectonic activity along the Karakoram fault. For obtaining the above objectives, methods like identification of Soft sediment deformation structure in the field optically stimulated luminescence dating and anisotropy of magnetic susceptibilty will be applicable.

The sequential databank of the palaeoearthquakes and its relation to soft sedimentary deformation structure can be interpreted based on the various studies operated in the field area. Optically stimulated luminescence chronology will date the exact time of various possibilities related to soft sediment deformation structure and palaeoearthquakes while anisotropy of magnetic susceptibility will explain the fabric analysis.

Reactivation of the Narmada – Son lineaments around Barman, Distt. Narsinghpur, Central India, M.P.

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Neo tectonic activities were observed along the Narmada valley near Barman Village, in the Distt. Narsinghpur, Central India. The river is originating from the Amarkantak plateau, flowing towards the north, and ultimately towards the west direction, to join the Arabian Sea. This river is flowing in the Deccan Trap basalt rocks right from the Amarkantak up to Jabalpur, and then it enters in to Mahakaushal Super Group, and traveling in this terrain and forming the paired and unpaired terraces and a beautiful water fall at Dhuandhar near Bheraghat in Jabalpur Distt.

The Narmada – Son line separates the Vindhyan Super Group with rocks of Mahakaushal Super Group. It intersect almost the whole of Peninsular Shield from ENE to WSW, by it's straight trend, great length and size of topographic effect forming a Rift Valley. This N-S Lineament lie almost in a straight Rift valley and even more interesting is remarkable manner in which the different geological boundaries coincide with line, i.e. in the North (NNE) escarpment of Vindhyan Super Group and within Rift Valley, characterized by the rocks of Mahakaushal Super Group and in the south Narmada-Son Rift is directly touches the rocks of Satpura Super Group exposed at Tilware ghat in Jabalpur. North of N-S Lineament, no rocks of Gondwana Super Group are found and in the south of it no Vindhyan rocks (Proterozoic) are evident. To the north, the Deccan lava flows are spread over upto Sagar Distt. Along the Narmada Valley at Lameta ghat the Lameta beds (middle cretaceous) were disposed in the border of the south Narmada-Son fault.

The river Narmada has major tributaries- Hiron, Tawa, Sidhora and Tendoni. The total catchments is about 98796 Sq. kms. This river is flowing on the Deccan Trap Basalts, and Archean formation, Infratrappean, interetrappean, Lameta rocks through the Gondwana rocks and alluvium. This river has followed a structurally weak zone, so called Narmada- Son Lineament and given rise to the structurally controlled drainage patter in the area. Being the cacthment area falls on the northern most end of the peninsula, so called the stable shield area, which is bordered by the Narmada – Son lineament. The May 22, 1997 Jabalpur Earthquake of 6.5 on the Richter scale has proved that this area is not a stable landmass. The seismic record of the peninsular India for the past 20 years has put a very big question mark on the stability of the various part in the Narmada river valley. Tremors related to Balaghat, Khandawa, Latur Earthquakes and continuous minor tremor in Mandala, Seoni, Lakhnadoun and Narsighpur and in Chhindawara areas has proven that this area is not safe for the future planning for the harnessing the hydroelectric power generation and for the construction of large reservoir/ dam on the Narmada river valley.

Attempt has been made to correlate the seismo- tectonic activity with the structural/ tectonic setup of the area on the stability of the various river valley projects on the river Narmada.

Charophyte flora from the Tappar locality of Miocene (Kutch), Gujarat, India: Biostratigraphic and Palaeoenvironmental implications

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Charophytes represent a group of land plant ancestors living in freshwater or brackish environments. Their calcified fructifications i.e., gyrogonites and utricles, generally fossilize. Fossil gyrogonites have been recovered in non-marine deposits worldwide from the Silurian to the present. Although there are many reports of charophytes from the Neogene Siwalik deposits, there is no report from the Miocene of Kutch, Gujarat. This study documents and describes, for the first time, the charophyte flora from the Late Miocene deposits of Tappar locality (Kutch), Gujarat, India. Eighteen charophytes were recovered from the pseudoconglomerate layer at the present locality. The taxa comprised of four species, namely *Chara globularis* cf. *aspera, C. globularis* cf. *globularis, C.* sp. *indet. and Nitellopsis (Tectochara) meriani.* Charophytes also provide valuable information about biostratigraphic range and palaeoenvironmental conditions of a particular area. The presence of *Chara globularis* cf. *aspera*, *Chara globularis* cf. *globularis* and *Nitellopsis (Tectochara) meriani* at Tappar locality suggests the existence of lacustrine environments with salinity less than 5‰. Further, the presence of two *Chara* species at the locality suggests that the biostratigraphic range of these two species extend to the Late Miocene (11-10 Ma).

Resolving issues in the sub-pixel classification of glacier facies

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Knowledge about the glacier facies aids the glacier dynamics research and their changing extents are indicative of their response to the climate change. Satellite-based remote sensing provides a means to extract such information using per-pixel classification (PPC) or sub-pixel classification (SPC) techniques. SPC techniques are however more appropriate for heterogeneous areas due to their ability to handle the mixed-pixels. Unlike PPC, the SPC techniques are yet to be explored for the extraction of multiple glacier facies. This is because the application of SPC is often constrained by the selection of appropriate input data, generation of reliable soft reference data and inability to achieve higher classification accuracies. With the application of Support Vector Machines (SVMs), this research attempts to demonstrate the role of certain factors such as the surface heterogeneity, input and reference data on the SPC of the Gangotri glacier, central Himalaya. After testing the SVM-based SPC approach on synthetic data, it was implemented on the input Advanced Wide Field Sensor (AWiFS) and reference Multi Spectral Instrument (MSI) data, integrated with different combinations of topographic attributes, band ratios, spectral indices, texture measures and Landsat 8-derived thermal data. The experimental results validated our SVM-based SPC approach and revealed a high dependency of SPC accuracy on the glacier's surface heterogeneity and the selection of input and reference data. An overall accuracy (OA) of 95% was achieved from the SPC of synthetic data. With increase in the surface heterogeneity, OA reduced by ~18%. ~5% decrease in OA was observed when the source and timing of reference data differed from the input data. OA positively differed by ~11% when the spectral data was coupled with all the ancillary layers. A strong correlation of >0.9 was observed between the input and reference fractional area of the classified glacier facies.

Theme IV:
Natural Hazard and Mitigation

Application of ERT in Active Tectonic Study of Nalagarh Region, Northwest Himalaya

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Geometrical characterization of active fault is significant in understanding of potentially seismogenic areas for hazard vulnerability assessment. Beside the geological approaches, inclusion of geophysical method shall add another dimension upon our understanding of active tectonics. Geophysical method provides subsurface imaging and is helpful in delineating subsurface extension of identified surfacial features. ERT is one of most promising geophysical tool that help in characterizing subsurface in terms of resistivity distribution. Given the variability of resistivity of different lithology and rocks, resistivity is an important parameter in understanding subsurface dynamics. The multi-electrode resistivity tomography (ERT) has been applied in the Nalagarh area of Himachal Himalaya across the morpho-tectonic scarp along which late tectonic quaternary activity is well documented by previous research. The high resolution ERT data is obtained using Wenner Schlumberger and Wenner-Alpha array configuration with 2 m spacing and 48 electrodes. In the area, the fault zone comprises of lower tertiary rocks mainly sandstones and shales which are folded and reverse faulted over late Pleistocene alluvial fan deposits comprising gravels, sandy and silty mud units. The study aims to investigate the structural setting mainly the geometry of faults in the subsurface. The availability of trench data allowed us to understand resistivity image of subsurface features and helpful in evaluation of efficacy of ERT method in active tectonics. In the inverse modelled resistivity section of acquired data, the fault is traced up to 18m depth from the surface. The inverted section shows clear vertical offsets of resistivity layers and have lateral variations along the ERT profile. The location of the fault in the subsurface is identified below the morphological scarp of thick unconsolidated quaternary sediments. The obtained resistivity model allowed us to interpret and correlate subsurface lithology with the trench log of paleo seismic trench excavation across the fault. The applicability of ERT method successfully allowed us to reconstruct the geometry of sub surface active fault in the quaternary deposits. The reconstruction of depositional setting is in agreement with an interpretive geologic section based on trench log data.

Hydro-chemical evolution of groundwater in Anand District, Gujarat

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In the present study, groundwater quality of Anand district has been evaluated to infer hydrochemical processes and suitability for drinking and agricultural purposes. The study area is situated in the semi-arid alluvial plain of Anand district. A total of 20 samples had been collected during the pre-monsoon season and total 22 physicochemical water quality parameters were analyzed. The total ionic dominance (meq/L) pattern follows the order Na^{2+}> Cl^{-} > HCO_3^{2-}> Mg^{2+}> SO_4^{2-}> CO_3^{-}> Ca^{2+}> NO_3^{2-}> K^{+}> F^{-}> Br^{-}> Li^{+}. The ionic ratios, PCA and chloro-alkali index confirms the type of groundwater in the study area. The results show that groundwater have higher pH, EC, TDS, Na^{+}, Cl^{-}, F^{-}, NO_3^{-}, SO_4^{2-} and HCO_3^{2-} than the desirable limit of WHO. According to the De Weist twelve samples are permissible for drinking, five for irrigation and three samples are unsuitable for irrigation and drinking according to their TDS values. The piper plot shows the dominance of Na^{+}+HCO_3^{2-} and Na^{+}+Cl- types of water while monovalent cations (Na^{+} and K^{+}) and anions (Cl^{-} and HCO_3^{2-}) are dominant. The scatter plot shows the dominance of silicate weathering and ion exchange processes while Gibbs plot explains the rock dominance and evaporation dominance in the study area. RSC, %Na and KI values shows 70% samples are unfit for irrigation in the study area.

Study of Nhachüko Landslide, Kohima, Nagaland

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A landslide occurred at Nhachüko area of Kohima town on 2nd June 2017, which blocked the small stream flowing through the area. A section of the proposed Asian Highway 1, connecting the Secretariat Complex and other important offices with the Medical College construction site, was cut off along with damage to some property in the area. The lithology, structure and water conditions of the area were mapped. Geotechnical studies have been carried out to decipher the mechanical properties of the rocks and soils. The Disang shale with minor intercalations of siltstone and sandstone of Eocene age make up the rocks of the study area. The slope materials comprise weak soils and fragile rocks that are highly fractured and jointed. The soils are silty in composition with low to moderate plasticity and low shear strength. The slope stability has been weakened, with a low cohesion value of 10 kN/m^2 and friction angle of 18°. This region is part of the Inner Fold Belt of the Indo-Myanmar Ranges, whose configuration is due to the subduction of the Indian Plate below the Burma microplate. This subduction is due to a NW-SE compression. As a consequence, the fold and thrust axes of the region are aligned NE-SW. The dominant joints are parallel to this trend. Soil from earth cutting was indiscriminately dumped in the stream channel, which restricted the flow of water through a small culvert, leading to build-up of pressure. Prolonged and heavy rainfall during the monsoon increased the pressure to a level exceeding the frictional limit of the soils, which led to the failure of the entire slope. Planned and scientific method of excavation and maintenance of proper drainage are important in weak areas to prevent landslide.

Frequency and lapse time dependent coda wave attenuation in western Tibet

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Spatial variation of coda wave attenuation (Q_c^{-1}) has been analyzed for western Tibet using single isotropic scattering model. We are the first to map Q_c^{-1} in the crust for this region. 628 local events with a hypocentral distance less than 200 km recorded at Y2 network of broadband stations during 2007-2011, are used for this analysis. All the events are crustal having maximum hypocentral depth upto 40 km. The estimation of $Q_c^{-1}$is made at central frequencies 1.5, 3, 6, 12 and 18 Hz through five different lapse time windows from 30 to 70 s starting at 1.2 times of S wave arrival time. A strong frequency dependence nature of Q_c^{-1} is found in this region, which indicates that the region is tectonically active with high heterogeneities. We have also estimated the Q_{0c}^{-1} (Q_c^{-1} at 1 Hz) and frequency dependent parameter *n* using the relation $Q_c^{-1} = Q_{0c}^{-1}.f^{-n}$. There is a tendency to increases *n* with increasing observed Q_{0c}^{-1} values, and vice versa. Variation of Q_{0c}^{-1} with different lapse time and its corresponding apparent depths are also studied. We found that the level of heterogeneity decreases with increasing depth.

Geotechnical studies of the major subsidence affecting Lower Officers' Hill and AH 1, Kohima, Nagaland

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Surface instability such as subsidence, landslides and other forms of mass movements are common phenomenon in hilly terrain. The study area, a part of the hilly Kohima town, has also suffered from surface instability. A major portion of the Lower Officers' Hill has been adversely affected, including ~200 m of the Asian Highway (AH)-1. Continuous, differential subsidence of the highway over many decades has severely disrupted traffic flow, causing great inconvenience to the inner districts of Nagaland and the state of Manipur. The area is composed of rocks of the Disang Group that are made up of shales intercalated with thin beds of siltstone and fine grained sandstone. These rocks are highly jointed and fractured; two faults trend NW-SE and another NNW-SSE. This area receives abundant rainfall. Water easily percolates through the rock fissures and weak soils of the slopes; the upper saturated soil horizons provide domestic supplies of water throughout the year. The Sitsie Rü, flowing NNW, and its two tributaries, parallel to each other and flowing WNW, are highly erosive and are responsible for intense toe erosion. The NNW-SSE trending fault controls the alignment of the Sitsie Rü. The present study involves geotechnical analyses of the slope material to determine the mechanical properties of the rocks and soils. Analytical results indicate that the soils are mostly clays possessing low to high plasticity. Direct shear and triaxial compression test were carried out to evaluate the cohesion (C) and internal friction angle (ϕ) for soils of the study area, and from which the shear strength of the soil was computed. Point load test data of the intact rock samples collected from the area indicate weak strengths of 3.5 Mn/m^2. Rock and slope mass ratings indicate weak rocks and unstable slope conditions. Kinematic analysis from joint data is used to assess the potential failure mode. Joint attitude plotted against slope in stereographic projections indicate possible wedge failure towards WSW. A low factor of safety of 0.30 is estimated, which points to severe instability in the area.

An experimental study on rheological behaviour of debris flow materials in Indian Himalayas

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Debris flow rheology is the science of flow and deformation of materials under the effect of an applied force. Debris flow rheology is considered as an essential controlling factor for debris flow runout .Therefore, for the prediction of debris flow runout as well as flow characterisation, rheological properties of the materials involved, has to be obtained. Rheological models are used to characterise the flow behaviour of debris flow materials. Debris flow runout estimation using numerical model based on continuum mechanics need a suitable rheological model. Rheological parameters of debris flow materials are obtained either directly from the field by back analysis of a real event that took place in the past or from laboratory analysis.Rheometers are used to carry out rheological measurement.

Debris flows are one of the most destructive phenomenons in Indian Himalayan, causing loss of life and property every year often initiated by rainfall or earthquakes. Factor which governs the debris flow includes the topography, material properties and triggering factors. Most of the studies are limited to landslide hazard or susceptibility zonation, slope stability assessment, geotechnical characterisation and very few on landslide risk assessment and corresponding design, planning and implementation of landslide mitigation measures. But rheological characterisation of debris flow material is still lacking.

In the present study, an experimental study was carried out in the laboratory to characterise the rheological behaviour of debris flow material using a rotational rheometer. The material used for this study was collected from the source zone of an active debris flow site in Indian Himalayas. The aim of this study on rheological characterisation lies in understanding the flow behaviour of such debris material with varying coarse and fine fractions. Two rheological models, Bingham model and Herschel-Bulkley model were adopted in this study to describe the rheological behaviour. The debris flow material collected from the study area showed non-Newtonian, visco-plastic behaviour. Its flow index value is less than 1 (0.345), indicating the shear thinning behaviour of the material which makes the material capable of moving a greater distance due to their low viscosity. This kind of materials is responsible for travel of debris material to a large run out distance. The value of yield stress and the plastic viscosity of the debris flow material were found to be 417.313and 15.387 respectively.

This study can be used for the site specific material characterisation based on rheological behaviour of debris flow material which is essential for prediction of the runout behaviour of debris flow where detailed data on past landslides are not adequate or completely absent.

Estimation of Site response by H/V method for the 2016 Kumamoto earthquake

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A strong earthquake of magnitude (M_{JMA} 7.3) struck Kumamoto city, Japan on April 16, 2016. The near field data of this earthquake recorded by eight stations are used to estimate the site effects using H/V method. Site effects have been calculated using complete time history as well as for S-phase at these stations. In this regard, almost similar site effects are observed for both the cases at different stations. The selection of S-phase window is always debatable and in order to avoid this we have considered the complete record length for further studies. The predominant frequencies are calculated at different stations to estimate the site effects. We have observed relatively higher predominant frequencies (6.0-9.0 Hz) at stations KMMH01, KMMH02, KMMH11 and FHOK10. As predominant frequency is inversely proportional indicator to the sediments thickness/basement depth, therefore the stations having high predominant frequencies are more likely to have less sediment thickness and vice-versa. This suggests presence of a thin near surface low velocity layer below the above said four stations. On the other hand, low predominant frequencies (0.7-3.0 Hz) at stations KMMH03, KMMH13, KMMH16 and MYZH12 suggests the presence of near surface thick layer of loose sediments with low velocity. The results obtained in the present study are compared with the near surface geology of the recording sites. This provides a reliable match between the estimated results and geology below the sites.

Identification of landslide susceptible areas along NH-10 from Singtam to Gangtok, East Sikkim using Thematic Maps

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Landslide is a widespread phenomena or natural disaster all over the world. In order to understand the affect of landslides/mass movements in Sikkim region, NH-10 has been selected for identification and investigations of slope failure processes. The NH-10 is the only communication system in this region and called as a life line of the state that also fulfills the demands of defense forces working in border areas. For the present studies, a part of NH-10 that is of 18 km long from Singtam to Gangtok has been chosen. This road length is affected by various types of mass movements. The causes responsible for these movements are mainly geology, hydrology, seismicity and engineering behavior of slope forming material etc. Besides these, the study area is also affected by heavy rainstorms and alteration of geometry of slope which consequently results different types of slope failure phenomenan. Geologically, the area is made up of mainly quartzite and phyllite which belongs to Gorubathan and Reyong Formations of the Daling Group. Further, an attempt has also been made to mark the landslide prone areas along the road with help of different types of thematic maps. The Author (s) have prepared the Digital Elevation Map, Slope map, Aspect map, Contour map, Drainage map, lineament map and landslide susceptible map using CartoDEM on Arc GIS 10.5 software.

Kinematic Analysis of Noklak landslide, Tuensang district, Nagaland

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Surface instability such as landslides and other forms of mass movements are common phenomenon in hilly terrain. The affected zone is located in south-west part of Noklak Town, Nagaland covering an area of about 1.84 sq kms and has been going on for more than two decades. Geologically, it is predominantly composed of Disang group of shales. Noklak town is situated on the far eastern part of Nagaland and is incorporated in the survey of India toposheet no. 83 N/4 and lies in 95º00′39″ east longitudes and 26º11′52″ north latitudes, the area lies in the Inner Fold Belt of Nagaland where the rocks are generally weak and unstable due to folding, faulting, shearing and weathering. The rocks in the vicinity of the slide zone are highly jointed, fractured and weathered. The area receives abundant rainfall and water percolates through the joints and fractures which makes the area more unstable. The present study involves kinematic analysis of the slope material to determine the potential mode of failure, it is the most simplified failure analysis in terms of joint sets, bedding plane, cut slope and angle of internal friction. Kinematic analyses have been performed from about 1,195 joint attitudes taken in the field to determine the probable mode of failure and also to determine the dominant joints that controls the instability in the area. Total 50 rock samples were collected to determine the rock strengths, Point load test data indicates low values for the rocks. RMR (Rock Mass Rating) value indicates poor rock quality. Soil Mass Rating (SMR) values for this slope fall in Class IV which indicates highly unstable slope conditions with both planar and wedge failure. Results from the kinematic analysis shows planar and wedge type of failure.

A numerical study of effect of valley-weathering on the ground motion characteristics

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A study of effect of valley-weathering on the ground motion characteristics and associated differential ground motion (DGM) is documented in this paper. A forth-order-accurate staggered-grid finite-difference (FD) program has been used for the simulation of SH-wave viscoelastic responses of the various considered valley models. Simulated results revealed that the defocusing caused by valley is frequency-independent in contrast to the ridge-focusing. ASA decreased from trough to the top of the elliptical valleys in contrast to the triangular valleys, where there is an increase of ASA. Overall, the amplification/de-amplification pattern was larger in case of triangular valleys as compared to the elliptical valleys. Based on the simulated responses of the weathered triangular and elliptical valleys, it can be concluded that the dwelling along the flanks of a non-weathered elliptical valleys is safer than the triangular valleys for the earthquake point of view. But, inverse inference is in case of both the weathered elliptical and triangular valleys.

Exploring earthquake databases for the preparation of magnitude-homogenized catalog for the Himalayan seismic belt (HSB)

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A catalog for earthquakes that occurred in Himalayan seismic belt during the period 1964–2017 is compiled for achieving homogeneity for magnitudes. The aim of present study is to prepare a homogenized earthquake catalogue for the Himalayan seismic belt and adjoining regions. It should be free from dependent events (foreshocks and aftershocks). The examined region is one of the most active seismic regions of the world which has witnessed four great earthquakes of M≥8.0 and more than dozen earthquakes of M ≥7.0 in recent past. The available earthquake catalogues from international and national seismological agencies for this region are not homogenized in one magnitude scale. Therefore, we have developed depth-dependent magnitude conversion empirical relations for instrumental period to convert classical earthquake magnitude scales into $M_{W,HRVD}$ proxy estimates. For this purpose, different published earthquake catalogues and literatures have been consulted from different seismological agencies e.g. International Seismological Centre (ISC) of UK, National Earthquake Information Centre (NEIC) of USGS, Harvard Centroid-Moment Tensor Catalogue (HRVD), International Data Centre (IDC) of CTBTO, China Earthquake Information Centre, Beijing (BJI) and National Centre for Seismology, New Delhi, India (NDI). Different empirical regression relations have been established for moment-magnitude ($M_{W,HRVD}$) with the body-wave magnitude (m_b), surface-wave magnitude (Ms), local magnitude (M_L) and duration magnitude (M_D) scales provided by different agencies for shallow, intermediate and deep depth ranges. General Orthogonal Regression (GOR) and Orthogonal Distance Regression (ODR) techniques have been used to derive the regression relations. To prepare Mw-homogenized earthquake catalogue for the Himalayan seismic belt, we defined code numbers or number combinations, which describe in a unique way how proxy estimates for $M_{W,HRVD}$ have been derived. The same code numbers have been used to convert pre-1964 earthquake magnitudes. Priority has been given to direct Mw of HRVD and proxies Mw have been estimated for ISC (Ms, mb), NEIC (Ms, mb), IDC (Ms, mb, M_L), NDI (M_L, M_D) and BJI (M_L). We have also illustrated the difference between proxy $M_{W,\ HRVD}$ derived from different seismological agencies for different magnitude scales with the original $M_{W,HRVD}$ which suggest the reliability of converted proxy $M_{W,HRVD}$ values. The prepared $M_{W,HRVD}$ based homogenized earthquake catalogue during 25 B.C – 2017 have been declustered (removal of dependent events) using suitable windowing method. Our future aim is to analyse the completeness of the catalogue in space and time.

Fmax. and kappa (K) value in Tohoku region of Japan

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In the present study a data set of 10 events occurred in Tohoku region of Japan has been analysed .These events have been reported by kik net network established by NIED Japan. The network consists of surface as well as well accelerometers these 10 events recorded at 185 surface stations and 169 well stations. Hence total 1062 accelerometers are used in the study. The source parameters; corner frequency (fc), seismic moment (M0), Moment magnitude (Mw), Fmax., stress drop and kappa(k) values are estimated using software EQK_SRC_PARA_K. The seismic moment (M0) varies from 7.33E+12 to 1.32E+17 (in Nm), Moment magnitude (Mw) varies from 2.5 to 5 and stress drop values varies from 7.94E-01 to 1.41E+02 (in pascal).The variation of fmax. Is from 1.75E+00 to 3.89E+01 (in hz) in surface events and from 5.4E+00 to 3.65E+01 (in hz) in well events. The variation of kappa (k) is from 1.0E-03 to 8.0E+01 in surface events and from 9.0E-03 to 8.0E-02 in well events.Various plots of Fmax. And Kappa (K) have been analysed from surface and well events. The plots shows higher degree of scatters hence indicates less dependence of Fmax. and Kappa(k) on source. However Fmax. Plots shows less scatter in plots as compared to kappa (k).

Landslide Susceptibility assessment using GIS-based multiple statistical approaches in the Goriganga river basin, Kumaun Himalaya

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Landslide is a common phenomenon in the Himalayan terrains and is a part of normal geomorphic cycle. It is reported because of this hazard about 200 - 300 people get killed every year and many villages in the Himalayan terrain get displaced or abandoned. Therefore there is an urgent need for the assessment of landslide susceptibility/hazard in an area and is thus an integral part of the disaster management cycle. For the present work, large scale landslide susceptibility maps of the Goriganga river basin from Jauljibi village to Milam village using high-resolution satellite images have been prepared using GIS-based numerous standard multiple statistical approaches like frequency ratio, information value, and Yule's coefficient.

The studied area encompasses ~ 2170 km^2 on either sides of the river. Geologically, the river cuts across all the rocks of the Himalayan sequence right from Tethyan sequence in the north to Lesser Himalayan sequence in the south. An inventory of 180 active landslides ranging in area from 50.74 m^2 to 384961.7m^2 were prepared and eleven possible causative factors of landslides viz. lithology, slope angle & aspect, elevation, curvature-plan, curvature-profile, distance to drainage, road & thrusts, landuse and land cover and past seismic events were taken into consideration for the preparation of landslide susceptibility map of the area and the thematic layer for each was prepared using the primary as well as the secondary data. Of these 180 landslides, 70% were randomly selected for the assessment of landslide susceptibility using the bivariate statistical approaches, and the remaining 30% were used for validating the models.

It has been noted that models prepared by all the three methods have more or less similar area under curve (AUC) values ranging from 0.86 to 0.88 for success rate curve and 0.79 to 0.85 for the prediction rate curve. Further, the study concludes that amongst the methods used, the frequency ratio model exhibit the highest performance with an AUC value of 0.88 and 0.85 for SRC and PRC, respectively.

Remodeling of topographic corrected Magnetotelluric data

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Magnetotelluric method is the powerful 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 two-dimensional topographic effects 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 responses in two dimensional. In three-dimensional, the topography effect is both galvanic and inductive in either TE or TM mode and hence the interpretation is complicated. This paper represents the effects of three-dimensional topography for a hill model using Winglink software package using a finite difference method. This paper presents the impedance tensor correction algorithm (by calculating correction coefficients derived from a homogeneous background resistivity) to reduce the topographic effects in MT data. In this study we analyze the response of ramp, conductive and resistive dyke.

The correction method developed has been applied to the real data from Sikkim Himalayas. The one-dimension inversion of the topographic corrected MT data brought out the true nature of the basement in this region. The 3D topographic correction is applied to few sites from northern segment. The whole data set was remodel on flat earth model. This inferred the final subsurface geoelectrical structure of the Sikkim Himalaya, which is free from topographic distortion.

Relationship of landslides, litho-tectonics, and precipitation regime, NW Himalaya

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Landslides are one of the principal mass wasting processes in tectonically active mountains. Climate has also been considered to control the distribution and frequency of landslides. Such mass wasting process, however, has been noted to vary spatiotemporally due to varying climate and tectonic conditions. Nonetheless, the interrelationship of climate and tectonics in association with landslides have rarely been attempted in the Himalaya despite the significance of this interrelationship in hazard assessment, landscape evolution, and effects of changing climate. This study explores spatial interrelationship of landslides, tectonics, and precipitation regime in the Satluj, Yamuna, Bhagirathi, Alaknanda, and Kali River valleys of the Indian Himalaya.

In order to infer tectonics in the river valleys, concavity index (Θ), steepness index (k_s), the ratio of valley floor width to valley height (V_f), topographic relief, and exhumation rates were used. Tropical Rainfall Measuring Mission (TRMM) rainfall data and Normalized Difference Vegetation Index (NDVI) were used as proxies of the precipitation. Field observation and high-resolution imagery were used to locate and map the dimension of landslides. The volume (V) and area (A), along with utilizing for spatial interrelationship were also used to find out the volume-area scaling relationship i.e., $V= \alpha A^{\gamma}$. Here, 'α' and 'γ' are scaling factor and scaling exponent, respectively. This scaling relation was aimed to understand the intrinsic relationship among landslide dimensions and to know whether this relationship is affected by the spatial variability of tectonics, precipitation and other factors.

The Tethyan Sequence (TS) region showed least tectonic activity, whereas Higher Himalaya Crystalline (HHC) and Lesser Himalaya Crystalline (LHC) are noted to have relatively high tectonic activity. The Lesser Himalaya Sequence (LHS) region, though, is not found as tectonically active as HHC and LHC, possess relatively high tectonic perturbance than the TS. Low rainfall, relatively barren hillslopes, and snowmelt induced rock mass failure are considered as the main factors for the landslides of the TS region. The HHC, LHC, and LHS region are found to have a simultaneous effect of tectonic activity and rainfall on the landslide distribution. Rock mass shearing at regional faults are observed to enhance the dimension of landslides. Rockfalls/Rock avalanches are mainly associated with high k_s and low V_f, whereas debris slides are dominantly associated with low k_s and high V_f. The MCT region is found to possess spatial coexistence of huge debris slides, high k_s and enhanced precipitation that strengthen the concept of interrelationship in the river valleys. Scaling exponent of the debris slides, rock falls, and rock avalanches is noted to be 1.5±0.3, 0.923±0.02, and 0.89±0.02, respectively. This paper attempted to reveal the interrelationship of landslides, litho-tectonics and precipitation regime that helped to determine the relative influence of these factors on the distribution and dimension of landslides.

Role of Site Effect for the assessment of Attenuation characteristics in Kinnaur, NW Himalaya India

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In the present work, the site effect study is carried out for Kinnaur region of Northwest Himalaya. The site effect or site amplification causes seismic amplification due to soft deposits overlaid on the bedrock and responsible for more damage during the occurrence of large magnitude earthquake. Therefore, site effect studies play an important role in the evaluation of seismic hazard of any region. The Horizontal to Vertical Spectral Ratio (HVSR) technique is applied to estimate the site effect for the data of each recording station of Kinnaur region. A total of 118 local earthquakes of magnitude range 1.8-4.7 recorded at 10 broadband stations within the epicentral distance of ~150 km are utilized to quantify the site characteristics. A number of earthquakes are considered at a single recording station for better assessment of the results. The Kinnaur Himalayan region is mainly *belongs to Higher Himalaya Crystallines (HHC) and Tethys Himalaya, where these two geological units are separated by the South Tibetan Detachment System (STDS). The southern part of STDS contains crystalline rocks while to its north low-grade sediments exists.* The comparatively large site amplification obtained for the data of the Tethys Himalaya support the presence of low grade sedimentary rocks suggesting higher seismic hazards. The study region belongs to the source zone of M 6.5 Kinnaur earthquake of 1975. Also a high micro-earthquake activity is observed in this part of NW Himalaya.

Attenuation property of Kinnaur region is also quantified by using a dimensionless parameter i.e. quality factor (Q), inversely related to attenuation. The obtained site effect are used for the computation of Coda wave quality factor (Q_c). The single backscattering method (Aki and Chouet, 1975) is used to calculate the coda wave quality factor. The coda waves filtered at seven central frequencies i.e. 1.5, 3, 6, 9, 12, 18 and 24 Hz are utilized to estimate frequency dependent ($Q_c(f)$). The horizontal component (NS and EW) of earthquake records is influenced by the site effect depending on soft sediment thickness beneath the recording sites. Therefore, these records are corrected for the site effect to estimate Q_c. To evaluate site amplification for the estimation of Q_c a numerical experiment of Sarahan station data is performed for different records. The evaluation includes (1) NS uncorrected ($119f^{0.99}$), (2) NS site amplification corrected ($81.97f^{1.08}$), (3) vertical uncorrected ($87f^{1.02}$) and (4) vertical site amplification corrected ($88f^{1.13}$). It is observed that the NS uncorrected and corrected records provide different results whereas vertical uncorrected and corrected records provide almost similar results in form of $Q_c(f)$. Results obtained by using the role of site effects suggest almost similar attenuation relations for the corrected records of NS and vertical components. The whole data set used to obtain regional $Q_c(f)$ relation of the form $Q_c(f) = Q_o f^n$ i.e. $(74 \pm 11)f^{(1.17\pm0.01)}$ for the Kinnaur region. The comparison of obtained relation with other available relation for Himalaya region validates that it falls within the range of values that are justified for tectonically active regions.

Coastal Pollution Signatures of Bio indicators: A study from Nizampatnam Bay-Lankevani dibba Coast, Andhra Coast, Southeast Coast of India

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Across the world, the coastal zones are misused by the people as dumping sites for industrial and domestic wastes. The various processing industries which are situated near the coastal fringe, release effluents into the estuaries and coastal zone. Estuaries are vital source of natural resources to man and are used for commercial, industrial, and recreational purposes. They act as the conducive nursery ground for variety of sea food. Biodiversity in this ecosystem is very impressive. In India, we have a combined length of 45,000 kms comprising 113 major and minor rivers. Anthropogenic interference in the aquatic bodies has caused considerable ecological imbalance and resulted in the large scale disappearance of their flora and fauna. Introduction of untreated municipal sewage and industrial effluents into these water bodies leads to serious water pollution including heavy metal concentration which gets biomagnified and reaches man through food - chain implications. Over the last Four decades the benthic foraminifera has been expanded to investigate their response to polluted marine environments (Schafer, 1973; Bates and Spencer, 1979; Bhalla and Nigam, 1986; Benerji, 1989; Jayaraju and Reddy, 1996). These earlier works concluded that foraminiferal species are definitely sensitive to pollution effluents and show morphological deformities in polluted areas. Few studies thus for have addressed the relationship between modes of deformities and environmental parameters. Coastal pollution studies using benthic foraminifera as proxy indicators were initiated by Resig (1960) although pollution effects on foraminifera had been mentioned earlier by other workers (Zalesny, 1959). Since Andhra coast is fast developing like any other coast in the world with installation of various industries along coastal zone in addition to ever increasing aquaculture development, it is very interesting and imperative to know how much the coastal zone and the river estuaries have subjected for pollution owing to anthropogenic stress which proves lethal to the marine life and bioecosystem. This base line data will be helpful to demarcate the highly polluted zone and to protect ecologically fragile coastal areas and estuaries, under the Environmental Act as directed by the Supreme Court (1996).

Magnetic Susceptibility Mapping of Road Dust: An Appraisal to Environmental Pollution

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Urbanization and fast industrial development in the Indian subcontinent is the most inevitable curse in disguise. Lack of transparency in the legal rules for pollution control and almost no environmental awareness in the common people are the prime factors that are leading the beautiful environment towards graveyard. Geoscientists and Environmental experts throughout the globe are struggling hard to develop sustainable ways to detect and control the aforesaid issue. Important among them stands the geophysical studies among which magnetic susceptibility mapping is mentionable. This lies on the fact that the Ferro-magnetic minerals (the chief contributors towards positive susceptibility), mainly magnetite, are good store houses of toxic elements. The present studies aim in unravelling the distribution of magnetic susceptibility in The Kolkata Metropolitan area for pointing out the potentially polluted areas by mapping the magnetic susceptibility value of the road dust collected throughout the city. The values of both the mass and bulk susceptibility show wide range of variation with average values of 41.17×10^{-8} m^3/kg and 128.321×10^{-6} m^3/kg respectively. The other necessary statistical parameters were calculated which reveals the same. Mapping (both in 2D and 3D) of the magnetic susceptibility shows that their values are higher in the areas with adverse vehicular traffic and other polluting sources. Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) analysis carried out for better investigation. Microscopic studies suggested that the dust particles showing mostly random shape, rough surface. However, some areas are evidently polluted highly but possess relatively lower susceptibility values on account of the dispersion of the magnetic pollutants due to available space. The overall study reveals that the major reason for the degradation of the environment is anthropogenic activities which need to be controlled by developing more and more awareness. It is worth mentioning that the authorities in charge is developing the same, still, the issue deserves more concern.

The spatial distribution of landslides vis-à-vis various morphometric indices along the Teesta river, Sikkim Himalaya

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Landslide, is a normal geomorphic process which have been occurring on the mountainous terrain since geological times. It is considered as one of the most important factors for landscape evolution. The causes for the occurrence of landslides are generally grouped as natural and anthropogenic. Natural factors are influenced by the tectonics and climate of the area and are responsible to maintain the topography, including the structures and geomorphological characteristics of the area. Whereas, anthropogenic factors are mainly deforestation and intervention on the slope by human activities. The present study deals in investigating the tectonically active zones along the 80 km stretch of Teesta river valley from Lachen in the north to Rangpo in the south and thereby establishing a relationship with the landslides.

Morphometric indices, like longitudinal river profile, Channel Steepness Index (K_s), Valley floor width to valley height ratio (V_f), capable of detecting the active tectonics in the area along with the Topographic Wetness Index (TWI) indicating the spatial soil moisture distribution, have been measured. An inventory of landslides with its dimensions, have been prepared and its inter-relationship with various morphometric parameters were made.

It has been noted that along all the valleys, areas exhibiting higher K_s and lower V_f represented by steep and long slopes, are tectonically active and characterized by the dominance of rockfalls and rock avalanche, while the area exhibiting lower K_s and higher V_f are represented by broad flat-floored valleys and are characterized by the dominance of debris-slides. Besides, clusters of landslides along the river valley are found near the litho-contacts and at knick points.

Multidisciplinary Approach for Site Specific Landslide Investigation

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Landslides are known as one of the most significant geohazards in the mountainous regions. This geohazards phenomenon has left almost none of the mountainous region unaffected due to urbanization and infrastructural developments. If attentions are not being paid to this occurrences it will pose serious and unpredictable danger to both lives and properties. Landslide study requires multidisciplinary approach which involves both surface and subsurface investigations. These investigations include, geomorphology, geological, geotechnical, geophysical, geodesy, hydrological among others. These involve detail mapping, surface and sub-surface investigation, hazard and susceptibility zonation, risk assessment and management, stability and remedial measures and monitoring. The main objective of this paper is to highlight various methods of investigating landslide beyond landslide hazard zonation. Maximum attention was given to site specific investigation of landslide. This helped in detailing out the risk involve in the failure of the landslide which help in designing a suitable remedial measure for the stability, monitory of the landslide. Avoidance and prevention of landslide occurrence as in integral part of land-use policies will becomes easier when properties and state of marginally stable slope is known. Integration of geophysical and geotechnical methods has been employed to investigate the sub-surface condition of Pakhi landslide which is one of the major debris slides of retrogressive nature along national highway (NH - 58) corridor from Rishikesh to Badrinath in Garhwal Himalaya, India. Integration of both methods has helped in the definition of the landslide activities and geometry. The results obtained will be useful in monitoring and mitigation program for the slope which will help in sensitizing the society on avoidance, prevention of their lives and properties in case of landslide disaster.

Evaluation of chirps for Meteorological Drought assessment in Bundelkhand region, India

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Drought is a recurrent and prominent extreme climate event in the semiarid region of India that significantly affects the social, economic, and environmental conditions of the region. Use of rain-gauge station data for drought monitoring and assessments have limitation due to spatial coverage, mostly in region with limited rain gauge observation networks, which hinders the robust spatial characterization of drought hazard. On the contrary, the satellite derived rainfall estimation proved as an effective alternative in solving monitoring of drought events at higher spatial and temporal scale. With this reference, the current study aims to evaluate the Standardized Precipitation Index (SPI) for meteorological drought monitoring using the satellite and ground integrated Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) version-2 rainfall data. The evaluation is conducted in Bundelkhand region, considered as one of the severe drought affected regions of Uttar Pradesh state, India. The CHIRPS data was compared against the ground-measured gridded rainfall data obtained from Indian Meteorological Department (IMD) for the period of 1990 to 2016 (26 years). Comparative study was performed at district level to determine the regional differences, and to statistically verify the performance of CHIRPS data in estimating the degree and spatial pattern of drought with IMD data over the study area at monthly scale. The SPI at various time scale (1, 3, 6, and 12 months) was computed using the open-source DRINC software. The statistical analysis indicated that CHIRPS shows the high correlation (R^2= 0.75) and low root mean square error (60.68 mm) and bias (0.58) compared with IMD rainfall over the study site. Moreover, it also successfully depicted the known historic drought years (2002, 2009, 2014 and 2015) and shows the central part of the region (Hamirpur, Jalaun, Jhansi, and Mahoba) experienced severe drought condition. Similar spatial and temporal pattern obtained from both the data set suggest that the performance of CHIRPS rainfall estimation against IMD observed rainfall is promising for meteorological drought assessment. Hence, the study concludes that the CHIRPS rainfall product could be used potentially as an alternative to ground data for meteorological drought monitoring that will assist in developing system for real time monitoring and early warning in the region.

Landslide Vulnerability Mapping Using Analytical Hierarchical Process – A Case Study On Rampur Tehsil, Himachal Pradesh

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Landslide is the most common type of natural hazard found in Himachal Pradesh, causing immense risk to life and properties. In India, about 0.42 million sq.kms of the area excluding snow covered areas are prone to landslide hazards. Out of this 0.14 million sq.kms of area falls under North Western Himalayas (Uttarakhand, Himachal Pradesh and Jammu & Kashmir). The present research paper is an attempt to assess the vulnerability of Rampur Tehsil to Landslides. Causative factors such as Landuse Landcover, Slope Morphometry, Relative Relief, Lithology, Soil, Landslide Inventory and Hydrogeology has been used to assess the Landslide vulnerability. Survey of India Toposheets, Geological Survey of India Maps, ASTER GDEM and LANDSAT 8 OLI/TIRS sensors are used as data sources. Analytical Hierarchical Process method has been used to categorize the Vulnerability Zones of the study area. The weightages were assigned based on AHP rule for Macro Scale Landslide Mapping The causative factors were analyzed and processed in GIS environment. These values were then integrated using weighted overlay to produce landslide vulnerability zones. With the help of weighted overlay each factor was compared with other factors to create error matrix table for consistency ratio. The final output was categorized into five types ranging from Very low hazard to Very High hazard. The aim of the results is to show that the proposed model of landslide hazard susceptibility can help to produce more objective and accurate landslide susceptibility maps, which not only take advantage of the information from the original data, but also reflect an expert's knowledge and the opinions of decision-makers.

Stability evaluation of Luxmanpuri landslide in Mussoorie, Garhwal Himalaya

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Landslide is a normal geomorphic process that becomes hazardous when it interferes with any human activities and poses a serious threat to the lives and properties in the region. In such cases, stability evaluation has been a common practice as it facilitates to find out the mitigation measures. The Luxmanpuri landslide (30˚27′22.02″N; 78˚05′ 39.9″ E), located on the Mussoorie-Chamba new bypass road is a complex landslide and occurs frequently, particularly during the rainy season. It is ~300 m long and ~50 m wide and is endangering the entire Luxmanpuri village and the connecting Mussoorie – Chamba bypass road.

The entire slope constituting the landslide and the adjacent slopes are made up of quartzite rock mass belonging to the Upper Tal Formation of the Lesser Himalaya. In general, the slopes are steep with angle varying between 45˚ and 50˚. Three prominent set of joints (J1, J2 and J3) dipping angle of 30º, 60º and 75º towards 170ºN, 345ºN and 070ºN, respectively were present. A seasonal stream present adjacent to the landslide adds instability to the landslide.

The stability evaluation of the said slope has been carried out using kinematic analysis of all the discontinuities present in the area and the finite element modeling (FEM). The data required for the analysis has been extracted from high resolution satellite imagery, fieldwork, laboratory analysis and the rain gauge based rainfall data. For the FEM analysis two slope sections along the length of the landslide were chosen. The Shear Strength Reduction (SSR) method was utilized to quantify the existing slope strength and to infer the pattern of strain and displacement.

The analyses indicate that the slopes exhibit factor of safety (FoS) of 0.9±0.1 and accommodate maximum shear strain and total displacement in the order of 0.001- 0.006 and 0.08 - 0.20 m, respectively. The kinematic analysis reveals planar as well as wedge failure in the rock mass that corroborates with the field evidence of rock failure.

Saltwater Intrusion: An Emerging Coastal Hazard along the East Coast of India

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Saltwater intrusion is a natural phenomenon, which deteriorates the coastal groundwater resources throughout the globe. Especially in the coastal regions of eastern India, there is a scarcity of freshwater due to saltwater intrusion which needs urgent attention. A study has been conducted with the aim to understand the severity of saltwater intrusion and observe spatio-seasonal changes in coastal groundwater quality. Groundwater samples have been collected from sixty shallow tube wells spreading across nearly 900 square km area in the coastal region of Puri district, during pre-monsoon and post-seasons of the hydrological year 2016-17. Electrical conductivity (EC) and pH were measured in the field, while ionic concentrations were determined in the laboratory. These parameters have shown wide spatial variations, while from the analysis of variance (ANOVA), no significant seasonal changes have been observed. Further, the water quality parameters are found to be exceeding the world health organisation (WHO) prescribed permissible limits in a majority of water samples. Around 52% of the collected water samples are found to be of brackish – saline in nature and unsuitable for drinking purpose during both the seasons due to their higher total dissolved salt content. From the Piper diagram, the groundwater is mainly characterised by Na-Cl type of water (63% during pre-monsoon and 73% during post-monsoon). From the Cl/HCO_3 ratio, it is found that all the water samples, except 7 samples during pre-monsoon and 10 samples during post-monsoon, are under slight – strong influence of saltwater intrusion. The influence of saltwater intrusion is also confirmed from the Cl/Br ratio of groundwater in comparison with the Cl/Br ratio of seawater. Spatial distribution for the saltwater indicators (EC, Na, Cl, and Br) was obtained using geospatial interpolation technique, from which saltwater intrusion has been traced up to 10 km inland from the coastline. It is interesting to note that the samples located close to the coastline are having freshwater characteristics during both the seasons. Digital elevation model (DEM) and remotely sensed images of the region showed the presence of sand-dunes and paleochannels nearer to the coast, where the freshwater pockets were located. These geomorphic features act as perched aquifer to store freshwater even in saltwater intruded coastal aquifer, while the presence of thin clay layer at the sub-surface prevent mixing of intruding saltwater with the upper laying fresh groundwater. Identification of such perched aquifer for groundwater exploration could provide an immediate solution to deal with the problem of freshwater scarcity in the coastal areas. Construction of sub-surface barriers, continuous monitoring of groundwater, rainwater harvesting, artificial recharge, and awareness among the local community could be adopted as mitigation measures to fulfill future water needs and reduce the effects of saltwater intrusion.

Satellite Rainfall Thresholds for Initiation of Landslides in Wayanad, Kerala: A Conceptual Framework

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Landslides are one of the major natural hazards in Kerala, where 13 out of the 14 districts are prone for landslides. Majority of the landslides in the Western Ghats are Debris flows triggered by intense rainfall events. Devastation caused during the recent floods of August 2018 reiterates the need for elaborate investigation on landslide mapping, monitoring and forecast. The present study is an earnest attempt to establish cumulated rainfall–duration relationship vis-à-vis landslide occurrences leading to identification of rainfall thresholds that can stimulate debris flow. The multi-satellite precipitation product – Global Satellite Mapping of Precipitation (GSMAP) reanalysis rainfall data for Wayanad region of Kerala is used to establish the relationship between intensity/cumulated rainfall and debris flows. The power law based model determines the cumulated event rainfall–rainfall duration (ED) thresholds adopting frequentist and bootstrapping techniques on the rainfall conditions that triggered the landslides via the Calculation of Thresholds for Rainfall-induced Landslides-Tool (CTRL). The landslide inventory of Geological Survey of India (GSI) as well as data collected by NCESS has been used in this study. The rainfall records indicate that majority of events occurred on the 7^{th} -$8^{th}$and 16^{th}-17^{th} of August 2018 reiterating the prevalence of intense rainfall prior to and on the days of the failure. The results highlight that short duration spells as well as long duration spells with an overall cumulated rainfall of 250mm respectively contribute to the slope failures. Eventually, high intense short duration spells lasting up to 40 hours and low intense long duration spells (>200 hours) accorded for most of the slope failures. Probably, the antecedent nature of *in situ* soil moisture condition also has to be collated from microwave satellite information to arrive at a precision threshold functioning.

This is an initial attempt towards building rainfall thresholds for triggering landslides along Western Ghats using the Satellite derived reanalysis data. Non-availability of a structured landslide inventory mainly without the exact date and time of occurrence is a major impediment towards rainfall threshold modelling. Hence the study proposes for a paradigm conceptual framework for landslide inventory mapping using satellite-based information integrated with field inventorying in addition to strengthening field measurements of rainfall to validate and augment satellite derived rainfall products. Rainfall threshold studies need to be done with improved datasets which can further enable better understanding of process which can lead to forecasting of the hazard thus reducing the risk and ensuring safety of life in future.

Control of carbon and nitrogen cycles on pedogenesis in a high altitude Himalayan landscape

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The conversion of bedrock to mobile soil is governed broadly by physical, chemical and biological processes. These processes are highly site specific and the nature of soil being formed depends on the local conditions - nature of bedrock, slope of surface, precipitation, upstream and downstream runoff, type and intensity of vegetation, microbial colonisation etc. The control and contribution of all these factors are preserved in the soil structure and geochemistry.

In this study we investigate a preliminary survey for the Carbon and Nitrogen distribution in a small tributary basin of the Pinder River to understand the role of elemental cycles in pedogenic processes and the nutrient dynamics. The concentrations of the two elements are analysed from the soil samples collected from the top surface from Pranmati Watershed in Chamoli, Uttarakhand.

Our results show a strong positive correlation between the two parameters. The concentrations are strongly controlled by local parameters such as slope, organic debris, anthropogenic sources and activities. Concentrations along depth profiles show a higher contrast in case of stable in situ soil as compared to transported soil. This clearly indicates a process of vertical mixing in case of transported soils.

Assessment of continuous soil radon data for the identification of anomalous changes during moderate earthquakes of the Garhwal Himalaya

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Continuous measurement of radon data is being carried out since year 2007 at multi-parametric geophysical observatory (MPGO), Ghuttu for the purpose of earthquake precursory research. To examine the effect of earthquakes on radon data and to extract anomalous changes, we carried out a statistical analysis. For this study, we selected 25 cases of moderate sized and bigger earthquakes which occurred within 300 km of epicentral distance from MPGO, Ghuttu. On the basis of availability of data, the period of this study is chosen between 01 January 2007 and 30 June 2017. Past radon data of more than a decade period highlight a high effect of rainfall precipitation on the radon emanation mainly of soil concentration. It is found that out of total 25 earthquakes, 14 events are occurred in the monsoon season when data of radon is fluctuating mostly due to rainfall precipitation. Therefore, it is difficult to isolate the variations in radon data due to seismic events. However, 11 cases of earthquakes are occurred in pre and post-monsoon seasons when there is no effect of rainfall on the radon data. Hence, the fluctuations due to earthquakes can be identified in the radon data. Out of these 11 cases, anomalous variations in radon data are observed in 8 cases of earthquakes. To examine these anomalous variations, statistical analysis of radon data is carried out by calculating mean (m), and then obtaining deviation (σ) from mean values. Changes in the radon concentration are treated anomalous for values exceeding one and two standard deviations ($m\pm\sigma$ and $m\pm2\sigma$) from the mean value for the selected duration. The observed results are explained in the light of dilatancy- diffusion model.

Seismogenic fault along the Mishmi Thrust, Wakro, Arunachal Pradesh, India

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The Mishmi Thrust (MT) is the frontal most thrust along the eastern flank of the Eastern Himalayan Syntaxis (EHS). The region was witness to the century's greatest Mw 8.6, 1950 Assam earthquake and contrasting fault plane solutions (thrust, strike slip and normal fault) were proposed for the causative fault. Based on its aftershock distribution, a knee-bend meisoseismal zone with dual surface ruptures along the Himalayan Frontal Thrust (HFT) and MT was proposed. Recently, surface rupture of the 1950 event was identified along the eastern HFT at Pasigaht, Arunachal Pradesh (Priyanka et al., 2017), but it is ambiguous whether the 1950 event also produced surface rupture along the MT?

Consequently, we conducted detailed geological and geomorphological mapping with the aid of 2.5 m high resolution Cartosat-1A imagery integrated with a trench investigation along the MT. We identified and mapped three levels of terraces (T1, T2 and T3) on the basis of their respective elevations and maturity of surfaces from the Kamlang River.

Along the central part of MT at Wakro town, we identified a ~14 m high fault scarp, striking ~NNE-SSW, extending ~0.4 km across the left bank of Kamlang River. Further, extension of the scarp along its strike is mapped for ~10 kms both north and south of Wakro town. We surveyed the scarp site (27.76° N, 96.35°E), using Real Time Kinematic Global Positioning System (RTK-GPS) to generate a high resolution micro-topographic map of the area. A trench (20 m length, 8 m width and 8 m depth) was excavated across the fault scarp to investigate the paleo-earthquake history. The excavated trench exposures were thoroughly cleaned and grids of 1x1 m were laid using strings with a leveler. For making photo mosaics and logs of trench exposures, photographs of each 1 m grid were taken using the same resolution. Photo and hand-drawn logs of the trench exposure were prepared for detailed study of the fault displacement and displaced soil horizons. Detrital charcoals for radiocarbon (AMS) dating and OSL samples were collected to bracket the age of recent displacement and thereby, the earthquake event.

Paleo-current analysis of river borne sediments of trench exposures reveals that Kamlang River had flown along an ~ NE-SW direction, but deflected to a due west direction. This implies a significant shifting of river course is due to a recent earthquake along the MT. A minimum dip-slip displacement of ~6.5 m is evident in the trench exposure along a ~18^{o} east dipping fault plane, which is insufficient to form a 14 m high scarp. The mismatch of fault slip and scarp height may be related to either co-seismic slip is distributed due to folding or tilting of strata or maybe accomplished by multiple events. We infer that the MT is an active, seismogenic, emergent thrust with high potential to produce surface ruptures. By considering the observed fault slip and using the empirical relation of Kanamori (1983), a minimum magnitude of Mw 7.6 is ascertained for the scarp forming event in this area.

Landslides and Subsidence Investigation along Mumbai - Pune Expressway

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Landslides and subsidence are very common in Western Ghats during and after monsoon. The intensity of these movements is controlled by the combined action of geology, geomorphology, hydrology and engineering behaviour of slope forming material existing at the sites. Geologically, these failed slopes are made up of weathered and jointed Deccan Basalts of Cretaceous Age.

The present studies are focused along Mumbai - Pune Expressway. It is the India's first expressway, which has six high speed lanes and has very high traffic load which crosses hilly region of Deccan Basaltic Province. The failure sites are located near Bhatan Tunnel (18.91416667N, 73.17861111E) to the exit point of Kamshet Tunnel (18.72944444N, 73.5400E). After every monsoon season, this expressway is suffered by various types of mass movements such as rock fall, subsidence, debris slide, debris flow and debris slump etc. These slope instability problems are being investigated and finally, mitigation measures for minimizing these movements, the loss of human life and property will be suggested after comprehensive field and laboratory investigations. In general, the adverse geological, geomorphological, hydrological and engineering geological conditions might have caused the slope movements along this expressway. An attempt is being made to investigate these problems, causes and mechanism responsible for slope failure and finally possible recommendations for controlling these movements. Lastly, the outcome of the present studies may be useful for similar situations existing in other mountainous tracks of India.

Observation of normal modes at MPGO Ghuttu using the high-resolution gravity data through Superconducting Gravimeter

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The first superconducting gravimeter (OSG-051) in India was installed at the Multi-Parametric Geophysical Observatory (MPGO) established in 2007 by the Wadia Institute of Himalayan Geology, at Ghuttu (30.53^0N, 78.74^0E), Garhwal Himalaya. Superconducting gravimeter (SG) is very sensitive gravimeter, no other gravimeter gives accuracy up to 1 nGal. Sudden release of seismic energy during the occurrence of large magnitude (mainly M≥8.0) earthquake sets the entire Earth into vibration, with natural frequencies of oscillation that are determined by the elastic properties and interior structure of the Earth. These free oscillations involve a quite complex three-dimensional deformation of the Earth's spherical shape.

The SG of Ghuttu is among the few SGs around the globe that records the gravity values at high sampling rates. The response of the MODE filter of the SG is sampled and digitized at 1 sample/s. The scale factor of Ghuttu SG (OSG-051) is assumed to be the same as of that of the Canadian SG OSG-12 (Arora et al. 2008, Current Science). The dominant component of the signal is attributed to the solid earth tides, which has a range of ~300 μGal variations. The background noise recorded in the data is ~0.4 μGal.

Seven great earthquakes (M≥8.0) including M9.1 Japan earthquake of 2011 are recorded during 2007 to 2012 by the SG. Many seismic phases from these earthquakes were clearly visible on the SG record. The Free Earth Oscillation are made up from infinite number of decaying sinusoids. This decaying nature introduces errors in amplitude estimation through conventional Fourier analysis. We avoided this by estimating local amplitude in successive overlapping windows. The local amplitude estimate of each sinusoid was obtained in each segment and the attenuation in terms of the quality factor *Q*, was estimated using the change in the amplitude of a particular frequency in successive windows.

As a result, the normal modes data recorded by SG-051 are numerous and of good quality. The data is useful to extract the information of nearly first 50 fundamental modes in the frequency range of 0.3-5 mHz during each earthquake that also includes 5 main gravest modes clearly visible using M>8.5 earthquake data. M9.1 earthquake data strengthen the results of the spitting process of 4 gravest modes. Successfully the data is used to obtain the attenuation characteristics of different sub-splitting modes.

Use of site effect for the determination of source parameters of local earthquakes in Garhwal Himalaya, India

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In this research work, site effect study is conducted in highly mountain terrains of the Garhwal region, North-West (NW) Himalaya, India by using Horizontal to Vertical spectral ratio method (H/V). It is the ratio of Fourier spectrum of horizontal and vertical component of the record). The acceleration record of 35 local earthquakes recorded during the year 2016-2017 and the S-phase of these records are utilized to characterize the site effects of the Garhwal Himalaya region. These 35 earthquakes having magnitude range 2.1–4.5 (M_w) includes one moderate earthquake of magnitude 5.8 (M_w) occurred in Rudarprayag district of Uttarakhand on 06 February 2017. The site amplification curves are enumerated by using the H/V technique proposed by Nakamura (1989) and later modified by Lermo & Chavez Gaarcia (1993) for S-wave. A window covering the S-phase is utilized to compute the site amplification at each recording stations. A large number of events with proper azimuthal coverage are considered for better assessment of the results. The spectrum is computed for North-South (NS), East-West (EW) and vertical (Z) component separately and Fourier amplitude spectrum of horizontal component is divided by the spectrum of the vertical component. The horizontal spectrum is obtained by square root of the sum of square of NS and EW components.

The acceleration spectra of the ground motion recorded at the surface are affected by local sites so records are corrected for the site effect to compute various source parameters of local earthquakes occurred in the Garhwal region. The obtained corrected spectra of S-Phase from above acceleration records are compared with the theoretical spectra defined by Brune (1970) at each station for the horizontal component of the records. The long term flat level (Ω_o) and corner frequency (f_c) values are selected on the basis of minimum root mean square error by adopting grid search method and are further used to calculate source parameters. The acceleration spectra of the ground motion recorded at the surface are influenced by local site effect and to check the effect of local site amplification an attempt is made in present work. In this attempt, firstly of all acceleration spectra without consideration of site effect is compared with theoretical Brune spectra. Afterward, acceleration spectra are corrected for site effect to compare with theoretical spectra and it is observed that spectra with the correction of site effect provide less root mean square error as compared to the spectra without considering site effect. Hence acceleration spectra corrected with obtained site effects provides final values of 'Ω_o' and 'f_c', which are finally used to compute various source parameters of local earthquakes i.e. seismic moment, stress drop and source radius lies in the range 1.2×10^{12} -3.24×10^{24} Dyne-cm, 12-348.9 bars and 1.2-12.1 km, respectively.

Theme V:
Natural Resources and Ecosystem

Appraisal of hydrocarbon prospect zones, Masila oilfield, Yemen

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Hydrocarbons form the prime energy source of the world and backbone to industrial developments. This paper attempts to explore the hydrocarbon potential by using spatial multi-criteria decision-making method. To demarcate hydrocarbon potential zones in Masila oilfield, Yemen, various thematic layers of multi-criteria factors which affect hydrocarbons viz. Basement Depth Map (BDM), Gravity Anomaly Map (GAM), Magnetic Anomaly Map (MAM), Subsurface Faults System Map (SFSM), Upper Syn-Rift Isopach Map (USRIM), Post-Rift Isopach Map (PRIM) and Lower Syn-Rift Isopach Map (LSRIM) were generated by using the information extracted from geophysical and wells data. GIS technique was used to generate various thematic maps; then maps were converted to raster format and reclassified into various classes, depending upon their relative importance. These thematic maps and their feature classes were designate weights (Eigen value) and rank through Analytical hierarchy process (AHP) and following the theories of Multi-Criteria Analysis (MCA). Further, these maps were superimposed using Weighted Linear Combination (WLC) in GIS platform. The integration of thematic maps results were classified into five hydrocarbon potential zones viz. very high potential zone (19.6%), high potential zone (20.2%), moderate potential zone (24.6%), low potential zone (24.5%) and very low potential zone (10.9%). The cross plots of hydrocarbon occurrence of the reservoir, existing oil fields, and wells locations figured out for validation. Validation results show a good prospect for hydrocarbon potentiality in the study area. The new quantitative approach in this study is capable to provide better understanding results and assessment of hydrocarbons in the Masila oilfield and elsewhere.

Petrography and mineralogical studies of Bauxite deposits in Mainpat Plateau, Surguja district, Chhattisgarh, India

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Bauxite is an ore which is the main source of alumina (Al_2O_3). Mainpat is one of the chief sources of bauxite deposits in Chhattisgarh with the Deccan trap Basalt as host rock having an average tonnage of 33 metric tons. The deposits of mainpat are one of the easily mineable deposits in the state because of its flat topped topography, shallow depth deposition and less overburden. The average maximum depth of the bauxite deposit is about 10 m to 14 m from the surface; following it is weathered Basalt deposit. A clayey, soft, pink plastic layer called Lithomarph is present which separates the Bauxite and Basalt deposit. The major soil types are red / yellow lateritic soil, loamy and muddy soil. Here, six samples were collected to study the petrography and mineralogy of the bauxite deposits. X Ray Diffraction (XRD) study reveals that it exhibits minerals like Gibbsite, Boehmite as major minerals, Hematite and Kaolinite as minor minerals and Anatase as accessory minerals. X Ray Fluorometry (XRF) studies reveal the major elemental compositions like Al_2O_3, Fe_2O_3 and SiO_2. Due to complete alteration of the clay phases (micas and feldspars), it lacks Quartz and Micas. High Al_2O_3 of 65 to 70 % was found towards Narvadapur while medium to low Al_2O_3 of 35 to 50 % were found towards Barima.

Assessing spatio-temporal variations in benthic foraminifera abundance and diversity in a coastal lagoon and their implications

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Estuarine and coastal ecosystems are the most dynamic transition ecosystems due to mixing of both fresh and saline water. Chilika, the largest brackish water lake in India, is connected to freshwater rivers in one end and to the Bay of Bengal in another end. This makes the lake the most suitable place to assess ecosystem variability due to differential input of both fresh and saline water, which affects the benthic foraminifera population. Bottom sediments were collected from 22 fixed stations of the lake during three different seasons viz., September (SWM), January (NEM) and May (PSWM) and both live and dead population of foraminifera along with the grain size distribution were analyzed in sediment. Physicochemical parameters of bottom water were also determined *in-situ*. The spatial variation in physico-chemical parameters and foraminifera abundance is more prominent than the seasonal variation in the lake. Multivariate statistical analysis involving various abiotic and biotic parameters suggests that the region proximal to river mouth have freshwater ecosystem during SWM. Low abundance and diversity of foraminifera throughout the year in this region also reaffirms the prevailing of fresh water ecology. The interior region of the lake away from river and sea mouths maintains brackish water condition throughout the year and associated with high abundance but low diversity of foraminifera, dominated by *Ammonia* genus. Silty-clay substrate with high pH and medium energy condition of this region enhances the rate of reproduction of foraminifera. The region near to the sea mouth experiences brackish water ecosystem during SWM, which gradually changes to marine ecosystem during PSWM due to regular influx of tidal current. High salinity and high energy condition with sandy to silty substrate support high diversity and moderate abundance of benthic foraminifera. Both calcareous and agglutinated species along with few planktic foraminifera are responsible for high diversity of foraminifera in this region. Higher abundance of dead foraminifera in comparison to living suggests environmental stress conditions that is further supported by dominance of 63-125 micron size fraction and morphological abnormalities in foraminifera tests.

Thermal maturity and source rock palynology of Disang - Barail sediments in Tuli-Merangkong - Mukokchung road section of Mukokchung district of Nagaland

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This study deals with the palynological analysis and hydrocarbon potential of the Eocene – Oligocene sediments which are exposed along Tuli – Merangkong – Mukokchung Road Section of Mokokchung district in Nagaland. Nagaland is a part of the Northern extension of the Arakan –Yoma Range representing some of the Cretaceous and Tertiary orogenic upheavals. The study area mostly covered by rocks of Disang and Barail Groups that are exposed all along the road section comprised of alternating bands of sandstone, siltstone and shale. The indentified palynofloral assemblage recorded from this area is quantitavely moderate and consist a large number of amorphous organic matter, black and brown debris, followed by Phytoclasts, woody debris and leaf cuticle and also fungal remains. Based on these palynological assemblages a shallow marine depositional environment for these sediments are suggested indicating ingress of a sea during the Eocene – Oligocene time where these sediments were deposited. The Rock Eval Pyrolysis data show low TOC value ranging from 0.5 % to 1.91 %, which indicate negligible potential for hydrocarbon. From the S2content and Tmax value it can be assumed that the most of the organic matters present in the investigated samples are immature or over mature and they represent mostly type- III Kerogen which signifies predominance of gas.

ASTER spectral characterisation for mapping alteration minerals in Sonakhan Greenstone Belt, India: An approach to regional scale reconnaissance survey of gold in a moderately vegetated terrane

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The Sonakhan Greenstone Belt (SGB) particularly within Sonakhan and Baghmara regions are considered as metallogenetically very significant for Gold exploration in Central India.Gold mineralisation has been reported from mafic and felsic volcanics in the form of quartz veins and quartz-carbonate veins in a mesothermal–greenstone setting [2, 3]. The hilly undulating topography, moderate to dense vegetation cover, unpaved routes and inaccessibility of vast regions due to reserved forest make its study challenging especially for academic researchers and perhaps this is the reason why none of the previous research works done in this area involve investigation of satellite image to identify alteration zones associated with gold mineralisation. However, this case study is a modest attempt towards mapping hydrothermally altered minerals and iron rich oxidised zone on a regional scale using efficient digital image processing algorithms. An ASTER image covering a part of SGB is used in this study. Iron oxide/hydroxide minerals such as hematite, goethite and limonite are mapped using the spectral absorption features in the VNIR region and based on spectral signatures, ASTER band ratio of 2:1 (equivalent to 3:1 in LANDSAT) is employed to enhance iron oxides. Band ratio of 4:6 is employed for identifying Al–O–H bearing minerals such as muscovite, illite, kaolinite, and montmorilonite which have high reflectance in band 4 and strong absorption in band 6. Band ratio of 6:8 is employed for identifying Fe, Mg–O–H bearing minerals such as chlorite, biotite, epidote and CO_3 bearing minerals such as calcite, dolomite which have high reflectance in band 6 and significant absorption in band 8. In order to minimize the effect of vegetation, an image enhancement technique based on a directed principal components (DPC) analysis called the software defoliant technique [1] is applied and ASTER band ratio 3:2 is used as vegetation indicator because of its characteristic red edge effect. The DPC analysis of aforementioned band ratio images differentiate the responses of vegetation on the basis of eigenvectors and the RGB combination of the suitable PCs is used to map and discriminate respective zones in the study area. The DPC result is validated using NDVI map of the study area and the comparison shows that the pixels with NDVI value more than 0.35 (i.e., dense vegetation canopy) are differentiated successfully. Furthermore, supervised classification techniques like Spectral Angle Mapper (SAM) and Spectral Information Divergence (SID) are applied using reference spectra of aforementioned minerals from USGS spectral library. All the techniques used in this study show conformable results. The only ground–truth gold location i.e., the Baghamara Gold Block is used to validate the results. The visual comparisons clearly depict the presence of oxidised zone in the Gold block in association of other alteration minerals. Based on extensive oxidised and alteration zones around the Gold block and in other regions, it can be concluded that the study area may have great potential for further gold prospects. The approach used in this study provides a quick, cost-efficient tool for gold exploration in similar areas elsewhere.

Are the Gas Hydrates an Energy Resource or Geohazard?

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Natural gas hydrates are unconventional energy resources. They occur worldwide in the permafrost and the ocean bottom sediments. In nature, the gas hydrates predominately comprise of saturated hydrocarbon, mostly methane. The focus on the gas hydrate studies is essentially twofold: a) its potential as an energy resource, b) geohazards such as slope-failure and abnormal gas seepage. These catastrophic events are instigated by the sudden gas release from hydrate deposits, due to dissociation triggered by the fluctuations in the controlling parameters like pressure (p), temperature (T) and salinity, etc. However, no conclusive evidence for these geohazards and hydrate structural stability have been unambiguously ascribed. The current study aims at providing experimental evidence for the "abnormal" structural stability and triggered mineralogical variations in the methane hydrate system, synthesised with pure and saline water. The results indicate an increasing percentage of salinity alters the hydrate stability, to lower-temperature, e.g., for 0.0 wt % and 0.5 wt % NaCl concentration, the hydrate dissociation at atmospheric pressure is around 271 K, closer to ice melting temperature. Further, for systems with higher NaCl percentage, i.e., 1.5, 3.0, 5.0 wt % the dissociation shifted to 253 K. The drastic shift in dissociation temperature is due to the eutectic melting of the hydrohalite ($NaCl.2H_2O$), a cold mineral often formed in seawater at low temperatures. The hydrohalite is formed in solutions with higher salinity (1.5, 3.0, 5.0 wt %). The Micro- Raman spectroscopic measurements confirm the methane hydrate phase is coexisting with hydrohalite phase. The characteristic vibrational band of methane molecules trapped in $5^{12}6^2$, and 5^{12} cages of sI are observed at 2905, and 2915 cm^{-1} and the signatures around 3406, 3420, 3436 cm^{-1} confirms the hydrohalite phase existing with the hydrate phase. The X-ray diffraction studies demonstrate the diffracted peak positions for cubic hydrate (Pm3n), hexagonal ice (P63/mmc) and monoclinic hydrohalite (P21/c). The sequential and systematic study describes the self-preservation phenomenon of the methane hydrates in ionic solutions and also enlarges the role of hydrate stability on the climate change aspect.

Slab melting and formation of hydrocarbon in Mantle transition zone: a natural example

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Subduction of oceanic crust and CO_2 degassing through volcanism are known as the principal mechanisms of carbon influx and outflux respectively in the global carbon cycle. However, contribution of deep mantle abiogenic hydrocarbon is poorly understood in this regard. Here we show presence of C-H and H_2 along with (Fe, Mg) CO_3 inclusions in a forsterite xenocryst residing within a carbonatite related to the Karguelen Plume. We suggest that these phases were formed in an Mg-rich carbonate melt during slab melting at the Mantle Transition Zone in a highly reduced environment. The forsterite xenocryst belongs to a carbonate peridotite formed at the base of the upper mantle, due to metasomatism caused by the Mg-rich carbonate melt. Plume carried the carbonate peridotite to shallower depth where it partially melted and formed carbonatitic magma. Our study emphasizes the importance of mantle plume and carbonatites in oxidation and outfluxing of deep mantle hydrocarbons.

Chromian Spinel Composition as a petrogenetic indicator of Ghutrigaon Banded-Chromite-Quartzite deposit of Singhbhum Craton, Odisha

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Chromite occurs in form of Banded-Chromite-Quarzite (BCQ) in Ghutrigaon, Dhenkanal, Odisha. Chrome spinel composition of Ghutrigaon deposit was compared with chromitite from the Sukinda and Nuasahi massifs in Singhbhum Craton, India. Microchemical results of three chromite deposits plotted in different binary [Mg/Cr_2O_3, Mg/Cr, $Mg//Fe^{3+}/Cr^{3+}+Al^{3+}+Fe^{3+}$, $Fe^{2+}/Mg^{2+}+Fe^{2+}//Cr$, $Mg//Fe^{2+}/Fe^{T}$] and triangular diagrams [Cr-Al-Fe & Cr-Mg-Fe] show distinctly different domains. When the chromite analysis of Ghutrigaon are plotted in established discrimination diagram, $Cr^{\#}$ vs. $Mg^{\#}$ in particular, an isolated field way apart from Stratiform- Alpine type complex and spinel xenoliths attest to a different tectonic setting. The compositional results of Sukinda-Nuasahi chromite ore plot in the field that indicates their orthomagmatic origin. The nature of field occurrence within ultramafic complex, and association of peridotite-serpentinite confirms their orthomagmatic parantage. On the contrary, the compositional plots of Ghutrigaon chromite is seen much array from established stratiform/ alpine deposits. The EPMA results reveal very low Mg-number (0.014-0.092) of chromite in contrast to very high Mg-number of Sukinda- Nuasahi (0.32-0.82) chromite ore bodies of Odisha. The nature of mineralisation, sedimentary features, volcaniclastics association and petrogenetic study indicate Ghutrigaon BCQ to have formed through volcano sedimentary processes. It is proposed that a distinctly separate field shown by Ghutrigoan chromite ore may be assigned to a syn-sedimentary-syngenetic type of chromite deposits elsewhere in India. The study thus demonstrates that the genesis of an unknown chromite deposit can be indicated from its spinel composition.

Modelling forest cover resilience in India using Dynamic Vegetation Model

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The forest cover distribution in any region attributes its prolonged climate conditions or the environmental conditions, which regulates the mechanisms of feedback, growth, reorganization and adaptation. With a mega-biodiversity ecosystem, the assessment of forest cover resilience in India will enhance the effectiveness of climate adaptive conservation strategies. The study of forest-climate relationship enables to estimate and project the potential forest cover distribution and their resilience. However, processes like climate change and its impacts are comparatively slower in nature than short term climate events as forest fire, drought, flood etc. Thus, the study of climate change and its impact on forest cover distribution requires long term assessment. Moreover, the highly resilient forest covers mostly absorbs the smaller disturbances, and creates rare example of forest cover regime shift. Although the impact of climate change has been regarded as the dominant factor to the change of vegetation functionality, structure and shift, there is high uncertainty in its degree of influence. Again, the impact of same climate alteration may be different across the climate regimes. In this study, we have simulated the MC2 dynamic vegetation model (DVM) at 0.5 degree scale to estimate forest cover resilience at life form level in India. The global datasets as FAO soil data and Climate Research Unit (CRU) climate data were used in the MC2 model. The default model parameters were mostly used; whereas, the value of leaf area index (LAI) and biomass threshold used for life form categorization in the model were optimised. For calibration and validation, the net primary productivity (NPP) data from MODIS sensor and vegetation type map of India were used. The vegetation type map was reclassified in to life form categories as forest, scrub, grassland and treeless dominated regions. Forest cover dominated areas were observed in 18.44% areas, whereas, scrub and grassland dominated areas were observed in 3.67% and 1.80% of the total Indian landmass. About 6.66% areas were observed as treeless areas, whereas as the rest of the areas were occupied by the land uses as cropland, water body, built-up etc. Based on the observed forest cover distribution in India, the default LAI value of 1.75 was optimised as 3.75; and the default biomass thresholds value of 1150 gCm^{-2} was optimised as 500 gCm^{-2}. The overall accuracy of the simulated life form was obtained as 81% and correlation (R^2) with MODIS NPP was obtained as 0.66, indicated close agreements with the observed data. According to model estimation, majority of the forest covers (83.75%) in wet regimes of India were estimated highly resilient, where only 6.16% were estimated least resilient. Least resilient forest covers were mostly estimated in the dry semi-arid region, which may exhibit regime shift towards scrublands or grasslands. Similarly, scrubs in wet climate regions are estimated change prone towards forest rather than grassland, whereas in dry region, they are estimated to change prone grassland rather than forest covers. The estimated forest cover resilience map may have policy level implication to mitigate the effects of climate change.

Tracing the chemical weathering processes in the headwaters of the Teesta River basin, Sikkim Himalaya (India)

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River Teesta is a major tributary of The Brahmaputra system, It drains through the Sikkim Himalaya and transports a large flux of water and denudation material to the Brahmaputra which finally to its flood plain and the Bay of Bengal. In the present study, chemical denudation of silicate rocks in the headwaters and associated CO_2 consumption rates have been estimated which have a bearing on regulating the global climate on longer time scales. Source of the major ions to the river has also been evaluated from the sediment and water samples collected along the River Teesta and its associated tributaries. Results indicate that, the headwaters of the Teesta have relatively low TDS values ranging from 19.3 to 84.1 mg/l which are largely controlled by dissolved Ca^{2+} and HCO_3^-. All the samples were found to be unsaturated with respect to Ca^{2+} (SI -8.88 to -0.07) which points toward absence of calcite precipitation from River water. The correlation between (Ca^{2+}+Mg^{2+}) and (HCO_3^- + SO_4^{2-}) and high ratio of (Ca^{2+}+Mg^{2+})/ HCO_3^- (~0.67) indicates the presence of Sulphuric acid mediated weathering in the basin, possibly routed through pyrite oxidation resulting SO_4^- to the river waters. The contribution of ions derived from silicate rocks is found to be ~24% (n=24), while thermal spring, sulphide rock and carbonate provide the rest. The maximum contribution of carbonate rocks to the ionic budget is in average ~58% (n=25). The Chemical Index of Alteration (CIA) estimated from the major elements in the bed sediments suggests that the intensity of silicate weathering is not prominent in the basin. However, the CIA values from the Teesta are marginally higher than those from the Brahmaputra basin. The CO_2 drawdown due to silicate weathering in the basin is estimated to be 2.8 x 10^5 moles km^{-2} y^{-1} and 5.9 x 10^5 moles km^{-2} y^{-1} for pre-monsoon and monsoon period respectively. This rate of CO_2 consumption (2.8-5.9 x 10^5 moles km^{-2} y^{-1}) in the basin is 3 to 6 fold high in comparison to the world's average.

Invisible Gold Occurrence within the Pyrite of Chandil Formation, North Singhbhum Crustal Province, Eastern India

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The Meso Proterozoic metasedimentary rocks of Chandil Formation, belongs to the northern part of Singhbhum Crustal Province and lies within the North Singhbhum Crustal Province (NSCP). The study area i.e. Chandil Formation is demarcated at its southern extremities by Dalma volcano-sedimentary belt. Tamar-Porapahar shear i.e. South Purulia Shear Zone zone separates the Chandil formation from the Meso/Neo-Proterozoic (0.9–1.7 Ga) Chotanagpur Gneissic Complex (CGC) at its northern boundary. Lithologically the area is characterized by quartz-mica-sericite-schist, quartzite, amphibolites, carbon phyllite, etc. The field and the petrographic studies from the area indicate the evidence of multiple phase deformation and is well evident by the presence of S-C fabric, S_1-S_2 planes of schistosity, alternate layers of coarse and thin quartz, and other shear zone associated structural features. To the south of the Tamar Porapahar Shear Zone (TPSZ) lies a primary zone of mineralization along a lineation running parallel to TPSZ and is known as Babaikundi-Birgaon axis. Geophysical studies along the axis indicate the presence of shear zone and sulphide mineralization. The gold mineralization within the area is confined to the reef quartzite along the contact of mica schist and ambhibolite. Associated ore minerals observed in the area are pyrrhotite, arsenopyrite, chalcopyrite, pyrite, sphalerite and magnetite. Most of the sulphide mineralization is associated with the ferruginous quartz in the area. Gold in the area occurs in three distinct forms, as native gold (form of nugget), as lode gold and as invisible gold occurrences within the pyrite mineralization.

Field observations, reflected and transmitted light microscopic study, SEM analysis and electron probe micro analyser (EPMA) were used to give a brief account of the mineral chemistry and presence of different forms of gold (including first report on invisible gold). The occurrence of gold in the crystal lattice of the pyrite may be attributed to the substitution and replacement of Fe ion of the pyrite by the hydrothermal fluids as evident by the presence of hydrothermal alteration within the area.

Estimation of lateral distribution of porosity along a 2D line of Krishna Godavari Basin, eastern margin of India

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Porosity is one of the several heterogeneous rock properties found in reservoirs. The understanding of the distribution of this property will help to delineate the existence of hydrocarbons. Estimation of porosity is essential for the appraisal of reserves and planning of production operations. The porosity data is available only at particular locations where well is drilled and this will not be enough to find out the variation of porosity of an area. The generation of porosity log, using available information, at each point of the 2D line will give the porosity section. The present study investigates the possibility of artificial neural network (ANN) for the delineation of lateral variation of the porosity along a 2D line of Krishna–Godavari basin. The porosity logs of the two well sites NGHP-01-4A and NGHP-01-11A through which the 2D seismic line passes is used in the research. The research utilized two mathematical formulations: multiattribute regression analysis and probabilistic neural network (PNN). The attributes required for the prediction of porosity are derived using stepwise regression analysis. First the multiattribute transform technique is used to predict the porosity in which the best selected combination of attributes is utilized. These attributes are again used to train the PNN. The training error and validation error is checked in each case. It is found that the training and validation error is decreased as we progress from multiattribute regression analysis to neural network. The well log data, seismic data and impedance data are integrated in this research to predict the porosity of interested section of the 2D line. The study area comprises huge gas hydrate reserve. Hence the research delineates the porosity distribution above the Bottom Simulating Reflector (BSR) identified from the 2D line. The study gives a porosity range of 50.3%-71.6% which better matched with the porosity logs. The BSR is obtained from inverted impedance section. The porosity predicted above the BSR is low and gradually increasing below the BSR. The low porosity can be considered due to the presence of gas hydrates. This study can be further extended to the estimation of saturation along the 2D line.

An Approach to Delineate Gas Hydrate zones using Inversion and Seismic attributes in Krishna-Godavari Basin

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The present study is carried-out using seismic data constrained with log data in Krishna-Godavari basin where the massive gas hydrates deposits are found during National gas hydrates program expedition 01 (NGHP-01). Seismic attributes are measurement of seismic data that helps visually enhance and infer the features of interest and define the structural or depositional environment. Therefore, we need to study certain attributes to ascertain whether bottom simulating reflector (BSR), prime marker of gas hydrates, is related to gas-hydrates or to identify gas-hydrates without a BSR that is hard to demarcate from visual inspection of seismic section. We have characterized BSR and gas hydrate bearing sediments by computing attributes such as reflection-strength, instantaneous frequency and seismic 'blanking' or reduction in seismic amplitudes from a seismic data set in the Krishna Godavari basin. Further it's validated that these attributes can be used as important indicators of Bottom Simulating reflector (BSR) and thus for the exploration of gas-hydrates and free-gas. Next, we have performed model-based impedance inversion to corroborate our findings. The high acoustic impedance is observed where the gas hydrate zone is present whereas low acoustic impedance represents the free gas zones. It is observed from the results that BSR is present at the depth of 116 mbsf.

The Effect of Petrographic Characteristics and Engineering Properties on Quality of Commercial Granites of Jalore District, Rajasthan

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The petrographic characteristics and their physico-mechanical properties influence the durability of granites which is an important dimensional and decorative stone. The studied granitic rocks were selected from Jalore district is located between latitudes 24^0 37' 00" to 25^0 49'00" and longitudes 71^0 11' 00" to 73^0 05' 00" with an area of 10,640 sq. kms with large reserves of different varieties of granite which were emplaced during Neo-Proterozoic as an intrusive phase within the Malani Igneous province. Rajasthan has huge deposits of different varieties of granite but Jalore is the largest producer of commercial granite in the state with their trade names *viz.* Bala Flower Jalore, Chima Pink Jalore, Golden Pearl Jalore, Rosy Pink Jalore *etc.* Granites of the area show wide variation in color, texture and their petrographic characteristics. The essential minerals of the granites of the area include potash feldspar (orthoclase or microcline), quartz and plagioclase, accessory minerals are hornblende, reibeckite, biotite, aegirine, muscovite, apatite, zircon and opaque. Secondary minerals are chlorite and sericite. Adequate utilization of a building material demands sufficient knowledge of its mechanical properties. The physico-mechanical rock properties are one of the most important parameters used in the analysis and design of any major building and engineering structures.

This paper examines the effect of petrographic characteristics along with physico-mechanical properties to determine the long term stability of the commercial granites of the area. The durability index for each parameter has been prepared on five point scale and it is observed each parameter *viz.* texture, alteration, quartz percentage, mica percentage, quartz to potash feldspar ratio, rock hardness, compressive strength, specific gravity, water absorption and modulus of rupture, determine the quality of commercial granites of the area. Therefore, petrographic characters and physico-mechanical properties affected the final strength of commercial granites of the area.

Stable isotopic evidence for a mantle and/or magmatic origin of granitoid hosted orogenic gold deposits, Jonnagiri Schist Belt, Dharwar craton, India

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Jonnagiri gold deposit is unique granodiorite hosted gold deposit in the eastern part of Dharwar Craton, India. This is narrow sigmoidal shaped, Jonnagiri greenstone belt is located near Gooty, Kurnool district, Andhra Pradesh, have similar geological and structural characteristics to other orogenic gold bearing greenstone belts. In the Jonnagiri greenstone belt, the gold mineralization is hosted in laminated quartz carbonate vein (QCV) emplaced within sheared granodiorite that occurs with another rock unit, typically of Archean greenstone-granite assemble. An inconclusive opinion exists regarding the source of ore fluids responsible for this deposit. The present work, therefore, aims to constrain the source of auriferous ore fluid of this deposit through stable isotope study of the auriferous QCVs occurring in this granodiorite hosted Jonnagiri orogenic gold deposits. The carbonate samples from these auriferous QCVs were analysed for their C and O isotope composition at Physical Research laboratory, Ahmedabad.

The $\delta^{13}C_{PDB}$ and the corresponding $\delta^{18}O_{SMOW}$ values are between -1.9‰ to -12.6‰ (average -5.2 ± 1.9‰) and 1.66‰ to 20.56‰ (average 8.5 ± 3.6‰) respectively. There is a spread in both data of $\delta^{13}C$ and $\delta^{18}O$ however, the maximum number of data falls within $\delta^{13}C$ values of -5‰ to -6‰ and $\delta^{18}O$ between 8‰ to 9‰. The "fluid-rock interaction modelling" shows that most of the samples have retained >80% of their primary $\delta^{13}C$ and $\delta^{18}O$ values enabling us for constraining the source of ore fluids. The δ13C values like -5‰ to -6‰ (average-5.2 ± 1.9‰) and $\delta^{18}O$ values like 8‰ to 9‰ (average 8.5 ± 3.6‰) are consistent with those of mantle and/or magma derived hydrothermal carbonates.

We, therefore, interpret the auriferous fluids could be either of the mantle or juvenile magmatic origin or both with a major contribution from mantle derived fluids as the fluid-rock interaction modelling shows a minor interaction of the auriferous QCVs with later magmatic fluids.

Change Detection of Land use/land cover in Zunheboto sadar block of Zunheboto district, Nagaland

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The use of Geoinformatics in mapping land use/land cover is adopted for its cost-effective and efficiency in studying temporal changes over a large scale. Interaction of Man and its environments has greatly changed the appearance of our surroundings in time. The change detection of land use/land cover has been carried out in Zunheboto Sadar block of Zunheboto district, Nagaland. The reason for choosing this area is that it is the most populated place in Zunheboto District and there need of proper information to the residents about the changing land use/land cover for maintaining sustainable environments. Supervised classification of Landsat Satellite image for year 2009 and 2019 were carried out and 7 classes were delineated for both the years and compared. The 7 classes are River, Jhum cultivation, Settlements, Terrace cultivation, Sparse vegetation, Dense Vegetation and Moderate Vegetation. The topography of the study area is hilly where Jhum and Terrace cultivation are often practiced.

The study shows that the area of Settlements and Sparse vegetation has increased from 524ha to 776ha and 692 to 1379ha respectively whereas Moderate vegetation and Dense vegetation has decreased from 3331ha and 6693 to 3048ha and 6382ha respectively in the span of 10 years.

Geospatial technology based Groundwater potential zone mapping in parts of Noyyal basin, Tamil Nadu, India

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Groundwater is the most vital natural resources which are broadly utilized for different purposes over the world. Generally, the rapid growth of population, urbanization and agricultural development leads to a major issue for progressively stresses of water all over the world. Therefore, groundwater is gaining extensive attention to meet the demands. This study aims to delineate the groundwater potential zone (GWPZ) in parts of Noyyal basin, Tamil Nadu, India using remote sensing (RS) and geographical information system (GIS). Fissile hornblende-biotite gneiss, hornblende-biotite gneiss, fluvial (black cotton soil with gypsum), granite, charnockite, garnet sillimanite – graphite gneiss are the major rock types and amphibolite, fuchsite, sericite – quartzite, pyroxene granulite, patches of ultramafic rocks and calc – granulite and limestone are minor rock types in this region. Usually, the river flow is dependent both on northeast and southwest monsoons. The downstream portion of the river mostly in Coimbatore city is extensively polluted due to the direct discharge of domestic sewage and effluent from the dying and bleaching industries. Consequently, groundwater close to the river turns into contaminated. Hence, proper management and planning of the aquifer in this region are mandatory. This planning includes the preparation of a groundwater prospective map to identify the groundwater potential of the study area using RS and GIS. Several thematic layers such as geology, geomorphology, drainage, drainage density, lineament, lineament density, slope, soil type, soil texture, soil depth and land use/land cover (LU/LC) were built in the GIS environment to generate the groundwater potential zonation map of the study area. Each individual thematic layer was given appropriate weight and ranking based on their contribution towards groundwater recharge and storage using spatial analyst tool in Arc GIS 10.2. In this manner, a final map i.e. groundwater potential zonation map (GWPZM) was produced by compiling all the required themes. The map indicates that the GWPZ of the study area can be classified into four categories such as very good (32 km^2 of the area), good (334 km^2 of the area), moderate (727 km^2 of the area) and poor (331 km^2 of the area). The region falling in plausible groundwater potential category is auspicious for groundwater prospect. This study validates that RS and GIS provides a pathway to delineate the groundwater possible zones of the study area.

Physio-chemical studies of groundwater from six districts of Uttarakhand

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Quality of water depends upon its origin and history. Natural waters show, in general, quality characteristics of their sources. Many factors however, produce variations in the quality of waters obtained from the same type of sources. These variations derive from the opportunities for water to take substances into solution or to carry them in suspension. Climatic, geographic and geologic conditions all play important parts in determining the water quality. Physiochemical studies of groundwater from six districts (Chamoli, Udham Singh Nagar, Nainital, Almora, Pithoragarh and Champawat) of Uttarakhand were performed to determine its suitability for drinking purpose. This pilot study evaluates various physic-chemical parameters such as pH values, Electrical Conductivity, Total Dissolved Solids (TDS), Oxidation-reduction potential (ORP), Dissolved Oxygen (DO), Salinity as well as chemical analysis of various harmful elements such as Arsenic (As), Cobalt (Co), Chromium (Cr), Lead (Pb), Zinc (Zn), Copper (Cu) and Manganese (Mn) etc. A total of 569 samples were collected during pre-monsoon, monsoon and post-monsoon seasons of the year 2018. All the samples were analyzed by the microprocessor water equipment as well as Arsenic kits. Further, 219 samples were subjected to Atomic Absorption Spectroscopy (AAS) to obtain the most accurate and precise results. The preparation of the samples, sensitivities and the analytical precision along with results are presented based on BIS Guidelines for drinking water. The average pH concentration of all samples is about 7.54, Electric Conductivity as 405uS, TDS as 267ppm; DO as 5.13ppm, ORP as -25.02mV, salinity as 0.42 ppm, Co content as -0.0679ppm, Cr as 0.0052ppm, Pb as 0.2499ppm, Zn as 0.4935ppm, Mn content as 0.0382ppm and Cu as -0.0042ppm.

The present study suggest that a considerable size of water samples (hand pumps and artesian wells) contain excessive Lead (Pb), which is five times higher than desirable limit as per BIS guidelines. District Udham Singh Nagar is most vulnerable where about 38% waters (89 water samples) contain excessive Pb. This is undeniably an alarm to the people of state as Pb may cause diminution in mental capacity (mental retardation), interference in kidney and neurological functions, loss of hearing, blood disorders and hypertension. The main source of excessive Pb in the state may be due to diesel fuel combustion, discarded batteries, paint and leaded gasoline etc. On other hand, one sample from nearby area of Nanakmatta locality of Udham Singh Nagar also contains heavily excessive As, which may also be harmful for human society.

Hydrological modelling approach to estimate discharge of Jhelum River basin

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Predicting future global fresh water scarcity and providing attenuation, require knowledge of spatiotemporal dynamics of discharge for gauged basins. This study describes a hydrologic modelling approach for estimating discharge. The model was set up for entire Jhelum River Basin of North-Western Himalayan region. The accuracy of model discharge estimates from Variable infiltration capacity (VIC) model at grid size 5 km*5 km was investigated by comparing with in-situ observations for the time period 1990 to 2013. The VIC model is a large-scale, semi-distributed hydrologic model. The VIC model was set up and parameterised using field observed and remote sensing derived data. The fluxes obtained from VIC were routed to simulate discharge at 3 stations for the calibration and validation of the model. Results for Jhelum basin showed that the model can successfully simulate hydrological fluxes for large catchments with higher accuracy. Such modelling approach can be used to estimate future availability of water in the region by incorporating future predicted meteorological parameters. The model is very much compatible with RCM/GCM based data, as it works on grid scale.

Application of empirical mode decomposition for delineating gas hydrates and free gas in Mahanadi offshore basin, India

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Empirical mode decomposition (EMD) is a powerful signal analysis tool that splits the signal into individual decomposition modes, called the intrinsic mode functions (IMFs). Each IMF is associated with symmetric and narrow-band waveform ensuring that the instantaneous frequencies are smooth and positive. However, some negative features encumber its direct application namely the mode mixing and splitting, aliasing and end point artifacts. Two variants, ensemble EMD (EEMD) and complete ensemble EMD (CEEMD) have been recently introduced to overcome some of the negative features. We intend to show the application of this EMD for demarcating the gas hydrates bearing sediments, which are considered as viable major future energy resources. Gas Hydrates occur in the shallow sediments of the permafrost and along the outer continental margins, the presence of which is identified by an anomalous reflector, known as the bottom simulating reflector or BSR on seismic section. The present study in the Mahanadi basin of the eastern margin of India demonstrates that the EMD can be employed to demarcate the gas hydrates bearing sediments.

Geoelectrical investigation of saline water intrusion in the coastal aquifers of West-Bengal, India

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Saline water intrusion (SWI) constitutes one of the major concerns most commonly encountered in coastal areas. The coastal aquifers of West-Bengal are vulnerable to such hazards. Thus, SWI poses a serious threat to shallow freshwater resources in the area. Direct current resistivity method is the most widely used geoelectrical method for determining low resistivity zones that usually correspond to the presence of SWI. Moreover, Self-Potential (SP) method has also been used for detection of saline and fresh water aquifer where low anomaly zone can be correlated with saline water intrusion. A total of 5 resistivity profiling, SP and 2-D electrical resistivity imaging (ERI) was conducted at specific site for delineation of SI. Resistivity profiling and SP data suggest a low anomaly zone which is the potential location of SI. The obtained geoelectrical cross-sections from 2-D ERI data successfully revealed an undulating seawater–freshwater interface. The results obtained from resistivity data, SP and 2-D inversion of ERI data were also correlated well with those obtained from hydrogeological information such as Salinity, Total Dissolved Solids (TDS), Conductivity, pH and Temperature (°C) within the study area. Therefore, the results of this study indicate that SWI characterized by low resistivity (<5 Ωm) and negative SP anomaly.

Geochemical characterization of nutrients and heavy metals in the mangrove sediments of Kachchh district, Gujarat

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Mangroves are highly productive coastal vegetation thriving in the tropics and subtropics. These intertidal forest plays an important role in nutrient cycling and supporting coastal food webs. Due to change in land use/land cover and various anthropogenic activities has decreased the mangrove vegetation by 35–86%. Continual anthropogenic activities are generating a potential threat in this enriched ecosystem by elevating the nutrient and heavy metal load. The present study has been carried out in the mangroves from Kandla to Mandvi. In this study, distribution, enrichment and ecotoxicity potential of nutrients and heavy metals in sediment was investigated using some sediment quality indices. The metal concentration in sediment illustrates the following order: Iron (Fe) > Manganese (Mn) > Nickel (Ni) > Zinc (Zn) > Copper (Cu). Geoaccumulation index (Igeo) suggests that these are moderately contaminated with Zn and Ni. Pollution load index (PLI) was observed higher at Mundra site due to the contribution by Cu and Ni in the sediment. Cu and Ni, show a significant correlation with clay and silt particle which suggest that sediment texture has an important role in metal distribution. Sediment textural analysis played an important role in controlling the carbon and nitrogen distribution in mangroves and showed a good correlation of silt and clay with Carbon and nitrogen. C-N ratio suggests the transition region having both characteristics of marine and terrigenous input. The study area having several ports, industries such as textile, sugar, petrochemical, cement, fertilizer manufacturing industry, which might be the significant source of pollutants. The results of the present study could help in formulating the guidelines and controlling the deterioration of the ecosystem.

Change detection study for possible eastern lion corridor of greater Gir region in Saurashtra peninsula using geoinformatics approach

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Habitat loss and degradation in forest and other wildlife areas is a general phenomenon happening nowadays in all the forest patches of the world. To identify those areas of habitat and to take an immediate action for it is a very difficult task but due to modern technology like Geoinformatics one can demarcate those regions easily especially when management is working for a development of potential habitat sites for endangered species. Land use/ land cover change with its supervised areas can show the way to carry out better strategies for futuristic approach with changing behaviour of humans towards Agriculture and industrial approach over the defined and future time span. Major aim for this research study is to assess the change in landscape between 2013-2018 (5 years) with all the risk and sustainable factors so that, this charismatic species can establish their home far from gir with less conflicts and better management. This research study is used an open source software like QGIS with its different tools & plugins for LU/LC and Supervised classification to see the changes over the 5 years and to detect land cover changes happening due to anthropogenic activities using satellite images of IRS and LANDSAT available series. Saurashtra region falls under Semi-arid and arid regions with less rainfall every year. There are no big perennial rivers available in this region so water availability is a major concern for humans as well as Lions and other wildlife.

Integrated application of AVIRIS-NG and Sentinel-2A dataset in altered mineral abundance mapping: A case study from Jahazpur area, Rajasthan

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In this study Airborne Visible InfraRed Imaging Spectrometer-Next Generation (AVIRIS-NG) hyperspectral data and Level-1C cloud free Sentinel-2A multispectral data of Jahazpur area, Bhilwara district, Rajasthan have been used to get an insight on the mineral assemblages in the vicinity of ore-forming zones. Sentinel-2A reflectance data was used to compute RGB combinations and band ratios which aided in prediction of the occurrence of hydrothermally altered minerals. The imaging spectroscopic study of AVIRIS-NG data also revealed and spatially corroborated presence of similar altered mineral species containing hydroxyl, carbonate and iron-bearing mineral phases, more accurately owing to its high spatial and spectral resolution. Abundance mapping of these target mineral species were subsequently carried out by employing Spectral Angle Mapper (SAM) technique which was validated both on ground and by geochemical analysis. The result of the application of integrated multispectral and airborne hyperspectral data thus proved to be of great importance as far as their spatial distribution is concerned, albeit inheriting the limitations of any remote sensing data. Studies like this which amalgamates high resolution hyperspectral with advanced multispectral dataset can provide the required acumen in the field of lithological discrimination, mapping, and interpretation of ore formation systems, thereby providing crucial earth observation aid to sustainable mineral exploration.

Analysis of numerical dispersion of seismic wave propogation using finite difference method

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Numerical solution of seismic wave equation has played an important role in both theoretical and applied seismology. Finite Difference Method (FDM) is one of the most widely used for seismic waveform modelling, inversion and imaging, but the major challenges we face is the numerical dispersion. In the conventional finite difference modelling, increasing order (co-efficient in Taylor series) of finite difference approximation decreases the grid dispersion, but it requires more time and larger model space near the boundary to solve the wave equation. The resolution of the finite difference solution is also bounded by the stability criteria. By using the Spatial FD coefficients in both the time and space domain numerical dispersion can be reduced significantly in lesser time. Here, we propose an automated and highly optimized FDM using genetic algorithm to compute second order spatial derivatives. In this method the central finite difference coefficients are calculated using genetic algorithm to minimize the error in dispersion (phase velocity) for all wave numbers. In the proposed method, amplitude of the pseudo-spectral window (FD coefficients) are optimized in such a way that the phase velocity tends to the analytic solution at each frequency (or wave number). Comparison of our method with the analytic and a conventional FDM of various orders shows that the new method is very effective for acoustic wave propagation with negligible numerical dispersion. We use the central finite difference the staggered grid method for comparison.

Hierarchical cluster analysis and its translation towards spatial lithological proxy

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Lithology discrimination is not a simple task based on conventional wireline log interpretation. The downhole geophysical logging provides high-resolution geological and physical information on the stratigraphic section. The persistence behaviour of the wireline log data is confirmed by rescaled range (R/S) analysis, indicating that the data follow a local trend as per the lithological variation. Subsequently, we have used hierarchical cluster analysis (HCA) technique to accurately envisage and characterize the lithology of stratigraphic beds with variable thicknesses (thick beds in the order of 6 m; thin beds up to 0.3048 m) from gamma-ray (GR), bulk density (RHOB), sonic transit time (Δt) and thermal neutron porosity (Φ) logs. The results, derived from the log data in the Krishna-Godavari basin, acquired during the expedition-02 of Indian National Gas Hydrate Program (NGHP-Exp.-02), show that the non-traditional techniques are superior to traditional log interpretation procedures, and can predict the lithology in absence of core data as well as discriminate the finer beds. The HCA predicted lithology matches reasonably with the core derived lithology. Hence, the approach can be utilized for quick prediction of subsurface lithology in any basin.

Heavy mineral and geochemical studies of core sediment from Velankanni Coast, Nagapattinam district, Tamil Nadu, India

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The coastline of India has undergone various geological processes throughout the geological time. In the view of increasing population and industrialisation and in support of coastal management, the present study has been carried out at Velankanni beach to determine the concentration of heavy minerals (their provenances), to understand the transportation and depositional conditions from SEM photographs and geochemical distribution of sediments. Now a days the sand mining is prominent at the coastal regions due to high economic importance of the heavy minerals. Based on optical properties; hornblende, sillimanite, hypersthenes, garnet, garnet (subhedral), zircon, magnetite, magnetite (opaque), tourmaline, olivine and sphene are identified. From the compositional determination, heavy minerals may have been derived from granite, charnockite, pegmatite, hornblende-biotite-gneiss, gneiss, schist, granulites and marble along with sedimentary formations. Quartz micro photograph showing a set of sub angular grains exhibiting conchoidal fracture. Simultaneous mechanical and chemical impact on grains showing V- shaped marks of different dimension with irregular breakage blocks. Rounded sharp features in occur due to differential chemical action in highly tropical and chemically active environment.

Decrease in MgO content due to differentiation results in the increase of Al at the catchment area which is further transferred to the study area by Vellaiyar River. CaO, comes after Fe, indicate the carbonate content derived from calcareous shells present in the marine ecosystem. The Fe concentration is found to be high at all depths which due to its high absorption capacity in oxide form. V and Cr occurrences in the study region indicate municipal sewage along the coast and oil spill from the ships (due to the presence of major international port). Toxic trace elements such as Zn, Ni and Pb are are present in the sediments due to agricultural and industrial runoff as the study area is highly industrialized

Water-energy theory in plant life forms varies at regional scales

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Studying the underlying causes of co-existence of high species richness in Indian Himalayas has always been interesting topic in ecology. The Himalaya experiences significant variations in rainfall pattern, with an overall decrease in wetness from east to the west. The summer monsoonal rainfall, which causes heavy rainfall in the Eastern Himalaya by condensation, becomes weak in Western Himalayas. Western Himalaya gets rainfall from Westerlies during winter. Here we comprehend the relative importance of climate, physiography, disturbance and soil on plant richness of the Eastern and Western Himalayas, separately. The influences of water-energy dynamics and climatic heterogeneity on herb and woody richness of the Eastern and Western Himalayas are highlighted. From a least of 35 variables, eight variables (four from climate, two each from physiography, soil and disturbance) were considered by applying multiple variable selection methods. Using these selected variables and a national plant database; we assess the relationships between plant richness and environmental heterogeneity using generalised additive model (GAM) and structural equation model (SEM).

Potential evapotranspiration (PET) and annual precipitation considered proxies for energy and water, respectively, whereas precipitation seasonality and temperature seasonality were proxies for climatic heterogeneity. GAM and SEM predicted proportionately, but GAM is found to fit well for this study. The nonlinear settings are proved to show better correlation for plant-environment relationships. The GAM predicted PET has 30.3% deviance explanation in woody species richness and 39.6% deviance explanation in herb richness of the Eastern Himalaya and Western Himalaya, respectively. Similarly, annual precipitation was prominent in describing woody species richness of the Eastern Himalaya (31% explained deviance) and herb richness of Western Himalaya (42.1% explained deviance). This explains that water and energy variables have significant contribution to frame plant richness pattern substantiating the key influence of water-energy dynamics in plant richness of a region.

Overall temperature seasonality was more significant than precipitation seasonality. Cumulatively, both expressed more prominently in woody species richness (40.5±5.1% explained deviance) than in herb richness (30.1±0.6% explained deviance). This indicated that climatic variations have strong control in shaping plant richness and increase in temperature and changes in precipitation regime are likely to influence the plant richness pattern in the future.

Interestingly, soil is observed to be a prominent determinant in the Eastern Himalaya, more so than climate defined the plant richness of the region. The dominant presence of trees in the Eastern Himalaya could explain the dominance of soil on plant richness. The direct influences of physiographic variables were insignificant. However, socio-economic status of the people has great influence to deform plant richness pattern.

Our study contradicts the universalization of the large-scale pattern that plant richness is a maximised function of water and optimised function of energy. Rather the maximisation of water and optimisation of energy guided the herb richness; and optimisation of water and maximisation of energy explained woody species richness. It infers that large-scale patterns of plant richness vary at regional scales and between plant life forms. The expected outcomes are likely to improve the ecological understanding of the understudied Himalayan ecosystem.

Assessment of gas hydrates using rock physics of log data in the Krishna-Godavari Basin, eastern Indian margin

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Several Holes were drilled and logged, and core samples were acquired at 25 sites in the Krishna-Godavari (KG) and Mahanadi Basins along the eastern margin of India during the National Gas Hydrate Program Expedition 02 (NGHP-02) with a view to establish gas hydrate in sand dominant reservoirs. The purpose of this study is to characterize the gas hydrate bearing zones associated with two seismically inferred horizon R1 and horizon R2, and evaluate gas hydrates at Site NGHP-02-23 in the KG Basin. The upper reservoir linked with the reflector R1 contains both pore-filling and fracture-filling gas hydrates, while the lower reservoir linked with the reflector R2 has only the pore-filling gas hydrates. Since resistivity is the most affected physical property in the presence of gas hydrate, we have analysed the resistivity log data using the Archie's empirical equation based on assumed isotropic reservoir properties. In order to further assess gas hydrate saturation, we have performed isotropic velocity modelling using three-phase Biot equation (TPBE) and density-derived porosity. The average gas hydrate saturations, estimated from resistivity log data and P-wave velocity modelling, are 25% and 60%, respectively in the depth interval of 271–288 mbsf. The result is further verified with the available pressure core-derived gas hydrate saturation and show comparable results at R2-linked lower reservoir part due to presence of pore-filling gas hydrates. We observe that the resistivity-derived gas hydrate saturation shows more discrepancy than that of the velocity-derived result. The probable reason may be due to the isotropic resistivity analysis of the reservoir section having anisotropic behaviour.

Structurally controlled uranium mineralization around Devri – Pakni area, Surajpur district, Chhattisgarh

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Structures and metamorphism usually play an important role in many mineralizations which has been attempted to substantiate with reference to Sarguja shear zone (SSZ) is a part of Satpura mobile belt in around Devri-Pakni area. Major tectonic planes have been found with the hill shade map, lineament map, geological map of sarguja shear zone, and geological map of in Karwan–Manuva–Ginwar, Sarguja Chhattisgarh and supported with field investigation, are ENE- WSW, NW-SE and NE-SW, E-W,N-S and ESE-WNW. The whole area has signature of shearing, faulting and folding. Samples from Devri-Pakni area are showing radioactivity which is counted by Scintillometer (RSM/2014, S.no.129). The radioactivity in samples are anomalous. The mineralization in the SSZ occurs along the major tectonic planes of the SSZ and shows the structural control on mineralization. Here an attempt is made to understand the process of uranium mineralization in the area and their relation with structure and tectonics.

Comparison of cations and anions concentration in the groundwater of pre- and post monsoon period 2017, parts of Mahoba and Chhatarpur districts, Bundelkhand granitoids

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With an aim to understand the distribution of fluoride in groundwater in granitic terrain of Bundelkhand Granitoid Complex, Hydro-geochemical investigation has been carried out in parts of Mahoba and Chhatarpur districts Central India, covering an area of about 1800 Sqkm. The groundwater samples (60 in Pre monsoon and 78 in post monsoon 2017) were collected and analysed for electrical conductivity (EC), pH and total dissolved solids (TDS) with the help of soil water analyzer kit and total hardness, calcium hardness, concentrations of Ca^{2+}, Mg^{2+}, HCO_3^- and Cl^- using titration methods. Na^+ and K^+ were analysed using Flame photometer, SO_4^{2-} and NO_3^{2-} using UV-Spectrophotometer and fluoride ion (F^-) using fluoride Ionometer. The results of the analysis are plotted and carried out comparison of concentration of individual cations and anions during pre- and post monsoon period. This study will contribute in my further research work in understanding the relationship of (F^-) with other major ions, identification of fluoride-bearing groundwater zones, hydro-geochemical classification of groundwater and other related research activities that will finally benefits the society.

Identification of potential location for hydropower dam using GIS – A case study on part of Beas River basin

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Himachal Pradesh government is on keen motive and on its path to produce large potential of hydropower, hence in identifying potential location and constructing hydropower dam across the river. One of the river basin in Himachal Pradesh which shows an enormous source of hydropower generation is Beas river basin. The Beas River has an identified hydropower potential of merely 6000MW (State of India's Rivers for India Rivers week, 2016). As of now nine major hydropower projects with more than 50 MW installed capacity and ten mini hydropower projects up to 25MW are currently functioning. About eighteen hydropower projects with an aimed capacity of 3270 MW are under construction. Owing to these goals, the government often overlook the fact that it affects the environment and the ecosystem. This research is an attempt to identify the suitable location for obstructing the river and construct dam for hydropower potential based on the following parameters. A weighted overlay analysis will be carried out for the parameters that could contribute to the river potential such as rainfall which will analyzed using the IDW interpolation, Stream order and number, DEM classification based on the elevation and Land Use Land Cover. Based on the properties of each parameter's classification that could support the cause, weightage will be given and weighted overlay analysis will be carried out. The resulting maps displays the potential hydropower project location and be compared with the existing location to support the result, which will be useful in better planning and management of ecosystem.

A study of lignite deposits of Gurha, Bikaner-Nagaur basins, Rajasthan (Western India): implication on hydrocarbon potential

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In the present investigation, an attempt has been made to study lignite samples from the working mines of Gurha, Bikaner-Nagaur basin, Rajasthan with mention to their maturity and their hydrocarbon potential. The proximate components ash yield ranges from 3.6% to 7.4% (mean 5.1%); volatile matter varies from 44.7% to 54.9%, mean 49.9%; and the fixed carbon content ranges from 37.5% to 45.4%, mean 41.0% while ultimate components of carbon content ranges from 57.0% to 62.2%, mean 59.7%; hydrogen varies from 4.4% to 4.8%, mean 4.6%; nitrogen ranges from 1.4% to 1.6%, mean 1.5%; oxygen content ranges from 25.9% to 28.7%, mean 27.3% and the sulfur content is moderate and varies from 1.4% to 1.7%, mean 1.6%. Petrological components, huminite dominates and ranges from 59.1 - 86.7 %, mean 73.1 % ; liptinite ranges from 4.4 - 13.0 %, mean 8.3 % ; inertinite ranges from 3.5 - 24.0 %, mean 13.3 % and mineral matter varies from 3.9 - 7.4 %, mean 5.3 % whereas the Vitrinite reflectance (VRr) from 0.21 to 0.26% (average 0.23%). The TOC ranges from 50.6 to 58.1% (av. 55.1%), while T_{max} ranges from 401 to 410 ^{o}C (av. 402.9 ^{o}C). The value of S_1 peak ranges from 5.8 to 14.8 mg HC/g (av. 8.1 mg HC/g). Similarly, S_2 peak ranges from 110.7 to 142.5 mg HC/g (av. 131.8 mg HC/g), and S_3 peak ranges from 12.1 to 21.6 mg CO_2/g (av. 18.3 mg CO_2/g). The Hydrogen Index (HI) ranges from 191 to 356 (av. 241.6) while the Oxygen Index (OI) ranges from 24 to 37 (av. 33.3).

A study has been prepared on the basis of petrological and geochemical characteristics and further has been cross-checked by using empirically derived equation with the rock-eval data. The study reveals that the low rank coals of Bikaner-Nagaur basin contain mainly kerogen type-III organic matter and being high reactive macerals (85.97%) content and Rmax (0.39%) which favors the high conversion factor (94%) and high oil yield (64%).

Identification of potential rainwater harvesting sites for sustainable development of a semi-arid region Jilledubanderu River basin, southern India using SCS-CN method and geospatial technique

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Rainwater harvesting (RWH) is a standout amongst the most able frameworks to diminish water shortage issues and to build the accessibility of water for sustainable development in the semi-arid areas because of absence of precipitation and flighty precipitation patterns. The identification potential recharge zone (PRZ) with RWH and selection of sites cause a greater dispute for the water stakeholders because of deficient framework. The basic thematic layer such as land use/landcover, soil, geology, vadose zone, drainage density and derived layer slope, runoff, were used for identification potential PRZ and RWH sites. Analytical hierarchical process (AHP) carried out by assigning different weights to different thematic layers in this study area to determining the PRZ and RWH sites. The present research endeavours to decide the practical suitable areas for RWH, utilizing soil conservation service curve number (SCS-CN) based surface runoff with geospatial techniques. The enlargement of water asset is proposed by the development of RWH structures such as farm pond (FP), percolation tank (PT), check dam (CD) and gully plug (GP) having 73.53% (358.08 km^2) is appropriate for FP, 8.62% (42 km^2) reasonable for PT, 17.48% (85.16 km^2) is reasonable for CD and for GP 0.35% (1.71 km^2) of the present study region. Based on integrated mission of sustainable development specification 20 PT, 11 FP, and 4 CD having 85%, 90% and 100% accuracy in covenant among existing structures and expected potential site. The present study approach demonstrates the higher accuracy for identification RWH at any scale.

Identification of lineaments for natural resources exploration in western part of cuddapah basin, Andhra Pradesh, India using geospatial Technique

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Geospatial tools have mostly helped geologists to identify the Natural Resources viz., minerals and groundwater prospective zones for sustainable development. The origin, existence, movement of minerals and groundwater depend on numerous factors such as slope, geology, geomorphology lineament and lineament density. Based on these, the mapping and identification of mineral and groundwater potential zones were carried out in a western part of Cuddapah basin, Andhra Pradesh, India. Relevant thematic layers were prepared and assigned a scale and normalized weights by different techniques to identify minerals and groundwater prospect zones in the study area. Even though the western part of the Cuddapah basin is characterised by moderate to high lineament density, the above area is originate to be poor to moderate groundwater prospect zone because of high gradient and structural hills. The zone of intersection of strutural trends resulting in linear to circular shaped features, faults, dykes are mapped which could have accepted as potential areas of minerals resources in the study region. In this study, results reveal that the modelling assessment method proposed in this study is an effective tool for deciphering groundwater potential zones for proper development of groundwater resources various geological topography. Geospatial techniques like Satellite Remote Sensing and Geographic Information System (GIS) tools were used to prepare and analyze thematic layers of lithology, geological structure, and topography to detect the most of sites for minerals and groundwater prospecting zones in Cuddapah basin. A separate map of existing well was intersected with the generated maps to calculate the percentage of lineaments. Different GIS functions of intersection and spatial query were then applied to produce the final map for the most promising sites for groundwater and mineral exploration. The possibility of using digital classification of remote sensing data for mapping the most promising sites for groundwater, mineral exploration was also investigated by applying a Landsat ETM+ image. Results show that most promising sites for groundwater mineral exploration were dependent on the interrelated factors of lithology, topography, and geologic structures. The study shows that remote sensing and GIS provids professional tools for mapping promising sites for natural resource exploration.

Fault identification by using seismic attributes

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As faults play a very important role in reservoir characterization, we intend to map these by computing seismic attributes. We have used the similarity attributes, fault enhancement filter and curvature attributes for the delineation and characterization of faults. The similarity attributes are useful for the delineation of faults, which can be further sharpened by employing the fault enhancement filter. The curvature attributes exhibit the most positive (up-thrown) and most negative curvatures (down-thrown) where the fault blocks exist. We have demonstrated this study on 3D time migrated seismic data in the Taranaki basin off New Zealand with a view to understand the tectonic-activity and petroleum system of the basin.

Fluid inclusion and micro raman spectroscopy of anglesite: Implication for alteration process

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Himalaya has a number of sulphide occurrences, though the extension of mineralization is usually small. These sulphide mineralizations are broadly present in crystalline or carbonate rocks. The mobilization of sulphide minerals in shears is not uncommon. The present investigation focuses on the anglesite noticed in which sulphide mineralization in Parvati valley of Himachal Himalaya. The sulphide mineralization is found at the contact of Chail and Banjar formation at the northwestern extension of Larji-Rampur window. Polymetallic sulphide mineralisation in the area occurs in hard, metamorphosed and highly jointed vitreous massive Manikaran quartzite as breccia fillings and veins along shear zone. The mineral assemblage includes pyrite, arsenopyrite, galena and minor chalcopyrite. Ore petrography shows, the presence of primary ore minerals like pyrite, arsenopyrite and secondary ore minerals like scorodite, in close association with anglesite. Anglesite, a non-opaque ore mineral, is noticed under microscope, which represent the sulphate formation by the oxidation process of primary sulphides. The fluid inclusion and micro Raman spectroscopy have been conducted on anglesite to understand the nature of fluid and confirm the mineral species associated. Fluid inclusions observed in anglesite ore mineral are monophase or biphase aqueous primary in nature. Uncommon polyphase saline aqueous inclusions with tiny salt crystals are also seen. Some of the inclusions are necked down. The Raman spectroscopy confirms that the fluid is dominant aqueous saline, however, H_2S and SO_2 is also noticed dissolved in it. The composition of the fluid rule out the possibility of retrograde fluid in alteration, as such fluids in Himalayan domain are generally H_2O-CO_2 in nature. The PbO_{12} polyhedra in $PbSO_4$ (anglesite) are difficult to compress as compared to other sulfates like celestite or barite. Therefore, the fluids can be retained in it without any modifications/contaminations from surrounding fluid flow, at least at low pressure conditions of the near surface environment. An aqueous fluid migration along the shear zone to develop supergene minerals is attributed, wherein the alteration and dissolution process generated the gases like H_2S and SO_2.

Geochemical enrichment of trace elements in core sediment of Ghora Katora lake, Rajgir, Bihar, India

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Heavy metals accumulation in the environment has been attracting increasing attention from both researchers and policymakers because of their toxicity, persistence in the environment and subsequent accumulation in aquatic habitats. In general sediment plays a major role in determining the pollution patterns of aquatic systems being both as carriers and sinks for contaminants. Therefore present study is focused on collecting core sediments from lake to access the ecotoxic potential of the sediments. The concentration of Available phosphorus (AP), Total Organic Carbon (TOC), Zn, Ni, Mn, Cu and Pb in core sediments from Ghora Katora Lake in Rajgir (Bihar, India) were analyzed to evaluate the present eco-dynamics of the lake. Nutrients (TOC, AP) and trace metals (Zn, Ni, Mn, Cu and Pb) have been analyzed along with the depth variations (0-51cm). TOC and AP show decreasing trends with increase in depth. The TOC in core-1 varies from 0.29-1.71% and 0.38-2.17% in core-2 while AP in core-1 ranges from 0.018- 35.51 mg/kg and 4.0-23.14 mg/kg in core-2. The average concentration of trace metals in sediments followed the trend Mn>Pb>Ni>Zn>Cu. The mean concentration of Mn, Zn, Ni and Cu in the sediment samples were lower than the proposed average shale value of earth crust, indicating no harmful effects due to the presence of these metals. However, the results show higher concentrations of Pb than the proposed shale value. The geo-accumulation index (Igeo) shows Pb with class 3 which reveals Pb as moderately to strongly contaminated in both cores. However, Ni, Zn, Cu and Mn metals show no contamination (Igeo=0), while the Contamination Factor (CF) follows the order as Pb>Ni>Zn>Cu>Mn. The mean enrichment factor (EF) for Zn and Cu indicates minor enrichment, Ni with moderately severe enrichment while Pb shows very severe enrichment. The pollution load index (PLI) for the samples are found to be less than unity indicating no pollution. In addition, no significant correlation is observed among the trace metals as there is no point source of pollution in the lake sediments. Since there has been no anthropogenic source of pollution in the sediments, the eco dynamics of the lake has not been largely impacted. The Govt. of Bihar has declared lake as an eco-sensitive zone which certainly defines the no pollution indices as observed with the correlation analyses. However, some trace metals (Ni & Pb) shows enrichment which is mostly may be due to weathering of rocks from the nearby mountains or from parent bedrock or from long range transportation of metals. As sediments analysis provides a wide knowledge about the characteristics of it, providing a record of catchments inputs and reflecting the history of pollution, thus the study was carried out to check the enrichment of different elements in the lake sediment as it is in the ecological restoration period.

Prioritization, morphometry and hypsometric analysis of Dundsir Gad watershed a tributary of Alaknanda River by using quantitative method, remote sensing and geographic information system

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Prioritization, morphometry and hypsometric analysis has been carried out to understand the fluvial characteristic, geomorphology, geology, tectonics, structural antecedents etc. of the Dundsir Gad (Stream) a fifth order tributary of Alaknanda River covering an area of 49.7 km^2. Dundsir Gad has been divided into 4 sub watersheds (SW) ranging in area from 5.68 to 21.4 km^2. Remote sensing coupled with GIS tools have become an efficient and accurate means of understanding the influence of drainage, lithology and tectonic on a local or regional level basis for natural resource management, soil conservation, etc. especially if working on watershed. Various Geographical information system (GIS) techniques and quantitative method have been used for attaining the outcomes. Morphometric characterization was measured from linear, areal and relief aspects of four sub watersheds of Dundsir Gad. Bifurcation Ratio (Rb) value of 3.31(SW2) to 5.39 (SW3) shows low structural control on watershed, while Drainage density (Dd) ranging from 3.41(SW2) to 4.1 km^{-1} (SW4) showing weak and impermeable surfaces and Gradient ratio ranging from (Gr) of 0.13(SW4) to 0.30(SW2) showing mountainous relief. Prioritization of the sub-watershed has been done from ranking and evaluating various morphometric parameters, in which SW2 (3) has shown the lowest priority while SW4 (2.1) has shown highest priority. Regional patterns of Hypsometric integral (HI) and hypsometric curves in the watershed have also been computed to understand the role of tectonics and soil erosion in shaping the relief of the watershed, the outcomes have shown HI value ranging from 0.45(SW4) to 0.51(SW3) which suggest mature stage and moderate erosion of the watershed.

Presence of nickel in Phokpur magnetite deposit associated with Naga ophiolite belt and its importance in the national scenario

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The magnetite deposit (with nickel-cobalt) of Nagaland is a rare type of occurrence associated with ophiolite. The Phokpur magnetite deposit in Kiphire district of Nagaland is associated with ultramafic rocks and occurs at north-easternmost part of the Naga ophiolite belt. The ophiolite belt within India extends for about 200 km with an average thickness of 15 km from Pang (Nagaland) in the north to Moreh (Manipur) in the south. General thickness of the massif varies between 5m to 15m. It usually thins out towards the south to about 6 m. The average thickness is about 8 m. From the hilltop, the band extends down to a maximum inclined distance of about 600m with ground slope 30^{o} west. The outcrop is better exposed in the north. The massif in general show swelling and pinching both along the strike and dip direction.

Detailed field and laboratory studies reveal that the magnetite in the study area occurs as the tabular body at the top of the sequence comparable to a typical section of the ophiolite suite. Concentration of nickel in the magnetite layer ranges from 0.14 to 0.91 %, where as the iron content ranges from 40.51 to 55.95%. Small concentration of cobalt has also been reported in the magnetite samples. Nickel is a strategic metal in our country, and therefore, even a small deposit of nickel bears an utmost importance in the national economy. In the present paper, field observation, ore microscopy and geochemical studies of nickel-bearing magnetite at Phokpur in Kephire district of Nagaland has been discussed.

Host rock and structural aspects of base metal minerallisation in Betul Chhindwara Belt: a remote sensing and GIS based approach

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Betul Chhindwara Belt (BCB)) is about 135Km. long and 15-20 km wide inlier which is trending in ENE-WSW direction between Betul and Chhindwara districts of Madhya Pradesh. Basement rocks as hornblende granodiorite gneiss overlain by quartzites, stromatolitic carbonates, BIF and amphibolite represents Mahakaushal belt and Tirodi biotite gneisses represents Sausar supracrucstal belt limits the northern and southern extension of the BCB, respectively.

The mineralization is hosted by the felsic volcanic rocks and may have similarities with volcanic hosted massive sulphide deposits in the other parts of the world. Due to multiple phase of deformation including folding faulting and shearing effect the rock get altered and metamorphosed. The mineralization enriched along with these deformational phases and alteration zones. Thus, base metal mineralization occurring in the area seems to be structurally controlled. In the present paper an attempt is made to decipher lineament and drainage pattern surrounding Borkhap village and also to relate the mineralization with the structural trend of the area.

Heavy mineral and geochemical studies of sediment from Karaikal Beach, Pondicherry Union Territory, India

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Increasing demand in extraction of coastal products and processes needs frequent monitoring in detail to understand the problems along the coastal region. On this perspective, the aim of the present study is to investigate the Physico-chemical properties and distribution of elements in the sediments from Karaikal, along the east coast of India. The region is a monotonous peneplain. Aeolian action is evident in the coastal tract in the form of sand dunes and mounds. The study area is mainly covered by the alluvium with a soil cover namely, sandy loam and loamy sandy soil. The area is underlain by older formations of the Quaternary and Tertiary age. The provenance of the sediments has been determined by indentifying the heavy minerals under optical microscope. To know the transport mechanism and diagenetic processes SEM analysis has been used. The Geochemical characterization of sediments is carried out by using AAS. Hornblende, Hypersthene, Sphene, Garnet, Zircon, Diopside, Leucoxene, Sillimanite and opaque minerals (Magnetite and Ilmenite) are identified from the heavy mineral study. From the compositional determination, heavy minerals may have been derived from Granite, Charnockite, Pegmatite, Hornblende-Biotite-Gneiss, Schist, metamorphic rock along with sedimentary formations. Mechanical as well as chemical features incorporated over the quartz grains indicate sub-aqueous collision action is dominant with some indicating chemical alterations for anthropogenic sources. The Fe concentration is found to be high at all depths which due to its high absorption capacity in oxide form. CaO, comes after Fe, indicate the carbonate content derived from calcareous shells present in the marine ecosystem The trace elements i.e. V and Cr occurrences in the study region indicate municipal sewage along the coast and oil spill from the ships (due to the presence of major international port). Toxic trace elements such as Zn, Ni and Pb are are present in the sediments due to agricultural and industrial runoff as the study area is highly industrialized.

Significance of iron ore resources in the economics of Bhilwara district of Rajasthan – an overview

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The district Bhilwara economically depends upon textile industry, insulation bricks and large scale mining of sandstone, soap stone, iron ore and other minerals like feldspar, quartz, china clay, etc., out of which the role of iron ore mine is economically important. The district has huge deposits of low grade sponge iron ore. M/S Jindal Saw Ltd. with their innovative ideas and international exposure have thought of upgrading iron ore, from 25% Fe to about 65% Fe by way of magnetic separation and other beneficiation methods as the ore is mostly magnetite along with magnetite quartzite.

The total mineable reserves of iron ore (Magnetite) in Bhilwara 51.71 million tonnes and the present the rate of production of ROM ore have around 50 lac tonnes per annum but after proposed exploration the proposed rate of production will be around 70 lac tonnes and because of this production approximately more than 3000.32 lac rupees generated and these rupees helped 600-900 people employ. A numbers of schools, private as well as Government have run in the district. Market, Carpentry, Black-smithy and vehicle repair shops have come up giving employment to a large number of persons. Thus the mining have benefit about 2,500 persons in the area.

3 D ERT MAPPING: An advance approach of conventional ERT for real time monitoring and mapping of subsurface path for groundwater flow

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Water security is recognized as one of the major challenges to India's economic and social development .The ever increasing demand of water resources and resultant stress is causing a rapid and very worrying deterioration in the nation's groundwater resources. Among various geophysical methods, electrical methods have been most applied tools for groundwater prospecting. However, such conventional method of 2 D ERT survey finds difficulty in mapping the fluid movement inside subsurface. 3 D ERT provides a complete picture of subsurface fluid movement. Also this mapping can be used for real time monitoring for the coastal saline water intrusion.

For this study, 2 D, ERT data along 18 parallel profile lines has been acquired and merged to 3 D ERT mesh. Using Inversion, a complete 3-D subsurface image has been obtained, in which fluid movement can be marked as path flow. This Study reveals that the 3 D ERT has a potential application for formation characterization and can be used as an alternative tool for delineating fluid movement inside subsurface lithology.

Simulation of forward and inverse modeling for multiple conducting bodies to assist electrical surveys of underground gold prospects in North Singhbhum Mobile Belt, India

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For a geophysicist, it is quite common to locate subsurface anomalies like mineral resources, underground tunnels, cavities, drainage pipes, landfills, aquifers etc. that may have different shapes and sizes. In near-surface geophysics identification and exploration of such anomalies require a handful tool like electrical resistivity tomography (ERT). North Singhbhum Mobile Belt (NSMB) is a multi-phase folded Proterozoic age rock assembly where, moderate gold occurrences associated with Cu mineralization have been found within the rocks like quartzite, schist, phyllites etc. This paper presents an important role of electrical resistivity 2 D imaging for mapping of buried multiple conductors'structures and where we have tried to understand the shapes and sizes of such anomalies. In our approach we have compared the synthetic model-based inversion (forward modeling) with field measurements-based inversion (inverse modeling). Former inversion is done using Geotomo's RES2DMOD software and later was processed with RES2DINV software. North Singhbhum Mobile Belt is a core of mineral resources in India. Here we have taken models of some basic geometric shapes and at different positions and compared images with the 2D inverted images of field data. The results are quite clear and compared images were happened to match, thus this methodology gives an aid to future studies in detection of these types of buried anomalies in North Singhbhum mobile Belt and other areas with same geology.

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Cover page picture: Confluence of Indus and Zanskar Rivers (Ladakh)
Courtesy: Dr. Pradeep Srivastava