ABSTRACTS

7th National Geo-Research Scholars Meet

On

Geosciences: Emerging Methods

September 12-14, 2023

Organized by

WADIA INSTITUTE OF HIMALAYN GEOLOGY
33, GMS Road, Dehradun-248001
Uttarakhand, India

7th National Geo-Research Scholars Meet
On
Geosciences: Emerging Methods
September 12-14, 2023

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LT GEN GURMIT SINGH
PVSM, UYSM, AVSM, VSM (Retd)
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RAJ BHAWAN
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12 September, 2023

Message

It gives me immense pleasure to note that the 7th National Geo-Research Scholar's Meet (NGRSM) is being organized by the Wadia Institute of Himalayan Geology (WIHG), Dehradun between 12-14 September, 2023 on "Geosciences: Emerging Methods (GEM)."

This event aims to unite geoscience students, young researchers, and early-career faculty members from across India to address contemporary societal and scientific challenges. NGRSM emphasizes using advanced tools, fostering collaboration between generations of researchers, and promoting sustainable development. WIHG's commitment to geoscience education and research is evident through this annual event.

I applaud WIHG's choice of theme, which aligns perfectly with the evolving scientific landscape, highlighting the importance of advanced laboratory techniques, numerical modeling, and the role of Artificial Intelligence and Machine Learning in geoscience. These tools are pivotal in addressing climate change-induced issues like heavy rainfall, landslides, avalanches, glacial melting, and more.

I am sure that the young geo-research scholars, who are the upcoming technocrats of the country, will reap the rich fruits from the deliberations and discussions, and fulfil their incomplete tasks, and build disaster-resilient and climate-adaptable future for the benefit of mankind.

I wish the 7th NGRSM a resounding success!

Gurmit

Lt Gen Gurmit Singh
PVSM, UYSM, AVSM, VSM (Retd)

सत्यमेव जयते

डॉ. राजेश सु. गोखले
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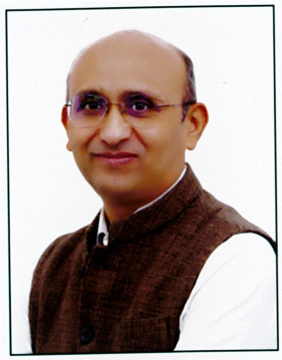

12th September, 2023

MESSAGE

I am happy to note that the 7th National Geo-Research Scholars' Meet (NGRSM) on the main theme "Geosciences: Emerging Methods (GEM)"is being organized by the Wadia Institute of Himalayan Geology, Dehradun during September 12-14, 2023 to bring students, young researchers and faculties at one platform to deliberate upon several issues related to Society that can be addressed by the Geoscientists.

The theme of the above meet has relevance to the current geoscientific issues as the progress of science is dependent on the sophisticated data acquisition, analysis/processing, advanced modeling, analytical facilities, and application of AI/ML. The Himalayan region occupies a special place in the mountain ecosystems of the world. The Himalaya is not only important from the climate change point of view and provider of water to the large part of Asian countries, but also it shelters to a rich variety of flora, fauna, human communities, and cultural diversity. In recent days, the people of the Himalayan regions face major global challenges and disasters. I am sure that the deliberations by the geoscientists and interaction between the young researchers and experienced resource persons in the Meet will give a boost for taking up challenges like climate change and geohazard related issues.

I believe that deliberations by eminent resource persons, researchers, and faculties in the 7th NGRSM will bring out meaningful recommendations for carrying out geoscientific research in the Himalaya and adjoining regions.

I congratulate the WIHG and convey my best wishes for the grand success of the 7th NGRSM.

(Rajesh S. Gokhale)

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Message

It gives me immense pleasure to know that the Wadia Institute of Himalayan geology (WIHG), Dehradun is organizing its annual event - the 7th National Geo-Research Scholar's Meet (NGRSM) during September, 12-14, 2023. The theme of the Meet is centered on "Geosciences: Emerging Methods (GEM)" that encompasses several disciplines of Geosciences. I am happy to see that the purpose of this Meet is to expose students, researchers and young faculties of Geosciences to numerous challenges for the society, which can be addressed by the geoscientists.

At the outset, I would like to congratulate the WIHG for their 7th consecutive years of organizing this event for the benefit of Geo-research scholars and the growth of Indian Geosciences. I am sure that the participants would gain through their deliberations, interactions and listening to peers in improving their Geo-scientific researches and technological advancement to meet the sustainable developmental goals.

I feel fortunate to bestow my heartfelt wishes to the participants and to WIHG in organizing such a purposeful Meet, and the event a grand success.

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Message

I am extremely happy to know that the Wadia Institute of Himalayan Geology (WIHG) is organizing its 7th National Geo-Research Scholar's Meet at its premises during September, 12-14, 2023. The theme of the Meet "Geosciences: Emerging Methods (GEM)" is the most appropriate, as we need new tools and new data to meet the need of New India, I understand that the event is orchestrated mainly for the budding students and early-career researchers in the field of Geosciences for understanding issues related to society and big scientific questions. The purpose is to expose them to several methodologies and emerging tools with a view to advance their research, create network for collaboration, and gain knowledge through interaction for sustainable development. I am delighted for this initiative of WIHG for the noble causes for the Geosciences of Society.

I congratulate the WIHG for organizing such wonderful program, and wish the event a Grand Success.

Shailesh Nayak

वाडिया हिमालय भूविज्ञान संस्थान

(भारत सरकार के विज्ञान एवं प्रौद्योगिकी विभाग का एक स्वायत्तशासी संस्थान)
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Dr. Kalachand Sain, FNA, FASc, FNASc
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Director

Message

It is heartening to note that the 7th National Geo-Research Scholars Meet (NGRSM) on "Geosciences: Emerging Methods (GEM)" is being held at the Wadia Institute of Himalayan Geology, Dehradun during September 12-14, 2023 covering varied sub-themes and diverse disciplines of Geosciences. This is an annual event of WIHG, intended mainly for the promising students, young researchers and early-career faculties to make them aware on the need of the hours. This year, we have emphasised on the state-of-art geoscientific tools for the data acquisition, processing/analysis and interpretation through laboratory visits, deliberations on societal issues, application of AI/ML to Geosciences, climate-tectonic interaction, and field visit to continental scale tectonic boundaries near Dehradun in comprehending the mountain-building processes.

The deliberations on several topics related to Earth-Science and critical issues, and the participation of 100 students, researchers and faculties from PAN India, 15-20 resource persons, and staff of WIHG would provide a great opportunity and platform for exchange of knowledge, development of network or collaboration, exposure to new tools or methodologies, enabling to comprehend causes of geo-hazards and plausible mitigation, and way forward on how to build disaster-resilient and climate-adaptable future for sustainable development and secured living.

I am sure that the participants will go back to their respective places with new knowledge in advancing their Geo-scientific researches, which can provide solution to societal challenges, answer to big questions related to Earth, develop new approaches, bring out opportunities and scopes, deliver plausible mitigation to existing challenges, and suggest for future plan.

I wish the NGRSM a resounding and grand success!

(Kalachand Sain)

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Abstracts Theme

Keynote Talks

Continent – Continent Collision Tectonics gave Birth to the Himalaya

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A vast NeoTethys ocean between India and South Eurasia was closed as a consequence of the subduction of the oceanic lithosphere of the Indian plate under the South Eurasian continent. The Himalaya originated as a consequence of a collision between the Indian plate and the south Eurasian plate during ~50 Ma. Northward convergence of the Indian plate produced crustal thickening as a result of shortening induced by imbrication of the northern margin of the Indian continent. The Main Central Thrust (MCT) was initiated first at the mid-crustal level and was responsible for exhuming the High Himalaya Crystalline and their cover of the Tethyan sedimentary sequence during ~33 Ma – 22 Ma. The ongoing convergence subsequently produced the Main Boundary Thrust (MBT) further south of the MCT during ~ 10 Ma that gave rise to a foreland propagating thrust system, with the formation of duplexes of the Lesser Himalayan sequence between the Ramgarh (=Chail) Thrust as the roof thrust and the Main Himalayan Thrust (MHT) as the floor Thrust. South of the MBT, the fold-thrust system of the Tertiary foreland basin was developed during the Pliocene - Quaternary time as fault propagated fold-thrust system of the Himalayan Frontal Thrust (HFT). The MHT represents a decollement between the top of the northward subducting Indian plate and the southward propagating fold-thrust system wedge of the Himalaya. The HFT represents the surface expression of the MHT defining an active deformation zone. In Himalaya, the frontal Sub-Himalayan zone is characterized by active late Quaternary – Holocene deformation. In this zone, the frontal Siwalik range abuts the alluvial plain with an abrupt physiographic break along the Himalayan Frontal Thrust (HFT), which defines the present-day plate tectonic boundary between the Indian plate and the Himalayan orogenic prism. The frontal Siwalik range is characterized by large active anticline structures, which were developed as fault propagated/bend folds over the HFT, e.g. Mohand, Chandigarh, and Janauri anticlines. The HFT is active in the Holocene - recent time as evidenced by fault scarps showing surface ruptures and offsets of present geomorphic surfaces observed in the field mapping and excavated trenches. In the hinterland between the HFT and the MBT, reactivation and out-of-sequence faulting displace the late Quaternary –Holocene sediments. In the past one hundred-plus decades years the Himalayan region has been devastated by three great earthquakes: 1905

Kangra, 1934 Bihar – Nepal, and 1950 Assam (now Arunachal). Paleo-seismological investigations reveal that the surface ruptures produced by the 1934 and 1950 and other historical earthquakes are recorded on the Himalaya front The occurrence of a low-velocity zone beneath southern Tibet is modeled to propose that the High Himalaya zone rocks are extruded at mid-crustal channel flow between the South Tibetan Detachment and the Main Central Thrust, driven by rapid erosion at the topographic front. The out-of-sequence faulting at the front of the High Himalaya is attributed to focused precipitation-driven erosion on the topographic front.

Two large-scale contrasting tectonic boundaries in the Himalaya

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Two large-scale contrasting tectonic boundaries, products of the Indian continental lithospheric subduction, characterize the Himalaya from northwest to east, besides the Main Frontal Thrust (MFT) and the Main Boundary Thrust (MBT)—the Main Central Thrust (MCT) and the South Tibetan Detachment System (STDS). We will deal with the MCT and the STDS, since the former is a contractional fault system, while the STDS pertains to the unique extensional fault system. In the Uttarakhand Himalaya, two regional-scale thrust systems, the Munsiari Thrust (MT) and the Main Central Thrust/Vaikrita Thrust (MCT/VT), exist in Garhwal and Kumaon. The former lies within the Lesser Himalayan (LH) formations, while the latter represents the terrane boundary between the LH rocks and the overlying Greater Himalayan Sequence (GHS). Their deformed rocks are grouped into the Munsiari Thrust zone (MTz) as the ~5.6 to 6.0 km-wide zone in the southern parts, while the latter contains the Vaikrita Thrust zone (VTz) as a ~2.0 to 5.0 km-wide zone. Both the thrust zones have high-strain cores and low-to moderate strain damage zones in different valleys. The heterogeneous deformation in both the shear zones varies from dominantly brittle to ductile, as evident by the presence of mylonite, cataclasite and fault gouge. Both the shear zones share a common history of progressive in-sequence top-to-S/SW ductile shearing and thrusting. This lead to successive fold formations, sheath fold structures, the early folds and mylonite foliations, which were later transposed. The detached limbs of these transposed isoclinal folds occur as tectonic imbricates at all scales, throughout the cores of both the shear zones (Dixit et al., communicated).In contrast, the STDS

is an important extensional normal fault zone, which separates the GHS from the overlying Tethyan Himalayan Sequence (THS). This fault is characterized by the occurrence of migmatite, granite and leucogranite in immediate footwall of the STDS, and reveals both the relict thrusting episodes and superposed large-scale extensional faulting. The Cenozoic reactivation of the STDS controlled further melting and emplacement of the Higher Himalayan Leucogranite (HHL) belt. Zircons, separated from these granitoids, reveal their growths from 33.99 ± 0.37 Ma to 13.30 ± 0.15 Ma for nearly 10.0 myr, and the presence of older grains (Gargi et al., communicated). Recent data from these fault systems provide us better constraints in modeling the tectonic evolution of the Himalayan Orogen during the Cenozoic.

Magmatic episodes driven by Indian plate movement during pre- and post-Himalayan formation

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The formation of supercontinents and their breakup is a cyclic process occurring throughout Earth's history. Models of the supercontinent cycle generally focus on the major continental blocks or minor fragments present either on the margin or within the interior; often ignored to a certain extent due to the unavailability of data. Continental blocks periodically move toward each other until the oceanic crusts between them are completely closed, which causes the collision of the continents and the formation of a large supercontinent. Once a supercontinent was formed, it again began to separate the continents apart and new oceanic crusts were formed, and this event is documented as a supercontinent break-up. The northern edge of the Indian plate played a significant role in the assembly-breakup of the different supercontinents during the Paleoproterozoic to Eocene periods. The Himalayan mountain range which was formed by the collision of Indian and Eurasian plates during the early Eocene (~ 55 Ma) has been a subject of debate in terms of global and regional plate tectonics. These mountain ranges have a record of several magmatic phases of igneous activities in four episodes: Paleoproterozoic, Neoproterozoic, early Paleozoic, and early Cretaceous. The first two episodes can be related to the amalgamation of Columbia and the Gondwana supercontinent, whereas the third episode is associated with the assembly of the Gondwana assembly, and the last episode is linked to the break-up of eastern Gondwana.

The eastern Himalaya, which is located in the north-eastern part of the Indian sub-continent comprises ~350 km long fold-thrust that extends from the eastern part of Bhutan up to the Lohit valley of the easternmost Arunachal Himalaya and is geologically less explored. The magmatism and sedimentary rocks of this region are partially investigated with no proper age constraint available. Due to the lack of such information, many researchers interpret that the supercontinent event did not affect the eastern Himalaya. And if the eastern Himalaya was an integral part of the various supercontinent, it is uncertain to explain its relationship with the supercontinent. The available magmatic ages of the rocks from the eastern Himalaya of northeast India are compiled to evaluate the nature and dynamics of the magmatism. The existing ages reveal four episodes of magmatism at ~ 1800 Ma, 1100 Ma, 500 Ma, and 132 Ma. The first and second episodes were possibly related to the amalgamation of the Columbia and Rodinia supercontinent, while the third episode was associated with the assembly of the Gondwana supercontinent, and the last episode was co-related with the breakup of eastern Gondwana due to the Kerguelen mantle plume activity. Therefore, it is evident that the eastern Himalayas preserve several phases of magmatism, which can be related to the assembly and break-up of the supercontinent.

Evolution and extinction of dinosaurs: the Indian context

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India's Mesozoic fossil record provides an excellent opportunity to study the origins, radiation, diversity and biogeographic distribution of dinosaurs in time and space. As currently documented, this record is restricted to three main intervals of the Mesozoic era: Late Triassic, Early-Middle Jurassic and the latest Cretaceous. The Late Triassic–Jurassic dinosaur fossils are known primarily from the Gondwana succession (Maleri, Dharmaram and Kota formations) of Pranhita–Godavari (PG) valley in the southern Indian state of Andhra Pradesh, although Middle Jurassic occurrences have also come to light from Kutch (Gujarat) and Jaisalmer (Rajasthan). The most recent discovery of a new dicraeosaurid sauropod (*Tharosaurus indicus*) from the Middle Jurassic (Bathonian, ~167 Ma) of Jaisalmer has attracted global attention since it represents the oldest global record of diplodocoid dinosaurs, strongly suggesting that India may have been the centre of origin and radiation for neosauropod dinosaurs and that they dispersed to other parts of the world using land connections in a

Pangean setting. This possibility is strengthened by the fact that several primitive eusauropod dinosaurs of Early Jurassic age, represented by the well-known genera *Barapasaurus* and *Kotasaurus* are already known from India. The newly discovered Middle Jurassic *Tharosaurus* from Jaisalmer was likely a part of the same lineage.

The dinosaur fossil record of India spanning the period from Middle Jurassic to much of the Cretaceous, a period of more than a hundred million years, is almost completely missing, and calls for sustained efforts to fill this gap. After a huge gap since the Middle Jurassic, dinosaur fossils in India are mainly found in the Lameta Formation and Deccan intertrappean beds of latest Cretaceous (Maastrichtian) age in the Deccan volcano– sedimentary province of central and western India, and a few sporadic occurrences in the Maastrichtian Kallamedu Formation of Cauvery Basin, Tamil Nadu, southern India. These dinosaurs thrived in a different geodynamic setting in which the Indian Plate was a northward drifting island continent. Interestingly, studies on Lameta dinosaurs date back to the nineteenth century when the British Army Captain Sleeman discovered titanosaur bones from the Lameta beds of Jabalpur, even before the term Dinosauria was formally coined. The Lameta dinosaurs, as currently understood, include large titanosaur sauropods as well as abelisaurid theropods such as the iconic *Rajasaurus*. Apart from skeletal remains, a number of dinosaur egg–bearing nesting sites are also known from the Lameta Formation of central and western India, extending for hundreds of kilometers across the states of Madhya Pradesh, Gujarat and Maharashtra. Ongoing studies of Indian late Cretaceous sauropods and theropods suggest close phylogenetic relations with taxa from Madagascar and pose interesting palaeobiogeographic problems of global significance in the context of India's supposed oceanic isolation, especially after its separation from Madagascar at ~ 88 Ma. Finally, the Indian dinosaur-bearing sequences (e.g., Lameta / Deccan intertrappeans) also hold considerable potential for allowing a documentation of dinosaur extinctions at the Cretaceous-Paleogeone (K-Pg) boundary at ~ 66 Ma, especially in terms of the impact of Deccan Traps volcanism on these extinctions. Overall, recent investigations have clearly established the global importance of the Indian fossil record in unravelling the mysteries of dinosaur origins, diversification, dispersal and extinction. Although striking gaps still exist in our knowledge of India's dinosaur fossil record, there is considerable promise that the dinosaur-bearing horizons of India hold, and therefore they need to be comprehensively explored through sustained efforts so that their potential is fully achieved.

Reconstruction of Late Pleistocene to Late Holocene paleoclimatic records from NW and Central Himalaya: an appraisal of proxy's response

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Climate change has emerged as a burning problem in the recent past. Thus, it's significant to assess the change in climate that happened over the past. Instrumental records of climate variation can't do such an assessment as they provide the data of a few decades; hence, in this situation, we required long-term paleoclimatic records reconstructed using various proxies from geo-archival depositaries. Here, we appraise the proxies in different parts of the Himalayas for their response to paleoclimatic/pale monsoon variation. India has a monsoon-dominated climate, covering 80% of total rainfall precipitation. The Himalayas significantly regulate monsoon precipitation as a snow house and orographic barrier for monsoon winds. The diatom-based paleoclimatic records from the Renuka Lake, situated in the southern foothill of Himalayan, respond to modern climate change and global warming. Environmental magnetism and Geochemistry of this lake reveal a link between solar irradiance and paleomonsoon—the Holocene summer monsoon records from the mid-altitude meadow of Chakrata area Uttrakhand responded well to the carbon isotope ($\delta^{13}C$) and Total Organic Carbon (TOC) data and grain size. The grain size analysis from the meadow is significant in understanding surface sediment dynamics, textual parameters, depositional processes, energy conditions, and the mechanism behind them. Based on these proxies, Intense Indian Summer Monsoon (ISM) phases were identified during the Early and Late Holocene, i.e., ~9.2 to 7.4 ka, ~4.8 to 1.5 ka, and ~1.5 ka to modern, whereas decline in the ISM intensity during ~7.4 to 6 ka, and ~6 to 4.8 ka. The Late Pleistocene climatic records from Baspa Valley, Himachal Pradesh, also show periods of intense ISM dated to ~15 to 14 ka, ~10 to 7 ka, and ~2.4 to 1.3 ka, which is ascribed to the post-older dryas. In contrast, the phases of weakened ISM are bracketed between ~20 to 15 ka, ~14 to 10 ka, ~7 to 2.4 ka, and ~1.3 to 0.24 ka. Here, we conclude that the response of various proxies in the Himalayas changes according to the altitude, geographical area, and type of geo-archival depositories.

Integrating Molecular biology in Geosciences: A New Frontier

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Molecular biology proxies applied to Geosciences include science of metagenomics and metabolomics. Metagenomics is study of ancient, environmental and/or sedimentary DNA and other genetic material (Deoxyribonucleic acid) whereas metabolomics involves quantitative measurement of organic molecules like lipids, alkanes, coprostanols and Poly Aromatic Hydrocarbons etc. that are mostly produced during cell metabolism. Utilization of these biological molecules extracted from sedimentary archives and reconstruct past Holobiome as a function of climate and environmental variability ranging in times from Proterozoic to Anthropocene is an emerging trend globally. Review of global research on the subject suggests that it can have incisive impact on understanding of stratigraphy, mutualistic behavior and responses of species, mass extinctions, environmental tipping points, paleofires, climate-human-microbe relationships etc. In Indian geosciences these applications have been largely ignored sofar though the strength of metabolomics is realized to some extent but that of metagenomics is largely limited to archaeology.

This talk will introduce the subject and discuss the preliminary results of application of biological molecules *viz*. ancient/sedimentary DNA and other biomarkers in understanding the processes involved in (i) in-situ rock weathering and (ii) post LGM (Last glacial maxima) climate variability in Garhwal Himalaya.

Tectonic and climatic control on landscape evolution during late Quaternary: Examples from Mainland Gujarat

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The history of landscape development in the mainland Gujarat region during the late Quaternary is complex involving the role of climatic variability, tectonic activity and sea level changes. The landscape evolution is manifest as distinct geomorphic surfaces in fluvial basins and sediment sequences exposed therein provide potential archives to understand the late Quaternary climate-tectonic dynamics. The present landscapes in these fluvial basins have

recorded movements along various faults indicating distinct phases of inversion during Quaternary that controlled the erosional and depositional processes. However, a large impact of climatic variability and monsoon conditions is also observed. For example, in the Narmada basin, four geomorphic surfaces (two erosional and two depositional) have been mapped. Three inversion phases are inferred – Late Pliocene to Middle Pleistocene, Early Holocene and late Holocene to recent. The area to the south of Narmada-Son-Fault was inverted in Late Pliocene, the area to the north of it was inverted during early Holocene. The alluvial stratigraphy was dominated fluctuating hydrological condition between 120 ka to 30 ka (meandering to braided). The aeolian processes dominated the landscape after 30 ka and until around 11 ka followed by a phase of quiescence between 11 to 8 ka. Present day fluvial regime appeared after 20 ka. The incision began during the low sea stand (<20 ka) and was intensified with onset of SW monsoon during 14 ka to 10 ka. This was followed by second phase of dune accretion (limited to Sabarmati basin) that commenced after 9 ka and continued till 5 ka. The sediment archives of the Mainland Gujarat rivers have preserved responses to tectonic and climate change however, the response type and time in the basins is diverse.

Climate-induced Geo-hazards in the Himalaya and their Plausible Mitigation

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The Himalaya is the World's youngest and rugged mountain chain in the world, which initiated in the early Eocene age by collision tectonics. The sediment-water transmit from high-altitude glaciers, snow fields and river water-sediments transmit are life lines to hundreds of millions of people for several purposes. The Himalaya also possesses plethora of other resources like precious minerals/ore bodies, cold springs, geothermal, hydrocarbon, and solar/wind energy resources. All these have made the Himalaya habitat for the agro-socio-economic development. But the Himalaya is stressed by several natural processes, anthropogenic activities, environmental degradation, and more intensely by the present-day climate-induced extreme events. The complex processes are still going on, which change the landscape and geomorphology. This, in turn, controls the damage pattern during a calamity, and thus people living in the Himalayan states are under threat due to various kinds of geo-hazards caused by climate-induced landslides or avalanches or flash flood or glacial lake outbursts with different magnitudes. To live with these adversities, we need to build a disaster-resilient and climate-

adaptable future for sustainability and secured living in the Himalaya and adjoining regions. Though natural processes cannot be avoided but their impact to lives/livestock and damage to properties/structures can be reduced by developing Integrated Early Warning Systems (IEWS) through establishing multi-parametric network of stations in the field; real-time transmission of data to a centralised centre; processing, analysis and integration of data sets; and development of alert mechanism against such disasters. With the dense network of high-resolution sensors, availability of fast computing machines, advancement of modelling, integration of multiple data sets using AI/ML, it is possible to achieve the goal of developing respective IEWS as mitigation measures against the disasters. The investment on monitoring and development of IEWS would be much less than the cost we pay towards the rehabilitation and restructuring, loss of properties and lives. We would discuss several aspects of Geo-hazards related to climate-induced landslides, flash-floods, avalanches, glacial lake outbursts, and their plausible mitigation based on AI/ML based approaches with a view to safeguard people living in the Himalaya and sustainable development with special reference to the Uttarakhand state.

Understanding Orogenic Exhumation using Thermochronology

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Exhumation is a key component that is essential to understand the uplift and landscape evolution history of a mountain belt. Normal faulting, erosion and ductile thinning are the three processes that exhume the deep-seated to the surface. Thermochronology provides the timing, cooling rates and exhumation paths of the rocks through which any rock unit travels from the sub-surface to surface temperatures. Closure temperatures, i.e. apparent temperatures at which any radioactive clocks start, for various thermochronological methods mainly range from ~60 to ~550 °C, can provide the exhumation paths of rocks for tens of kilometers on millennial timescales corresponding to the orogenic growth. The exhumation rates/paths can be constrained using simple cooling rates/geothermal gradient approach, estimating thermochronological ages along the vertical transects, and solving 3D heat-conduction advection equations through numerical methods. Spatial-temporal patterns of the exhumation rates in fold and thrust belts like Himalaya, provide clues to understand the structural evolution of the orogens, the tectonic-climate-topography interactions during the mountain building.

In the Himalayan-Tibetan orogen, the exhumation rates have been highest within the Higher Himalayan Crystallines, while the interior of the Tibetan Plateau characterizes slow exhumation rates. Fault kinematics, i.e., thrusting and folding and the geometry of the subsurface in combination with intense orographic precipitation are the major controlling factors of the patterns of exhumation in Himalayan orogen. The exhumation history of Tibet can be explained through the two end-membered models, i.e., Rigid body and Soft Tibet models. The rigid body model considers Tibet as a rigid block that extrudes eastward in between the major strike-slip domains. In the Soft Tibet model, the topographic uplift enhances exhumation through the process of delamination of the Tibetan mantle lithosphere followed by late-stage underthrusting of the Indian slab. Therefore, the interplay of tectonics, climate, and topography control the exhumation pattern of the Himalayan-Tibetan orogenic belts.

Seismic Interpretation: a peep into the subsurface

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Interpretation of subsurface geologic features in both onshore and offshore regions from surface measurements are of paramount importance for the exploration of hydrocarbons and characterization of reservoirs or delineation of aquifer, geothermal and mineralized prospects or imaging below volcanic terrains and thrust fold belts or understanding geotectonics and basin evolution. Thanks to the high performance computing system that have allowed advanced processing of a large volume of data within a reasonable time that has produced substantially improved images of subsurface. Seismic methods have been very efficient in bringing out finer details of the subsurface. Interpretation of seismic data provides an ample information on subsurface geological details thereby improving our understanding on the tectonic and stratigraphic settings of the sedimentary basin. This talk shall highlight the tools and techniques used to interpret seismic data by glancing in detail into the subsurface. Examples from Indian and worldwide sedimentary basins shall be showcased to ascertain the practical applications of seismic methods used to interpret the subsurface using seismic data.

National Geochronology facility (NGF) at IUAC New Delhi

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IUAC has established a national facility equipped with state of art instrumentations for generating high quality chronological & isotopic data for geoscience research with the financial support from the Ministry of Earth Sciences, (MoES) Govt of India. Three major equipment, the High-Resolution Secondary Ion Mass Spectrometer (HR-SIMS), Accelerator Mass Spectrometer (AMS) and High resolution ICPMS (HR-ICPMS) coupled with femtosecond laser are complemented by other active facilities, such as XRD, XRF, FE-SEM, Q-ICPMS and sample preparation laboratories. These instruments will help/are helping to understand the evolution of the Indian Lithosphere through time including the time scales of physical, chemical and biological processes acting on the minerals and rocks and to understand quaternary processes. NGF being at par with the international standards offers equal opportunity to all Earth scientists with scientific merit & innovative ideas being the only criterion. Instrumentation, research being done and process of utilization will be elaborated in the talk.

Geospatial applications for the study of active faults

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During the last decade, the Himalaya have witnessed six large-to-great earthquakes. The seismic potential and earthquake magnitude in the Himalaya are primarily controlled by the Main Himalayan Thrust (MHT) characterized by the present-day geodetically determined convergence rate, plate rheology, geometry, inter-seismic coupling, and width of the locked zone. The ongoing dynamic and continued convergence of 40-55 mm/year across the ~2500 km long Himalayan arc has given rise to large to great earthquakes along the Himalayan Frontal Thrust (HFT) or Main Frontal Thrust (MFT) of India, Nepal, and Bhutan. Despite enormous geological, geophysical, and geodetic investigations in the Himalaya, active fault zones and their characteristics remain unexplored. Identification and characterization of the late Quaternary active faults are vital to decipher their seismic potential and make the foundation for the seismic hazard assessment of any region. The active faults developed during the Late

Quaternary hold the possibility of deformation within a future period of concern to society. Studying active faults helps estimate seismic potential and other geologic hazards. In this talk, I will demonstrate the mapping of active faults using geospatial technology and remote sensing, combined with field mapping and geological investigations, thus integrating Geospatial Technologies (IGT) with geological studies.

Assessment of Himalayan Glaciers and Associated Hazards using Geospatial Techniques

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The Himalaya-Karakoram (H-K) has one of the largest concentrations of glaciers outside the poles. The meltwater generated from these glaciers is of interest for several purposes such as drinking water and irrigation. These glaciers also generate hazards in the downstream areas (e.g., debris flow and glacial lake outburst floods (GLOFs)). It is, therefore, important to monitor H-K glaciers for water resource management and hazard mitigation. However, monitoring of these glaciers and associated hazards is very difficult using only ground observations. Thus, remote sensing data and GIS techniques has abundant potential to monitor large number of glaciers at regular intervals. Glaciers in the Karakoram reveal irregular behavior as compared to the central and eastern Himalaya. Terminus fluctuations of individual glaciers lack consistency, unlike other parts of the Himalaya. Since the 1970s, total ice mass remains stable or indicates a slight increase. Such anomalies are addressed through a comprehensive mapping of surge-type glaciers and surge-related impacts, based on multiple satellite images, DEMs, ground observations, and archival material since the 1840s. Surge cycle timing, intervals and mass transfers are unique to each glacier and largely out-of-phase with climate. However, the mass balance of central and eastern Himalayan glaciers reveals mass reductions in recent decades, that destabilize the pro-glacial area and influence the occurrence of glacial hazards. Therefore, some case studies of glacial hazards in the central Himalaya (e.g., Gangotri and Chorabari glaciers) and Karakoram (e.g., Kumdan group of

glaciers) have been highlighted. Ice-dammed lakes formed by advancing and/or surging glaciers have resulted in several floods (~150) in the Karakoram region. Whereas, in the central and eastern Himalaya, the GLOFs are attributed to the failure of moraine dams due to the rapidly retreating or thinning of glaciers. Hence, regular monitoring of glaciers situated in the H-K region is imperative to understand the impact of climate change.

Hydrothermal fluids and linked exploration strategy

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Geofluids are undoubtedly recognized as one of the major factors controlling most geological processes. The hydrothermal fluids may be derived from the cooling magmatic bodies, from the large number of metamorphic devolatization reactions, or it may be saline fluids invariably present in almost all sedimentary basins. The globally occurring mineral resources are either formed by such fluids or reworked by them, and even the fluid driven migration of economically useful elements may be responsible for ore deposition. This modern concept that the hydrothermal fluids are fundamentally heated water naturally generated below the surface, has revolutionized the genesis of various ore deposits. The mixing of two or more of such fluids during geological evolution is always possible. Some of the several issues of hydrothermal systems linked to the ore deposition include the fluid boiling, mixing/unmixing, immiscibility, volatiles and salts in the hydrothermal system, pulsatory fluid fluxes and the enrichment of CO_2, boron and fluorine. The generation of ore forming hydrothermal fluids are not common, but their data is decisive in understanding updated genetic models of the mineral deposits and hence promote cost-effective mineral exploration. Several studies of the hydrothermal systems based on mineral phase chemistry, alteration zones, fluid inclusion microthermometry, stable isotopes and geochemical modeling have been carried out in various ore districts to distinguish between economically potential and insignificant zones.

Geophysical Tools and Techniques: Study of Geodynamics and natural Hazards in the Himalayan Region

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Geophysics aims to understand the earth interior using the methods of physics. It involves methods of study made on the surface to extract subsurface details. Investigation of uppermost subsurface structure of the Earth is of great importance for understanding geodynamic processes and natural hazards mitigation. However, the problem is difficult due to complex structure and tectonic effects, especially near the surface. For this purpose, various geophysical methods are used depending on different physical characteristics of the Earth materials. A particular geophysical technique utilizing its physical significance sheds light on one part of the problem. Sometimes, a reliable solution can be found by using more than one technique, either separately or in combination. Geophysical method uses the characteristic properties of earth materials like density, seismic wave velocity, seismic wave attenuation, magnetization, resistivity, crustal deformation and additional effects of fracture propagation and hydrological fluctuations. Seismic wave tomography is extensively used to characterize the crustal structure. Electrical resistivity is used to interpret subsurface rock types, geological structures, groundwater condition and depths to the bed rocks. The mass redistribution during the earthquake build up and its occurrence is reflected in time varying gravity field. Electrical and magnetic fields are associated with seismic and volcanic activities.

Many geophysical methods are in use to do multi-disciplinary research focused on one of the most complex region of the world, the Himalaya, inter-continent part of India-Asia tectonic plates. In this part, the inhabitants and infrastructure are exposed to extreme natural hazards associated with tectonics and geodynamics. Most of these hazards relate to rapid plate convergence together with under-thrusting of India plate beneath Himalayan wedge and Asian plate. The geodynamic processes have produced many great earthquakes (e.g. the recent Gorkha Nepal earthquake of 2015), rock-fall avalanches, landslides, and in the past volcanic eruption. The tectonics of the region is very complex with under-thrusting/subduction, windows, nappe and rift structures. The formation of high peak mountains is due to NNE movement of the Indian plate and its convergence on the plate boundaries, which started ~55

my ago. It should also be noted that damage and deaths from earthquakes also result from induced landslides than from building collapse and from shaking itself. Landslide and land-subsidence processes are slowly amplified and enhanced due to tectonics, seismicity and anthropogenic activities. In these investigations, the geophysical methods are gaining importance very rapidly because of their success in solving a variety of problems. In order to synthesize information from different geophysical methods, it is important to understand their similarities and differences. The presentation will shed light on the basic principles of geophysical methods and its application to geodynamics and natural hazard.

Landslide susceptible maps and their application for the sustainable development of the terrain

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Landslides and associated phenomena are becoming common in the Himalayan terrain, causing immense loss of life and damage to infrastructure worth Crores of Indian Rupees. Though these are attributed to many factors such as steep slopes, fragile lithology, high topographic relief, and complex geological-physiographical characteristics, in recent years, the change in the climatic pattern and increased incidences of heavy and extremely heavy rain have been the main cause of the increase in the magnitude and frequency of landslides. The increased anthropogenic activity on finite land resources in the form of excessive slope exploitation for varying purposes further contributes to the increased incidences of landslides. Though there are numerous causes for the occurrence of landslides, most of the landslides in the Himalaya are triggered either by rainfall or earthquakes, and between these, rainfall has been accounted as the major triggering factor responsible for the highest number of landslide occurrences, with ~ 16% of the world's total rainfall-induced landslides occur in India. These numbers are expected to increase in the future as climate change can exacerbate the rainfall intensity that may lead to landslides. The way forward for the sustainable development of the terrain, including the Himalayas is the prediction of the zones where the possibility of occurrence of landslides would be higher, through the preparation of the landslide hazard maps. This lecture

deals with the preparation of landslide hazard maps for the hilly states of Himachal Pradesh, Uttarakhand, and Sikkim at regional- and local scales utilizing advanced technology and various machine-learning tools combined with the slope movement indicators in the field. Finally, how the maps should be utilized for the further development of the area will be discussed.

Abstracts Theme

Geodynamics and Mountain Building Process

Evaluating the Tectonothermal History of the Lohit Valley in the Eastern Himalaya: Insights from Low-Temperature Thermochronological Data

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Lohit valley region of the Arunachal Himalaya, NE India, marks the easternmost part of Himalayan orogen bounding the Burman ranges to the north. The present study provides first low-temperature thermochronological Apatite and Zircon Fission-track data (AFT & ZFT) from the litho-units of the Lohit valley region. The combined analysis of newly generated AFT & ZFT along with the published and newly generated AHe and ZHe data across the major faults of exposed along the Lohit Valley constrain the recent exhumation behaviour of the prevailing lithounits. All these ages have been identified as cooling ages. The ZFT ages unveil the slowest exhumation rates since 17.6±1.2 Ma in the southern sector and since 37.8±8.1 Ma in the northern region. In contrast, the AFT cooling ages ranging from 1.9±0.4 Ma to 7.3±0.6 Ma, provides relatively higher exhumation rates since Mio-Pliocene. The ZHe ages range from 7.1±0.33 Ma to 12.51± 2.84 Ma, while AHe ages vary from 6.63±0.38 to 9.09±0.52 Ma within the Lohit Plutonic complex. This suggests that the Mishmi Crystallines exposed at southwestern mountain front are the slowest exhuming domain since ~12 Ma. Throughout the valley, the lowest ZHe ages are from the Demwe thrust zone which is contact between the frontal low-grade metamorphic rocks of Mishmi Crystalline and high-grade gneissic rocks of the Mayodia Group. Employing QTQt thermal history modeling of co-genetic pairs of ZHe and AHe cooling ages from the northeastern Lohit Plutonic Complex, we deduce exhumation rates that reached ~3.7 mm/year during the Pliocene-Quaternary phase. These substantial exhumation rates align closely with local topographic relief, hill slope characteristics, and channel steepness, collectively pointing to the establishment of the present-day topography of the Lohit Valley region by the Pliocene-Quaternary transition. Notably, variations in exhumation rates do not correlate with current precipitation patterns, highlighting the dominant role of tectonics as the primary driver of exhumation rates in the easternmost Himalayan Lohit Valley. Our investigation integrates a thermo-kinematic 3D forward modeling approach named 'PECUBE' to develop a suitable geometric model of the Lohit Valley. This model corroborates

our thermochronological findings and contributes to understanding the subsurface MHT geometry.

Upper Jurassic (Oxfordian-Tithonian) ammonites from the Spiti Shale Formation of the Spiti and Zanskar regions in the Indian Himalayas

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The Spiti Shale Formation in its type area, the Spiti and Zanskar regions of the Himalayas, has yielded several ammonites collected systematically from 10 outcrops. Some of these ammonites have a short stratigraphic range and serve as zonal fossils. The collection of ammonites from Zankar is poorly preserved compared to Spiti due to the intense tectonic activity. Although 19 genera represented by 46 taxa have been identified, taxonomically described and illustrated. The majority of the collected specimens belong to the Torquatisphinctinae, Paraboliceratinae, Virgatosphinctinae, and Himalayitinae. Taramelliceratinae, Streblitinae, and Berriasellinae are less common, whereas Mayaitinae are particularly rare. A single specimen of *Virgatosphinctes* cf. *discoides* is found to be very significant, as it is the sole record of the genus *Virgatosphinctes* from the Zanskar region. In the present study, the oldest ammonites were collected from Oxfordian strata in the Chichim and Langza outcrops of the Spiti region and identified as *Mayaites* and *Epimayaites*. The Kimmeridgian fauna is represented by *Torquatisphinctes*, *Pachysphinctes*, and *Metauhligites* recorded from the Chichim, Langza, and Hikkim outcrops of the Spiti region. The base of the Lower Tithonian is marked by *Kossmatia*, which was found to be associated with *Aulacosphinctoides*, *Stevensites*, *Uhligites*, and *Paraboliceras*. The uppermost Lower

Tithonian is indicated by *Indodichotomoceras biplicatus*, which represents the Biplicatus Subzone of the Virgatosphinctoides Zone of the Kachchh Basin in western India. This record is succeeded by *Virgatosphinctes*, *Malagasites*, and *Aulacosphinctes* mainly recorded from the Demul outcrop in the Spiti region. The Upper Tithonian in the Spiti region is characterized by Uhligites, Aulacosphinctes, Virgatosphinctes, Malagasites, Blanfordiceras, Durangites, Metahaploceras, and Himalayites.

Magmatism, deformation, and uplift history of the Karakoram Range

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In this study, we review the magmatic, deformation, and uplift history of the Karakoram Range (KR), existing in the western margin of the Himalayan-Tibetan orogen since the Neoproterozoic. A detailed correlation of whole-rock geochemical, zircon U-Pb geochronological, Sr-Nd, zircon Lu-Hf isotope data, K-Ar, Ar-Ar Muscovite, Biotite, zircon, and apatite Fission-track thermochronological data, cosmogonic, OSL, and glacial records litho-units across the Western, Central, and Eastern Karakoram has been made. In this review, we provide (a) a detailed analysis of the pre-to-post-India-Asia collisional magmatism from the KR, (b) detailed analyses of the Karakoram Fault (KF) activity and related magmatism, (c) the uplift history of the KR.

Two-stage of magmatism has been suggested: Stage-1 (~160-100 Ma) mainly consisting of hornblende (Hbl)-biotite (Bt) and only Bt-bearing granitoids. This group of granites consists of inherited zircon ages ranging from ~200-1838 Ma, indicating the incorporation of older crustal material into the crystalizing melts. Thermodynamic major element modeling suggests their formation through the assimilation of upper crustal rocks at ~0.9-1.5 kbar at low H_2O conditions (~1.5 wt.%). Stage-2 magmatism (~83-56 Ma) from the Pangong Transpression Zone (PTZ) mainly consists of Hbl-Bt bearing granitoids and is devoid of zircon inherited ages and bears juvenile isotopic signatures suggesting the role of melt from the mantle during their genesis. Thermodynamic major element modeling suggests their formation through fractional crystallization (FC) at ~1.2-4 kbar at ~ 5.0 % H_2O. We suggest that the granitoids in the PTZ of the Eastern Karakoram belonged to the Ladakh magmatic arc, contrary to being part of the

Karakoram Batholiths. The debate on the petrogenesis of leucogranites from the KR remains controversial. We suggest that there are two main groups of leucogranites, one with Hbl and tourmaline bearing, that formed due to water-fluxed melting of calc-alkaline granitoids and metasedimentary rocks caused by shearing along the KF zone. The second group of leucogranites are depleted in volatiles and are considered to be formed through dehydration melting of biotite in the lower crust as a result of crustal thickening after the India-Asia collision. We also propose that the entire KR experienced fast cooling during Miocene (~18 Ma) and provides valuable insights into the debate whether the uplift of the KR occurred before or after the India-Asia collision. We propose that the uplift of the KR occurred after the India-Asia collision. The uplift is mainly driven by different tectonic processes, including lithospheric delamination (~25-8 Ma) and underthrusting of the Indian plate (~4 Ma). The high topography of the Karakoram resulted from the interaction between tectonic uplift, likely due to lithospheric delamination and later underthrusting, and glaciation during the Quaternary or possibly even earlier.

Understanding the controls on Waterfalls of Chotonagpur plateau, India: A regional to local-scale approach

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The Cratonic plateau Chotonagpur considering as a *"hub of waterfalls"*, due its spatial distribution, the distribution indicating the correlation among location of waterfalls, morphology of waterfalls, bedrock joints characters. There have some good interpretation among the differences to show the outcomes from more widely bedrock joints, lithological differences, and the fluvial history. The result explained that shape of waterfall and typology may change due to local and regional control which emerges at a plateau environment. They demonstrate that the morphology and types of waterfalls may change due to both local and regional approaches to control in plateau region where fluvial erosion continuing its erosional activity and developed so many waterfalls with different location with different morphology which explain the reflect on the influence of sediment supply, joints and bedrock geometry. The plateau region belongs to a diverse characteristic regarding its fluvial activity which response of the landscape to autogenic dynamic and allogenic perturbations. The study is

carried out to show that channel patterns, their longitudinal profiles refers to the landscape evolution, digital data and the field survey was carried out for the purposes of quantitative analysis of geomorphometric parameters. All the basins are different in character with various morphological signatures and resulting in disequilibrium in the form of knickpoints. The spatial variation in the different catchments reflects the dynamic response and feedback between the preexisting topography and transient landscape evolution. We have analyzed the power law scaling between channel slope and drainage area, also faced the method of exploiting the relationship between topographic indices e.g longitudinal profile shape and characteristics, so that the stream profile data can be utilized to delineate the breaks of scaling with different geomorphic association which connect the detachment limited an expression of rock uplift rate and its control on this scaling. The plateau is suggested as control in heterogeneities of incision with symbolic nature of knickpoints, using the slope area analysis ($S = k_s A^{-\theta}$) to explore the possible relationship between steepness (k_s) and concavity (θ) indices.

Uplift history of Chotonagpur Plateau, eastern India, deciphered from bedrock channel profile analysis

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The Chotanagpur Plateau is one of the ancient Precambrian terrains of India, situated in the eastern part of Peninsular Shield and serves as a natural laboratory for understanding the interplay of tectonics, erosion, and erosional processes. It is usually considered a tectonically quiescent region, where ancient rocks and low-relief landscape predominate, surrounded by several high-relief topographic scarps. However, the topographic response to tectonic uplift is strongly indicated by the presence of large-scale knickzones in the channel network, which do not correlate with lithological contacts. Therefore, understanding the surface uplift history of the plateau is crucial for deconvolving the relationship between topographic development and erosion processes. The present study aims to utilize the digital topographic data for quantitative morphometric analysis of fluvial channel profiles to provide an understanding of the surface uplift history of the Chotanagpur Plateau. We analyzed downstream changes in channel steepness and associated knickpoints derived from 30-m SRTM DEM within the context of detachment-limited stream power incision model (SPIM). The analytical results provide a

promising affirmation that coupling slope-area analysis, integral approach and statistic test to steady-state bedrock river profile analysis and the deriving steepness (k_{sn}) are crucial in comprehending the tectonic history of the Chotonagpur Plateau. In the absence of strong climatic gradients and lithological heterogeneity, the systematic variations in channel steepness are difficult to explain unless there is a differential rock uplift. Projecting the relict topography indicates that the plateau has experienced a minimum upliftment of 750 ± 60 m. The study highlighted that the scarp zones act as major geomorphic markers, and the map view of scarp zones appears to be highly beneficial in identifying the zones of differential upliftment where maximum numbers of knickpoints are clustered. The results of steepness from integrated slope-area and chi (χ) methods suggest transient conditions of the drainage basins, where maximum knickpoints are slope-break with moderate to low steepness above the knickpoints and higher steepness value below it. The vertical distribution of knickpoints along the longitudinal profiles further clarifies the two clusters prominently. The first occurs at a height of 700 ± 50 m while the second one occurs at 550 ± 30 m, corresponding with the two phases of the uplift history of the plateau, where upliftment first occurred in the lower part and then it merely concentrated on pat regions of the plateau. Variation of chi values (χ) along the drainage divides further shed light on drainage disequilibrium associated with differential upliftment. The analysis provides a useful insight into the key control on landscape evolution, where the fluvial processes are the primary drivers behind topographic development, and differential rock-uplift rate exerts a critical control on the channel gradient that makes a difference in the steepness and concavity along different reaches of the channels.

Flood variability and channel changes in the Damodar fan-deltaic plain, western Bengal Basin, India

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Over the last few decades, several researchers have emphasized long-term records of high-magnitude floods, which are subjected to geomorphologically effective and produce substantial

geomorphic changes. Essentially the key drivers of geomorphic change, such as flood power, flood competence, and sequencing of flood events, result in extensive planform changes and substantial sediment input to the river systems. This study delves into the geomorphic effectiveness of extreme floods in areas of high flow variability in the western Bengal Basin. The rivers in this region have witnessed severe flooding, which influenced channel form, moved large volumes of sediment, and left strong imprints on channel morphology. Using a combination of mythological archives, old maps (1550 - 1893), instrumental records, historical information and sedimentary investigations, we have been able to assess the effects of the flood events in the Damodar fan-deltaic plain. Discharge and sediment load data for several hydrological stations along the Damodar River and its major distributaries have been analyzed to understand the present-day geomorphic implications of high monsoon flows. The historical flood records of the Damodar and its distributaries from articles and reports have also been incorporated to extend the length of the flood data series. A study of mythological accounts and old maps published in 1660 and 1685 reveals that the main flow of Damodar was restricted to the northeast direction. Due to a catastrophic flood in 1770, the Damodar left this channel. A shallow trenched sedimentary section ~20 km away from present-day Damodar in the abandoned lobe of the fan-deltaic plain is also studied. The sediment sequences of the section, comprising gravels overlain by ~6.5 m thick medium to coarse sand lithofacies, suggest a gradual change in palaeohydrological conditions marking a switch from braided to meandering fluvial styles. The study further indicates that the gravel deposits were controlled by the high stream power and large sediment influx and were in response to the increase in the discharge and competence of the river flow. This integrated study reveals that the changing courses of river Damodar were associated with avulsion, this river was more mobile in the past, and due to anthropogenic intervention, the annual peak flow competence and capacity remarkably decreased with time in the study area.

Inventory Assessment of Extreme Rainfall Events in the Himalayan Region

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The Himalaya, is the world's largest young mountain range, and the home to some of the world's countless rivers and high peaks with snow-capped tops, deep valleys, and glaciers., Being a very young and tectonically active mountain chain, it is inherently vulnerable to catastrophic events that have been difficult for humanity to deal with and have caused a number of damages. In this study we prepare inventory of cloud burst events over in the last six decades of Himalayan region. The factor contributing to those extreme rainfall event, the extent of damage to ecosystem, mankind and biodiversity. Assessments were carried out by the data which has been collected and reviewed from various reliable resources, the literature and published work on internet. There is compiled information of total 70 cloud burst incident that took between "1970-2021". Causes of these extreme events that the northern part of India suffers from the orographic disturbance every year. Himachal Pradesh, Jammu & Kashmir and Uttarakhand are the sates which are mostly affected these type of cloudburst frequencies and it can be seen that most of the events are in Uttarakhand state because of its geological and geographical condition. There are various factors which are responsible for these events included both natural and man-made. By looking at chronological sequence of events it's been evident that there is rapid hike in extreme rainfall events at fast rate every decade and it poses a serious threat to Himalayan environment. Awareness associated with these events and proper disaster management can mitigate these. And can also undertake the demand and utilization of future proposed warning system.

Archean Banded Iron Formations from the Dharwar Craton, Southern India: Implications for the redox state of Archean oceans

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The Banded Iron formations (BIFs) are important chemical sedimentary rocks to understand the Archean surface processes and they occur in a wide range of time from 3800-2600 Ma. They form key archives for our understanding of the redox evolution of Archean ocean-atmospheric system, biogeochemical cycles, and biologic activity. They are well preserved across Archean cratons in Brazil, South Africa, India, SW Cameroon, Greenland, and North China. Thick BIF sequences are found in the four Archean Singhbhum, Bastar, Dharwar, and Bundelkhand cratons of peninsular India. Here we present comparative petrological and

geochemical data of BIFs from the older Sargur group to the younger Dharwar group of the Western Dharwar Craton and discuss their origin, depositional environments, and the redox conditions of Archean oceans. The most significant part of these BIFs is their variable mineralogy which includes oxide, silicate, carbonate, and sulphide facies. Mesoscopic bands of recrystallized chert and iron oxides indicate a fluctuation in the atmospheric oxygen conditions on the ocean surface. The occurrence of Fe-Mg silicates (Riebeckite, Stilpnomelane) in some of these BIFs indicates their involvement in metamorphism. Major element composition from the previous studies showed significant enrichment of Fe_2O_3 and depletion of Al_2O_3 whereas carbonate facies of BIFs show enriched MgO, CaO, and MnO (e.g., Mukhopadhyay et al.,2019). Trace element data shows a relative enrichment of Ni, Cr, and Co than Zr, Hf, Th, U. The chondrite normalized REE patterns vary in a wide range (from 2.54-66.066 ppm), with an average value of 11.462. Overall, they show moderate LREE and HREE enrichment with sharp positive Eu anomaly while in some samples the magnitude of the positive Eu anomaly eventually diminishes and even turns somewhat negative. The REE patterns show no or very little positive Ce anomaly for Sargur group BIFs, a negative Ce anomaly for Dharwar basin BIFs, and no Ce anomaly for Bababudan and Chitradurga BIFs. These large variations of REE are due to the steady input of clastic materials during the deposition of BIFs. The trace element data indicate that the primary mantle-derived hydrothermal fluids were added to these BIFs during their formation. The relationship of Nd with Al_2O_3 and $Fe_2O_{3\,(t)}$ (Arora et al, 1995), shows both hydrothermal and continental source was involved in their formation. Iron hydroxide precipitation that was rhythmic and led to the banding of iron and silica layers appears to have been caused by irregular oxygen availability. The anomalous behaviour of Ce i.e., from positive to negative through no Ce anomaly reveals periodic fluctuations in redox state of the Archean oceans which was changing from anoxic to oxic (from 3.3 Ga Sargur group to 2.6 Ga Dharwar group) through suboxic conditions. This also probably links to the onset of oxygenation of oceans a few hundred million years prior to the Great Oxidation Event (GOE) at ca. 2.34 Ga.

Metamorphic evolution of the Tso Morari Crystalline Complex, NW Himalaya: a petrographic and thermodynamic modelling approach

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The Tso Morari Crystalline Complex (TMCC) of trans-Himalaya, part of eastern Ladakh, India marks the India-Eurasia collision zone in India. TMCC underwent continental subduction, eclogite grade metamorphism, and experienced rapid exhumation during the Himalayan orogeny. The TMCC is characterized by eclogite enclaves embedded within granitic gneiss (both ortho and para gneiss). Previous workers have extensively studied the TMCC in terms of its metamorphic evolution from the samples of same outcrop i.e., in the core of the complex, surprisingly giving varied results. Along with it, the presence/absence of Na-amphiboles and lawsonite is still a matter of controversy. For the present study, metabasic samples are collected from the core and western margin of TMCC. The samples are investigated in regard to detailed petrography, mineral chemistry, Raman spectroscopy, and *P-T-X* pseudosection modelling to address the differences and discrepancies from previous studies. Our study suggests peak metamorphism at ~2.75 ± 0.1 GPa and ~550 ± 50 ◦C, followed by a decompression stage at ~1.50 ± 0.1 GPa and ~580 ± 50 ◦C and subsequent high-temperature overprint at ~0.85 ± 0.1 GPa and ~680 ± 50 ◦C. Presence of omphacite + garnet + amphibole fine grained symplectite colonies at the grain boundaries indicate exhumation along with fluid infiltration. Omphacite is transitioned into a more calcic variety and is further replaced with amphibole. Moreover, diopside + plagioclase symplectite indicates post-peak decompression and fluid infiltration. Presence of carbonates in the matrix as veins and within fractures suggests the event of late-stage fluid infiltration and metasomatism. Our study finds no role of lawsonite and/or Na-amphibole in the metamorphic evolution of TMCC. Rather, the occurrence of omphacite breakdown, symplectite formations, and metasomatism due to externally derived carbonaceous fluids played a crucial role in the exhumation and retrogression. Based on the mineral chemistry data and metamorphic modelling of the present study, we opine that TMCC resemble a continental eclogite and hence cannot be compared with oceanic eclogites.

Paleo-proterozoic A-type granite magmatism from Khammam Schist Belt: Implications for tectonic evolution at the time of Columbia Supercontinent

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Proterozoic metasediments along with the associated granitic rocks at the cratonic margins can be a potent tool for deciphering the tectonic evolution, crustal accretion, and the paleogeographic reconstruction of an area. This abstract presents novel geochemical and U-Pb age data from K-feldspar bearing granites in the Mesoproterozoic Khammam schist belt, Telangana, India, Eastern Dharwar craton. Variably deformed quartz, K-feldspar, and plagioclase feldspar are major minerals present in the studied sample. Zircon, Titanite, and magnetite are accessory phases. The analyzed samples have SiO_2 and Al_2O_3 contents ranging between 70 and 77 wt.% and 12 and 15 wt.%, respectively. The K_2O and Na_2O concentrations range between 2.57 and 5.55 and 1.17 and 2.69 wt.%, respectively. This categorizes the studied samples to be peraluminous and silica-rich. Negative Nb, Ta, Ti, and Sr anomalies and positive Th and Pb anomalies characterize the studied granites in primitive mantle normalized spider plots. In a chondrite-normalized spider diagram, the granites show LREE-enriched and flat-to-depleted HREE patterns with a negative Eu anomaly (0.20 - 0.44), and $(La/Yb)_{CN}$ varying between 2.4 and 12.16. The studied samples yield Zircon saturation temperatures (T_{zr}) from 859 to 978°C that overlap with the crystallization temperature of A-type granites. In addition, the granites are classified as A_2 sub-type, which are post-collisional granites (Eby, 1992). In a U-Pb Concordia plot, the ages of magmatic zircon range between 1865 and 1858 Ma. The outer rim yields an average age of 1600 Ma. It is inferred from the geochemical and U-Pb age data that the 1.86 Ga post-collisional A_2 granites mark the collision of the eastern Dharwar Craton and the North China Craton. (Ganaie et al., 2023). The 1600 Ma age retrieved from the margin of the magmatic zircon suggests metamorphism during the maximum packing of cratons in the Columbia supercontinent The study confirms that Eastern Dharwar Craton was a part of the Columbia supercontinent that experienced magmatism and metamorphism within a timespan between 1865 Ma to 1600 Ma.

The Sinking Problem of the Himalayan Mountain Town of Joshimath: interpreting the Issue and its Causes

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In the beginning of the year 2023, sudden appearance of cracks on the ground and in houses, and gushing out of water at a location in the Joshimath town raised alarms throughout India. Joshimath is situated in the Chamoli district of Uttarakhand state, on a north-facing slope, above the confluence of the Alaknanda and Dhauliganga Rivers. The January event appeared as an accelerated slide, in an already reported 'sinking' Joshimath town. The issue of sinking, toe-erosion, subsidence have been reported in the past. The January 2023 extensive deformation has been observed in the Manohar Bagh, Singdhar and Marwari regions. This was somehow unexpected, as the signatures of slides have been seen mostly in Ravigram, Sunil, Gandhinagar and Lower Bazar wards of Joshimath in the past. The damage on ground followed a distinct arcuate clockwise east-west path, beginning from Manohar Bagh, and then extending southwards, down to the river at Marwari. The necessity to understand the deformation signatures and the possible causative factor of the slow-moving slides of Joshimath is of utmost importance. The Joshimath slope mostly comprises of presumably, glacial debris of loose, angular to sub-angular rock masses of varying sizes, mixed with soil. A spatio-morphometric analysis of Joshimath was done using airborne LiDAR data acquired at the end of February, 2023. Slope, aspect, and curvature maps were prepared, and Land Use Land Cover (LULC) mapping was done for the years, 1993 and 2022. Morphometric data shows that several channels have carved the slope down to the river. However, they seem to diffuse on the slopes. The nalas have been obstructed by widespread constructions all along the slope, especially in the past few years as observed from the LULC maps. LiDAR slope map shows that a huge 47% of the region falls under 30-50º slope angle. Satellite data, and the aspect map from the analyzed LiDAR data shows that two distinct facets showing scars of past major landslides are present. All the acquired data show that the latest events are initiated just above the paleo-landslide scars, and follows the arc of the paleo-slide. This suggests that the crown of the slide has now started to extend upwards, and has initiated a slow slide of the town. However, the entire phenomena of the slides in Joshimath are attributed to several contributing and accelerating factors. The significant role of water, both surface and subsurface, the nalas with obstructed paths, affected by at least two major extreme events in the past ten years and a three-day persistent rainfall in October 2021, has been a major cause of the Joshimath episode. The lithographic units with at least one set of joint planes oriented along the slope also provides a sub-surface slide-plane. The proximity to the two thrusts, the Vaikrita and the Munsiari Thrusts, the topography with steep slopes, and most importantly anthropogenic activities and

domestic water seepage into the already loosened, saturated glacial mass debris have all contributed to the landslide in Joshimath.

Preliminary record of diatoms from Tuman, Korba, Chhattisgarh in Core Monsoon Zone (CMZ) of India

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The Korba district in Chhattisgarh is geologically composed of rocks and sediments ranging from Archaean to recent and is presently a recognized region in Core Monsoon Zone (CMZ). The trench is done in lake at Tuman (22°12'11.0" N, 82°46'45.8" E) of Korba district to study the palaeolimnology based on diatoms. In order to understand the palaeolimnology of the lake, a set of 30 sediment samples were processed and studied for diatoms to record the lake level changes. The fact that diatoms possess a siliceous framework and inhabit diverse aquatic settings, spanning freshwater bodies, oceans, soils, and virtually any moist environment, is now widely acknowledged. These microorganisms are characterized as non-motile, although they can exhibit limited mobility along surfaces by releasing a mucilaginous substance through a narrow groove termed a raphe. Due to their autotrophic nature, diatoms are confined to the sunlit or photic zone, extending to water depths of approximately 200 meters depending on water clarity. Within this context, both benthic (bottom-dwelling) and planktic (floating) variations of diatoms coexist. Their sizes vary between 20 to 200 microns in either diameter or length. Within India, the Core Monsoon Zone (CMZ) holds significant importance for comprehending historical Indian Summer Monsoon (ISM) dynamics. This region stands as a crucial vantage point for witnessing the augmentation of monsoon patterns across a broader expanse. The preliminary study carried in the lake site from Tuman aims to recognize the distribution of diatom with monsoonal vicissitudes in CMZ. The diatoms recorded from the lake site comprise *Navicula*, *Eunotia*, *Nitzschia*, *Pinnularia*, *Gomphonema*, *Achnanthes*, *Bacillaria*, *Sellaphora*, *Caloneis*, *Encyonema*, *Frustulia*, *Stauroneis*, *Gyrosigma*, *Ulnaria ulna*, *Neidium*, *Luticola*, *Amphora*, *Discostella*, *Craticula*, *Achnanthedium*, *Planothidium*, *Diploneis*, *Surirella* in varying proportions. The composition of diatom communities mirrors

the fluctuating degrees of lake level shifts, encompassing both natural and human-induced factors. Natural alterations can be directly linked to evolving monsoonal patterns, encompassing runoff and elemental fluctuations. On the other hand, anthropogenic influences are evident in contemporary and historical agricultural practices. This investigation thus delves into the evolving limnological dynamics, utilizing diatom productivity as a tool to uncover the interplay of climate-induced and human-driven transformations within the Tuman lake site of the Korba region in Chhattisgarh.

Glacial Lake Outburst Flood Risk Assessment of a Rapidly Expanding Glacial Lake in the Ladakh Region of Western Himalaya

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Glacial Lake Outburst Flood (GLOF) has emerged as a prominent cryospheric hazard globally as well as in the Himalayas owing to the warming climatic trends. Western Himalayas have witnessed numerous GLOF events in the past, predominantly from the moraine dammed proglacial lakes, leading to significant loss of life and property. This study provides an integrative analysis of the GLOF hazard potential of a potentially dangerous proglacial lake using multi criteria analysis (MCM) and hydrodynamic modelling techniques. The surface mass balance response of the mother glacier to warming climate, flow dynamics of the mother glacier and the glacier-lake interactions were analysed for the past 22 years. The results reveal that this PGDL, situated above Panikhar village in the Sankoo tehsil of Kargil district, has witnessed a marked expansion (78.7%) in the past 22 years coupled with a significant recession of 13.2 % in its mother glacier. The lake was categorized as a high hazard lake owing to its rapid expansion within a short period of time. The hydrodynamic modelling of the lake was also conducted using Hec-RAS to estimate the GLOF risk asssociated with the lake. A comprehensive and detailed investigation coupled with regular monitoring is recommended in order to evade potential disasters in future.

Fluid evolution and decarbonation processes of the calcareous metapelite from Higher Himalayan Crystalline across Baspa Valley

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The Himalayan mountain range, a prominent active collisional orogen, is an ideal candidate for producing substantial metamorphic CO2 that could potentially impact long-term climate dynamics. Understanding the type and rate of processes that produce CO2 during metamorphism in metacarbonate rocks is crucial for comprehending the nature and scale of the orogenic carbon dioxide (CO2) cycle. This study specifically delves into CO2 generation through garnet-forming reactions within calc-silicate rocks. The investigation involves analyzing phase equilibria in the MnO–Na2O–K2O–CaO–FeO–MgO–Al2O3–SiO2–TiO2–H2O–CO2 system to elucidate the prograde evolution of calcareous pelites within collisional orogenic settings. The bulk-rock compositions are employed to explore the influence of calcite proportions in the protolith on the equilibrium mineral assemblages under distinct pressure, temperature, and fluid composition (P–T–X(CO2)) conditions. The observed mineral assemblage (Garnet+Feldspar+Amphibole+Clinopyroxene+Biotite+Sphene) stable at X(CO2) ranges between 0.05-0.15. The results of the modelling are compatible with the final metamorphic assemblages observed in the studied sample. Petrographic descriptions and data related to selected CO2-producing reactions indicate that prevalent calc-silicate rocks have the potential to serve as significant sources of metamorphic CO2. The initial amount of calcite in the protolith regulates the CO2 productivity of calcic metapelites. If calcite is totally consumed during prograde metamorphism, as it is projected to happen in the majority of LHS and GHS lithologies, the CO2 productivity observed in the Baspa Valley is 4.96 wt% for starting calcite modal proportions of 11.80 vol.%. Primary CO2 fluid inclusions are observed in quartz, whereas quartz also carries most of the secondary fluid inclusions. The trapped fluids as primary inclusions are purely carbonic in nature and initial melting temperatures are in the range of -56.4 to -56.8°C.

Influence of morphotectonic and morphometric features on the distribution of landslides in Yamne Valley, Arunachal Pradesh

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Landslide, characterized by sudden and often destructive movement of earth material down a slope, is a major geo-hazard around the globe. A significant portion of India's land area, around 12.6%, is prone to landslides, with a high concentration in Himalaya, including the NE Himalaya. The consequences of landslides can be devasting, causing loss of lives, damaging property, disrupting transportation routes, and also a negative impact on the environment. Landslides are generally caused by the combinations of geological, geomorphological, climatic, tectonic, and anthropogenic factors. The present study encompasses an integrated approach to evaluating relative active tectonics using a combined approach of morphometric and morphotectonic analyses with the spatial distribution of landslides in the Yamne Valley, a tributary of Siang Valley, Arunachal Pradesh. The study area comprises a wide range of lithological units such as sandstone, slate, schist, gneiss, quartzite, granite, basalt, and andesite. These are categorized into four main tectonic zones: the Trans Himalaya, the Higher Himalaya Crystalline (HHC), the Lesser Himalaya Crystalline (LHC), and the Lesser Himalaya Sedimentary (LHS), demarcated from each other by Tidding Thrust, Main Central Thrust (MCT) and Bomdila Thrust. 13 tributaries Yamne river basins were demarcated and various morphometric parameters such as stream order, stream number, stream length, stream length ratio, bifurcation ratio, stream frequency, drainage density, form factor, circularity ratio, and relief ratio were calculated for each basin. Morphotectonic parameters such as stream length gradient index (SL), hypsometric integral (Hi), asymmetry factor (Af), valley width valley floor ratio (Vf), steepness index (Ksn), stream sinuosity (Ss) and basin shape index (Bs) were also derived for the study area. All the parameters were extracted from digital elevation model (DEM) data of 12,5m resolution using ArcGIS 10.3. An inventory of landslides has been prepared using high-resolution satellite images along with field visits. The correlation between the parameters and landslides was established, to interpret the role of active tectonic processes on landslides. The study demonstrates that the high values of Ksn and SL index and low values of Vf occur along the thrust zones indicating that the areas around the thrust are relatively tectonically active. The spatial distribution of landslides is also clustered around the thrust indicating the role of tectonic regime on the spatial distribution of landslides in the area.

Morphometry, valley configuration and river dynamics along the Satluj valley: Implication to the landscape-climate-tectonic interaction

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Active tectonic regions like the Himalaya's changing landforms are the result of interactions between exogenic and endogenic processes. The Himalaya act as a natural laboratory for understanding tectonics and climate coupling and their role in sculpting landforms during the Quaternary period. The complex climate-tectonic coupling in the evolution of landscapes requires morphometric and morphotectonic analysis. Geomorphic indices are now widely employed in tectonic-geomorphic studies and serve as an important tool for understanding the tectonic imprints in the river basin. The present study is focused on the identification of tectonic-morphic and climatic-induced coupled features along the Satluj Valley. The Satluj basin shows immature topography and geomorphic features, indicated by active erosional processes, high relief, deep gorges, and high channel gradient. The numerous active tectonic features like river knick-points, strath terraces, stream migration, evidence of river capture etc., are evident. To understand the causative factors, morphotectonic variables such as the Valley-Floor Width to Height ratio (Vf), Stream Length Gradient Index (SL Index), Chi-slope (χ), Steepness Index (Ksn), and Hypsometric Curves (HI) are determined. The field study exemplifies the presence of triangular facets, deep V-shaped valleys, and folded Quaternary sediments. The results of the geomorphometric indices together with the field investigation suggested the Satluj Valley is tectonically unstable. The formation of dammed palaeolakes, active and stabilized/destabilized landslides, strath terraces, offsetting of incised channels, cascading, vertical gorges, and tilting and folding of Quaternary sediments are some of the remarkable geomorphic expressions which provide significant insight into the ongoing tectonic activities in the region.

Zoning in spinel oxides and its significance to ophiolite chromite

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The study of chromite spinel (MCr_2O_4, M = Fe, Mg, Al, Zn, etc.) is crucially important in the mantle sections of ophiolite, which helps shed light on their petrogenetic origin and tectonic setting. Though Cr-bearing spinel minerals are common minor components of basic, ultrabasic, and metamorphic rocks of the crust and the upper mantle, for example, gabbros, peridotites, dunites, basalts, serpentinites, etc. The spinel group of minerals is known to be the best container of past chemical and structural entities and retained deep Earth's history. In view of this, the present study focuses on the spinel oxides of podiform chromitite, present in the ultramafic rock of Karzok Ophiolite, Himalaya Suture Zone. While performing the high-end microscopy, it is observed that the cores of the spinels in chromitites are optically zoned and tend to preserve their primary magmatic remnants. However, in a few places alteration processes seen preserved in the form of thin rims around spinel grains, which might be prone to modify the chemical composition of their external parts. To unveil the primary magmatic entities, in-situ low-energy Laser Raman spectroscopy has been employed in this study, laser Raman is anticipated to be a powerful technique for the characterization of materials in terrestrial and extra-terrestrial bodies. Raman spectroscopy can provide straightforward, unambiguous identification of major rock-forming minerals and help retrieve micron-scale information on structural and compositional variants of many mineralogical groups. Raman spectral features of spinel oxides of chromitite and some of their solid phases are studied. Although most Fe-Mg-Zn-Cr-oxides produce relatively weak Raman signals compared to the altered mineral phases, however, sufficient information has been extracted from their active modes, which helps identify the end-member mineral phases as well as some information about compositional variations in the solid solutions. The Raman spectra, the position, and shape of the strongest peak generated from the core of the spinel oxides in the region 660–700 cm^{-1} (major active modes) the most useful for discriminating Mg, Zn, Al substitutions in the chromite-spinel series, but minor peaks in the range 300–650 cm^{-1} also assist in discrimination. From one of the rock chips of spinel oxides, Raman peaks identify magnetite and other Fe-Cr spinel phases develop on the primary phases at the cores. These new phases usually form narrow alteration rims surrounding the primary Cr spinel core or develop along cracks. The most significant Raman peaks of Fe-Cr-rich chromite v/s Al-rich chromite presumably point to its original melt generation and may help envision the tectonic setup.

Distribution of Seismicity and stress level in Garhwal-Kumaun region of NW Himalaya, India and its seismotectonic implications

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The Garhwal-Kumaun region in NW Himalaya lies between two major rupture zone i.e. 1905 Kangra earthquake and 1934 Bihar-Nepal earthquake. A broad band seismic network is continuously recording the earthquake events in Garhwal and adjoining Shimla Hills region of Himachal Pradesh since 2007. The earthquake data has been analysed for seismicity distribution, stress level, source parameters and source mechanisms. The data analysis for more than 4500 local events (2007 to 2022) indicate that majority of earthquakes are occurring in a narrow zone, south of Main Central Thrust (MCT) in the magnitude range between 1.8 to 5.7 with focal depths of 12 to 25 km. It is observed that hypocentres of main shock and its aftershocks are primarily clustered in and around the ramp which is in close proximity of Main Central Thrust (MCT). There exist a good spatio-temporal-depth correlation between the estimated results (b-value, fractal dimension, stress drop) which indicates the positive anomaly at 12–14 km (stress transition) beneath the Chamoli region. Interestingly, this region shows maximum geodetic strain rate with comparatively high-stress drop, low coefficient friction value and very low b- (0.583 ± 0.02) and Dc- (1.20 ± 0.01) values. Majority of moderate to strong earthquakes and swarms activity have occurred in this region with maximum crustal accommodation. It is also observed that the significant temporal decrease in b-value always followed by moderate earthquakes. Here shallow crustal potential seismogenic asperity controls the earthquake's stress drop and rupture propagation. The observed correlations strongly support the evidence of entrapped fluid-faults interaction which alters pore pressure that can generate a future significant rupture in the region.

The Activity of the Kerguelen mantle plume and its role in the fragmentation of Eastern Gondwana. Insights from the Lower Cretaceous mafic magmatic rocks of the Sylhet Trap Northeast India

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Mantle plumes associated with the Large Igneous Provinces (LIPs) have been associated with the fragmentation of continents, validated by the outpouring of mafic-ultramafic magma spanning from extensive continental flood basalt magmatism to submarine plateau volcanic events. This study presents a new set of geochemical and mineralogical data of mafic magmatic rocks from the Sylhet Trap, Shillong plateau, northeast India. The mafic magmatic rocks that were investigated are mostly sub-alkaline tholeiitic affinity. Basalt shows glomeroporphyritic texture, and in dolerite dykes, plagioclase laths are partially or fully enclosed in clinopyroxene, giving rise to sub-ophitic and ophitic textures. Chemically and mineralogically, dolerite dykes closely resemble basalts. The plagioclase crystal with higher Ca (76.2-66.2) and lower Na (23.1-32.5) falls in the field between labradorite and bytownite, the clinopyroxene from the Dolerite dykes, shows its affinity towards diopside with corresponding values of wollastonite ($Wo_{44.2-54.8}$), enstatite ($En_{39.3-54.8}$) and ferrosilite ($Fs_{0-9.4}$). The mafic magmatic rocks of the Sylhet Trap exhibit enrichment in light rare earth elements (LREEs), as evidenced by $(La/Yb)_N$ ratios ranging from 1.92 to 2.86 and La/Sm ratios spanning from 1.11 to 1.40. Additionally, these rocks display a relatively flat distribution of heavy rare earth elements (HRREs), and mild Europium anomaly (Eu), characterized by (Eu/ Eu*) values ranging from 0.94 to 1.05. The trace element characteristics of these rocks indicate their similarity to enriched mid-oceanic basalt (E-MORB), suggesting that they are likely to originate from a low degree of partial melting of a source containing garnet peridotite. The resemblance in geochemical attributes among the magmatic occurrences within the Sylhet Trap on the southern flank of the Shillong Plateau, as well as the Rajmahal Trap of eastern Peninsular India and Abor Volcanics of eastern Himalaya. Their geochemical characteristics also resemble with the Bunbury Basalt of western Australia, and the Cona mafic rocks crop out in the southeastern Tibet of Tethyan Himalaya, implies a genetic linkage to the Kerguelen mantle plume. Thus, we considered that the magmatic event of the Sylhet Trap is related to the Kerguelen mantle plume activity that played a significant role in the fragmentation of eastern Gondwana, giving rise to Greater India, Antarctica and northwest Australia.

Geophysical imaging of a critical zone in the Uttarakhand Himalaya for bedrock architecture and regolith thickness

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The active Himalayan mountains exhibit steep slopes and dissected topography dominated by overall compressive tectonic forces. These mountains primarily have coarse-textured thin soil layer with low water-retaining capability and are highly prone to erosion. Soil erosion is primarily driven by factors such as heavy rainfall, deforestation, landslides, agricultural activities on slopes and ongoing tectonic processes. These activities not only impact downstream ecosystems but also have adverse effects on the critical zone (CZ), the interface where atmosphere, geosphere and biosphere are interacting. In this study, a DC electrical resistivity study has been conducted in the Pranmati critical zone of the Alaknanda basin, the Lesser Himalaya to comprehend the erosion pattern, sediment transport and depositional processes by characterizing the underlying bedrock and associated regolith. A total of six electrical resistivity tomogram profiles has been laid in the catchment at two locations, one at a flat grassland, while the other in a cultivated field situated on a steep hill slope > 25 ^{o}. The study area is a part of the Baijnath klippe, mainly consists of quartz-biotite gneisses with layers of quartz mica-schist enclosed by thrust faults. The 2-D electrical resistivity sections in the downslope grassland site show a sharp resistivity contrast along the southwest- and northeast transects suggesting south-eastern increase in dip of the bedrock, oblique to the north-east facing surface topography and a thick regolith (> 10 m). While, the resistivity sections in the crop field site, yield a very thin layer of regolith (< 2 m) indicating significant soil erosion. From the study, we propose the water–rock interaction facilitated by shallow-level subsurface water circulation that acts as a potential source for the weathering of the bedrock and hence thick regolith. These observations align with existing hypotheses proposed on evolution and development of deep critical zones and hypothesize that the bedrock architecture and water channel paths within the CZ together controls the regolith thickness.

Evaluating Ground Motion Models (GMMs) through classical residual analysis: Application to Himalayan region

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Within Probabilistic seismic hazard analysis (PSHA), the robustness of hazard estimates relies on reliable ground motion models (GMMs). Such models predict the level of ground shaking and associated aleatory uncertainty, given earthquake magnitude, distance, and site-condition information in terms of ground motion intensity measures (IMs). However, regions with moderate to high seismic activity (such as the Himalayas) but having limited recorded data poses a significant challenge for developing endemic GMMs. Thus, for carrying out PSHA in such regions often GMMs from other regions (such as California, Europe, and Japan) are employed. There are two major questions that need to be answered when adopting GMMs from other regions to the study region (i.e., the Himalayas). First, do such GMMs capture the observed scaling of ground-shaking with magnitude and distance in the region? Clearly, large epistemic uncertainty is involved in regions with less recorded data. Then the second question is how well such GMMs capture associated epistemic uncertainty. This study evaluates existing GMMs developed for the Himalayan region and employs a classical residual approach. Our evaluation utilizes recently compiled ground motion datasets which comprise 150 earthquake events generating 519 acceleration traces recorded over 190 stations for a moment magnitude range Mw 3–7.4, recorded at an epicentral distance range $R_{epi} \leq 300$ km. By comparing the existing developed GMMs for the Himalayas, it becomes apparent that significant biases exist within the existing models across different magnitude and distance ranges for peak ground acceleration (PGA) and spectral acceleration (SA). Moreover, the existing models rely on a limited number of earthquake records, with the applicability of these models restricted to limited magnitude and distance ranges. Similarly, the residual analysis underscores substantial magnitude and distance scaling biases (and differences) in the existing Himalayan models. This points to significant aleatory and epistemic uncertainties inherent in GMMs developed for the Himalayan region so far. Notable, the range of epistemic uncertainty is much more extensive that in globally adapted models employed in PSHA studies in India.

Early Cretaceous Intra-Oceanic Island Arc System in Eastern Neotethys: Evidence from Mafic Rocks in the Lohit Valley, Eastern Arunachal Pradesh, North Eastern India

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The geodynamic mechanism of the precollisional Early Cretaceous magmatic rocks in the eastern Trans-Himalayan terrane remains controversial. To constrain the petrogenesis and tectonic evolution of the Early Cretaceous Neo-Tethyan oceanic slab, we have undertaken zircon U–Pb dating, whole-rock major and trace element analyses of gabbros from the Lohit Plutonic Complex of the eastern Trans-Himalaya in Arunachal Pradesh. The zircon U–Pb dating yielded an Early Cretaceous crystallization age of 147.4 ± 3.0 Ma (MSWD = 0.64, 2σ). The Lohit gabbro is characterized by large-ion lithophile elements (e.g., Rb, Sr, and Ba) enrichment and depletion of high-field-strength elements (e.g., Nb, Zr, and Ti). The gabbros originated from the partial melting of a depleted mantle wedge that had reacted with slab-derived fluids, and the ascending magmas underwent fractional crystallization without significant crustal contamination. Combining our data with those from previous studies of Early Cretaceous magmatism in the Trans-Himalayan belt, we proposed a double subduction system in the eastern Neotethys Ocean during the late Jurassic to early Cretaceous (153-143Ma) and the Lohit gabbros were produced in intra-oceanic island arc setting during the northward subduction of the Neotethys oceanic slab.

The migration of Sino-Tibetans in to eastern Himalayas and societal changes in northeastern India associated with a 4000-year climatic record

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During the Holocene, human beings developed a settled lifestyle and built-up cultures and civilizations in various times and regions of the world under equable climate. Therefore, the study of palaeoclimate in Holocene is incomplete without understanding human-climate interrelationship and its linked reforms in society. Our study from a speleothem from Mawmluh cave, Meghalaya, northeastern India spanning from ~5.5 ka BP to ~1 ka BP shows weak Indian Summer Monsoon (ISM) precipitation during 4.25-4.04 kyr BP (4.2 kyr event) and strong ISM during 2.74-2.39 (Minoan Warm Period-Roman Warm Period) kyr BP and 1.44-0.96 kyr BP (Medieval Climatic Anomaly). Studies say that ~4.7 ka BP, Sino-Tibetan people migrated from Tibetan plateau to the eastern Himalayas as a response to arid conditions in Tibet. The Bodo

people of Assam owe their origin to the Sino-Tibetans. ~3ka BP the inhabitants of the Gangetic plains entered north-east India, close to the time of higher precipition observed in our study. Further during 1.3-1.0 ka BP, a number of important political advancements occurred in Assam and Bengal during a strong ISM phase. The powerful Pragjyotishpura and Salastambha kingdoms flourished in Assam and Bengal prospered under king Shashanka and the Pala rulers. Effects of North Atlantic ice rafting events, migration of Intertropical Convergence Zone, and solar cycles of 200-year (DeVries/Suess cycle), 70-year (Gleissberg cycle) and 5-6 year (half cycle of 11-year sunspot cycle) are reflected in the climatic variation.

Inter-tectonic relation among the Surin Mastgarh Anticline, Main Himalayan Thrust and Medlicott-Waida Thrust in NW Himalaya from Seismic Data

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The evolution of NW Himalayan foreland basin bears immense interest in comprehending geodynamics, geo-hazards related to seismicity and landslides, and geo-resources like hydrocarbons. The Surin-Mastgarh Anticline (SMA) and Medlicott-Wadia Thrust (MWT) are two main tectonic features on the surface, whereas the Main Himalayan Thrust (MHT) is the major sub-surface feature. We would like to establish a link between the subsurface features with the surface observations using 2D seismic data in the eastern flank of the SMA, procured from the oil industry. Seismic images and attributes including the interval velocity have been utilized to shed light on the evolution of the NW Himalayan foreland basin by defining the inter-tectonic relation among SMA, MWT and MHT. It is found that the SMA, which is widely reported as the detachment fold on the MHT, has a gap of ~1000ms between them. There is Blind Thrust (BT) sandwiched between the SMA and the MWT. The MHT is terminated towards south below the SMA at ~4700ms depth. Presence of Duplex-Thrust Complexes (DC) have been delineated on top of the MHT. Analysis of Seismic facies shows that the DC, BT and MWT are made up of Late Proterozoic formation. The study elucidates evolutionary processes of the SMA and emergence of MHT. This also explains how the Late Proterozoic formation of the Indian plate came out on top of the MHT to constitute the DC, BT and MWT.

Reconceptualizing the evolutionary history of the polygenetic melt in the ophiolites of the eastern Indian plate margin

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Ophiolites are fossilized remains of oceanic crust which are widely studied to understand the ancient subduction zones. On the eastern margin of the Indian ophiolite, this ancient oceanic crust are represented by the Neo-Tethyan ophiolite of Tidding-Mayodia Ophiolites (TMO), Nagaland Ophiolite Complex (NOC), and the Andaman-Nicobar Ophiolites (ANO). It is widely assumed that the ophiolites of the eastern Indian plate (TMO, NMO, ANO), presently align in north to south position, are of the same forearc sytem and formed at the same subduction zone. The magma source and tectonic setting of mafic rocks from these ophiolites have been contributed to OIB, SSZ, and MORB types, with the addition of Back-arc setting in ANO. However the presence of polygenetic geochemical signatures in the mafic rocks of NMO and TMO does not fit well with the tectonic scenario of a single subduction zone. The mafic rocks of eastern Indian ophiolite shows a sub-alkaline character with Nb/Y < 0.40, low Nb/Th and low to moderate La/Sm indicating derivation from a slightly enriched mantle source (Mid-Oceanic Ridge Basalt). This is supported by their enriched LREE pattern with flat HREE $(La/Yb)_N$ = 1.54 TMO; 1.6 ANO; 1.72 NOC, and higher TiO_2 abundances (average TiO_2=1.2 TMO; 1.11 ANO; 1.21 NOC). However, they are depleted in HFSEs (Nb) and enriched in U and Pb, indicative of typical subduction origin. This polygenetic magma source of the studied samples shows its derivation from 15-30% partial melting of a depleted mantle source of spinel-peridotite facies. Recent geodynamic and paleogeographic reconstruction have suggested that the ANO might have formed in a back arc basin behind an intra oceanic arc, followed by subsequent subduction initiation to produce the metamorphic sole of ANO. For this reason, we align the new and existing geochemical and geochronological data of NOC and TMO with ANO to deduce its evolution and formation. We identify that the geochemical signatures of the eastern Indian ophiolite are comparable, and the literature geochronology data of 145 Ma from NOC basalt and Chert fit well into the evolution of the intra oceanic arc i.e. Incertus-woyla arc. Previous Paleomagentic and geochronology studies have suggested that the development of the Back arc basin behind the Incertus-woyla arc was a result of divergent double subduction. Therefore it is possible that the NOC, TMO and ANO mafic rocks might

have developed in a back-arc setting behind the intra oceanic arc, activated by the southwest subduction of Neo-tethyan plate.

Strain and kinematic vorticity analyses using mudball of the Imphal Valley, a transtensional basin in the Indo-Myanmar Range of NE India

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The current study employs a quantitative approach to assess natural strain characteristics, and kinematic vorticity number in the rocks of Imphal Valley, a transtentional or pull-apart basin formed during the later stages of Indo-Myanmar Range (IMR) tectonogenesis, influenced by dextral shearing along pre-existing thrust planes, resulting in a thinned-skin, cold basin confined within the IMR's sedimentary cover. The attitude of the most bedding plane is NNE, and SSW. Well-developed foliation (cleavage) planes, which also represent the X-Y plane of the strain ellipse, develop well in this region. Again, direction of X-axes of the strain ellipse of the mud ball is 4˚/N025˚. Measurements on deformed mud balls were made in the outcrops, which exhibit elliptical shapes. Maximum, intermediate, and minimum lengths of the axes were also recorded. Subsequently, their aspect ratios were and plotted in the form of Flinn diagram and Hsu diagram. From the plots, the value of k was found to be 0.78 which lies in the S-tectonite domain showing oblate shape, and their X-direction directions align with the NNE regional trend of the IMR. Such orientation is compatible with extension in the NNE-SSW (N-S) direction and compression along the WNW-ESE (E-W) direction of the IMR.

The mean kinematic vorticity number (Wm) is found to be nearly 0.34, implying a notable prevalence of pure shear (66%) and simple shear (34%). This finding suggests a distinctive deformation pattern within the region, where the effects of pure shear play a more dominant role compared to simple shear in the middle portion of the Imphal Valley.

Understanding the Effect of Discontinuities on the Slope Instability: A Manifold Approach

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Slope failures are frequent and widespread geomorphological and one of the hazardous natural phenomenon that threatens human life and property. Every year a number of persons lost their lives due to the landslides or slope failure. A World Bank report presents the following profile of world-wide exposure to landslide hazard issues: (i) Land area of the globe exposed to landslides: 3.7 million km^2, (ii) Population exposed: 300 million, or 5% of the world population, (iii) Land area identified as high risk zones: 820,000 km^2, (iv) Population living in high risk areas: 66 million people. The average estimated annual costs of the landslides in India is approximately 1.3 billion USD. Therefore, a better and qualitative understanding about landslide is very essential for adopting mitigation strategies for this type of natural hazards. The information on landslides from different climatic and geological setup are very essential for better understanding of the influence of weathering, rainfall, or topography on slope failure. There are varying conditions that lead to their emergence in different regions. The constructions and widening of the highways are accelerating landslides due to steepening and removal toe support of slope. The factors involved in slope failure are the angle of the slope, the lithology of the bedrock, the topography, the type of vegetation, and also the construction process of the road. In this work, a slope stability analysis was carried out in and around the Manali area at selected locations, considering some important parameters to its probable roles of geo-factors that induces slope failure. It has been observed recently in this region that there have been landslides causing more casualties and damages. The jointed rocks, highly weathered rock mass and unconsolidated overburden material of the studied locations were analysed after undertaking both field and laboratory studies. The Rock mass classification and slope mass classification systems are frequently used as the basics for evaluating slope stability conditions and further stability analysis and calculations provided factor of safety. The variability of parameters and their effects on stability of the natural slope has been studied incorporating the conventional stability analysis. The study also includes the need for reliable studies to identify the different causative factors that may contribute to the development and mitigation of slope failures.

New micromammal fossil assemblages from the Dunera, Punjab, India and its biostratigraphic implications

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The Dunera locality of the Siwalik Group in the Pathankot district of Punjab, India is known for a few megavertebrate fossils, but no microvertebrate fossils have yet been reported. The locality was tentatively assessed as equivalent in geological age to the classic Chinji (middle Miocene) or Nagri formations (late Miocene) on the Potwar Plateau of Pakistan based on the few collected macromammal taxa including *Dorcatherium* sp., *Giraffokeryx* sp. and an indeterminate bovid. However, the precise age of the fossil locality is not known due to the lack of age-diagnostic fossils. Recently, diverse microvertebrate isolated teeth have been recovered from the same locality and horizon. The rodent materials are identified as Murinae indet. (*Progonomys hussaini*), the ctenodactylid (*Sayimys sivalensis*), the cricetid (*Democricetodon fejfari)*, and the sciurid (cf. *Tamias urialis*). Apart from chronologically informative rodents, a few lizard fossils such as Acrodonta (cf. *Uromastyx*, Agamidae indet.), Scincoidea (Scincidae indet.); fishes such as Cypriniformes (Cyprinidae indet.), Perciformes indet.; crab (Decapoda, *Sartoriana* indet.) are also recovered. These microvertebrate specimens are discovered for the first time in this region. Micromammals, specifically rodents, play a significant role in establishing high-resolution biostratigraphy of the Siwalik Group. Based on the biostratigraphic ranges of these rodents from well-dated localities in the Siwaliks of Pakistan along with previously collected magnetostratigraphic data, Dunera locality best correlates to between ~11-10 Ma (early Late Miocene), approximately equivalent to the lower half of the Nagri Formation.

Characteristics of podiform chromite of the Naga Ophiolite belt in Phek district of Nagaland

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The Naga Ophiolite Belt, which occurs as a narrow arcuate body along the Indo-Myanmar border, trends in a NE-SW direction and lies between the Nimi Formation in the east and the Disang Group in the west. This belt consists of a variety of magmatic, metamorphic and sedimentary rocks of Mesozoic and Cenozoic age that originated at the convergence of the Indo-Myanmar plate boundary. The ophiolite rocks in Phek district in Nagaland is characterized by tectonized to massive serpentinized peridotite, dunite, pyroxenite and volcanic rocks along with primary ore mineralization of chromite (chromitite), nickeliferous magnetite and sulphides. The occurrences of chromite in the ophiolite rocks of Nagaland is mainly found in Phek district, and are characterized by massive (chromitite), granular, nodular and disseminated types. Massive type chromitite are compact, fine to medium-grained with very small amount of serpentine gangue whereas granular type is of coarse-grained. Nodular type exhibit elliptical clots of chromite completely surrounded by serpentine or in close contact with each other. In disseminated type, chromite grains are distributed in a matrix of serpentine groundmass of ultramafic host rocks, as small, disseminated grains. Under reflected light, intense brecciation and fracturing are common features of chromite grains where their interstices and intergranular spaces are filled with silicates. Pull-apart textures are also prominently exhibited in the disseminated grains, where the interspaces are filled with altered silicates mostly serpentine, which indicate shearing or volume expansion during serpentinization.

Possible surface rupture of a 18th century earthquake along a Backthrust in the eastern Himalaya, India

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Segmentation model is challenged in terms of surface rupture propagation of great earthquakes because of the lack of pre-historic earthquake data on either side of a transverse fault. To check this hypothesis, a pop-up Ultapani anticline (UA) lies between the Kopili and Dhubri Chungthang transverse faults, was studied at the Ultapani, outboard of the Bhutanese range front in the State of Assam, India. The systematic logging and sampling across the UA gave ages ranging from 1436 BCE to 1953 CE. The results advocate that the fold growth across the

Ultapani anticline initiated since ~1436-1131 BCE, with the youngest event dating post ~240-509 CE, possibly related to the 1714 CE earthquake. The results shows a maximum uplift rate of 8.2±0.1 mm/yr at the vicinity of the Ultapani anticline in the last ~3000 years, agreement with the previously reported rate at the nearby sites in the Bhutan foothills. Using Kanamori equations and comparing the results of the present study with adjoining regions a minimum seismic quiescence of ~306 years remains, which is capable of generating a magnitude ~8.0 Mw in the region.

A review on the mechanisms of Gneissic Dome Formation in the Himalaya

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The process of gneissic dome formation is a first-order thermo-tectonic process that is ongoing on Earth since pre-Cambrian. These domes are created through complex processes such as diapirism, folding and Faulting. The gneissic domes in the Himalayas have evolved due to the thickening of the crust caused by the continued convergence of Indian Plate in to the Eurasian Plate. The crustal thickening results deformation, metamorphism, partial melting due to the dehydration reaction, and the ascent of partial melt through the isothermal decompression process which are most common characteristic features of these domes. In this review, we discuss all the possible models such as channel flow, tectonic wedging, and wedge extrusion which can explain the transfer of the partial melt to the surface, within the core of the gneissic domes of the Himalayan orogen. The partial melt of the gneissic domes characterizing the presence of migmatitic core are generally mantled with the low-grade rock metamorphic rocks. These gneissic domes are formed at mid-crustal depths of ~20-30 km. The Himalayan gneissic domes divided into two types: Type-1 and Type-2, based on their formation mechanism. Type-1 domes characterize orogen-parallel extension and were formed during Middle Miocene, while Type-2 shows orogen-perpendicular extension formed during the late Miocene. We compiled all the published geochronological and thermochronological data from all the prevailing domes in the Himalaya and carried out 3D thermo-kinematic modeling using Pecube to understand the paths of the high-grade rocks of these domes to surface. Our analysis suggest that crustal channel-flow is the major mechanism for the ascent of the partial melt to the surface during the Middle-Miocene. The ductile flow of rocks is followed by the late-stage orogenic-

scale extension along all the gneissic domes of the Himalayan which suggest the extensional-collapse of the Himalayan orogen in the Late-Miocene.

Mineralogical study of lamprophyres of Garo Hills District: their geological significance

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The different types of granitoid of Meghalaya massif, Northeast India, are widely studied, but studies on the mafic intrusive dikes are lacking. Small lamprophyre intrusives intrude the granitoid host rocks along the N-S trending Nongchram Fault, East Garo Hill District, Meghalaya. Petrographically the rock shows porphyritic to panidiomorphic textures. Clinopyroxene and amphibole are present as large heterogenous macro-crystals (~2mm). Common accessory minerals are apatite, pyrite, chlorite, rutile, titanite, etc. The mineral chemistry of clinopyroxene is diopside, and amphibole is magnesio-hastingsite. Mica shows compositional variation ranging from phlogopite to biotite, and the equilibrium pressure and temperature range from 4 to 12 kbar and 1180 to 1350°C, respectively. Normal and reverse zoning in cpx and the elemental variation in amphibole signifies the episodic intermixing of melt uprising from the magma chamber.

Estimating earthquake potential of the Eastern Himalaya and its environs: insights from paleoseismology

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The frequent earthquakes in the Indian Sub-continent are caused by the ongoing collision of the Indian and Eurasian plates. Unfortunately, these events have caused significant destruction, resulting in massive loss of life and infrastructure. For example, one of the largest ever recorded continental earthquakes, the 1950 Assam earthquake with a magnitude of Mw 8.7 ruptured an area ~30,000 sq km and the 2005 Kashmir earthquake with a magnitude of Mw 7.6 claimed the lives of over 80,000 people. In the Himalayas, the release of accumulated interseismic strain

along the basal decollement, i.e., Main Himalayan Thrust, during the great earthquake (Mw>8) events causes surface rupture along the frontal thrust(s). However, the extent and termination of these great events remain a topic of debate. It is also uncertain whether such events are confined within topographic barriers or if they can surpass such boundaries, causing earthquakes ≥9 Mw. Based on the segmentation hypothesis of the Himalayas proposed from sub-surface geometric anomalies, transverse faults, gravity anomalies, seismic data and interseismic coupling, we have divided the Eastern Himalayas into four segments: Darjeeling-Sikkim Himalayas, Bhutan, Arunachal-Assam and Mishmi Himalaya. We have combined all the historical and paleoseismic published data to prepare a catalogue of possible great surface rupturing earthquakes in the Eastern Indian Sub-Continent. Further we have derived the earthquake potential of different segements of the Eastern Himalaya using moment magnitude equation of Hanks and Kanamori (1979). The magnitudes were inferred based on the timing of last surface rupturing earthquake and the geodetic convergence rates. Our inferences suggest that all the segments of Eastern Himalaya can accommodate an Mw>8 earthquake. As there exists a recurrence interval of 500-1900 years for different segments of Eastern Himalaya, these segments can uphold a 500+ years of interseismic strain accumulation period reducing the seismic hazard from a great earthquake. Nevertheless, in the Darjeeling-Sikkim and western Arunachal segments there hasn't been a great earthquake for >500 years and hence these regions have a high seismic hazard susceptibility.

Low-Cr and high-Al spinels do not always form in abyssal peridotite: An example from the Nidar Ophiolite, Ladakh, India

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The composition of Cr-spinel in mantle peridotite from an ophiolite belt has been widely used to decipher melt-/fluid-rock interaction, degrees of melt extraction and tectonic setting. However, co-occurrence of spinel with low Cr# [Cr#=Cr/(Cr+Al)], affinity to mid-oceanic ridge (MOR) setting, and high Cr#, a characteristic of supra subduction zone (SSZ) setting, are commonly reported in different samples of the same ophiolite belt worldwide. This duality of spinel composition has been interpreted to form either in different tectonic settings or

interaction of fluid/melt in SSZ setting. Similar spinel compositions are also found in the Nidar ophiolite, Ladakh, India, which represents part of the eastern Tethys regime. In this study, we explore the mechanism that causes this duality of the spinel compositions by employing field evidence, petrography and in situ major elements concentrations in the spinels of serpentinised peridotite from the Nidar ophiolite, Ladakh, India. The studied peridotites are characterized by cumulate peridotite and serpentinite which are found in association with clear litho-contact in the field. The spinels in cumulate have low Cr# (<0.6; 0.26-0.27) which were earlier interpreted to be originated in MOR setting, whereas that of the serpentinites show high Cr# (>0.6; 0.78-0.8) that were suggested to form in SSZ setting. In addition, the spinels with high Cr# (>0.6) are plotted in the field of podiform chromite and boninite interaction trends in contrast to the spinels with low Cr# (<0.6) which cluster towards the field of cumulate and MOR. Interestingly, the calculated parental melt compositions for both the spinels (i.e., low Cr# and high Cr#) are plotted in arc trend in the TiO_2-melt vs TiO_2-spinel plot. Such geochemical feature can be explained by the following: 1) the residual solid left after the larger melts extraction from the mantle wedge peridotite could represent the spinel with high Cr# in serpentinite, 2) the cumulate peridotite with low Cr-spinel could have formed from the extracted fore-arc/arc melts in the MOHO. We therefore, propose that the MOR-like and SSZ-like spinels in the studied peridotites from the Nidar ophiolite have originated from the same source in SSZ setting without invoking different tectonic settings. We also suggest that Cr# in spinels should not directly be used to interpret the tectonic setting of their peridotites without distinguishing residual and cumulate peridotite.

Mineral chemistry and redox condition of Lohit Valley, Arunachal Pradesh

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The Lohit Valley (LV) which is a part of the Lohit Plutonic Complex (LPC) of Arunachal Trans-Himalaya represents the northeast extension of Trans-Himalayan magmatic arc system located in the north of Indus Tsangpo Suture Zone (ITSZ). It is represented by early phase felsic magmatism of quartz diorite, granodiorite, trondhjemite. In order to assess the physico-chemical conditions, nature and tectono-magmatic evolution of LV magmas, a detailed study

on mineral phase chemistry of amphibole, biotite and plagioclase was carried out. The amphiboles from studied granitoids are calcic (Ca_B>1.5, Si = 6.30 to 6.89 apfu) and exhibit edenite-tschermakite substitutions typical to their evolution in metaluminous (I-type) calc alkaline magmas. Al-in-hornblende rims estimate emplacement of quartz diorite and granodiorite magmas at middle (ca 5 km) and deeper (ca 16 km) crustal depths respectively. Hornblende-plagioclase thermometer points to amphibole crystallization (799-628°C for quartz diorite; 790-696°C for granodiorite) near solidus which continued to cool under subsolidus regime. Biotites of LPC granitoids are transitional between magnesio- and ferri-biotites and represent primary, re-equilibrated primary biotites. The oxidizing or reducing nature of the magmatic environment based on Fe# (Fe/Fe+Mg) and Mg# ($Mg/Mg+Fe^t$) ratios of biotite and amphibole of the quartz diorite and granodiorite suggest moderately to strongly oxidized nature. Quartz diorite and granodiorite biotites evolved under oxidizing magma (log f_{O2}^{-13} to log f_{O2}^{-12}) in a temperature range of ca 750-950ºC, typical to its formation in calc-alkaline magma of subduction settings.

A geochemical study of coal seam from Sohagpur coal field and its implications for paleo-climate estimation

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Coal is an organo-clastic sedimentary rock. Most of the Indian coals are associated with Gondwana supergroup, deposited within the Permian rift basins, currently located in the northeastern part of Indian peninsula. Sohagpur coal field is one such prominent coal field, located within the Son river valley. The aim of the present study is to decipher the paleo climatic condition of Sohagpur coal field. Vegetal matter accumulated in oxygen-deprived swamps underwent partial decomposition to form peat, which later transformed into coal due to heat and pressure. The composition of clastic materials found in coal provides insights into the provenance and paleoclimate. In this study, Sohagpur coalfield's coal samples (eight pillar coal samples, T1 to T8) were analyzed to decode the paleoclimatic conditions during their deposition using geochemical proxies. Chemical Index of Alteration [CIA = Al2O3 / (Al2O3 + CaO + Na2O + K2O)], and Detrital to Authigenic Index [DIA = (SiO2+Al2O3+K2O+TiO2+Na2O) / (Fe2O3+CaO+SO3+MgO)], were calculated from X-Ray

Fluorescence (XRF) data to assess chemical weathering intensity and sensitivity to land surface temperature. The CIA value between 50-60 shows low chemical weathering (relative cool and/or arid climate), 60-80 indicates moderate chemical weathering (moderate temperature and semi-arid to semi humid climate) and 80-100 suggests intense chemical weathering (hot and humid climate). The results (between T8 to T2) show that the climate was hot and humid at the time of accumulation of vegetal matter in the swamps and just before the closer the peat generation episode, the climate started becoming relatively cooler and drier. The DAI value (ranging from 2.8 to 6.23) suggests fluctuating paleo-precipitation, with higher values indicating an allochthonous origin and lower values representing an autochthonous origin of the rock governed by paleo-precipitation. Overall, the study suggests a hot and humid climate with precipitation fluctuations during vegetal matter and inorganic sediment accumulation in the peat swamp, transitioning to a cooler and drier climate at the end of the peat swamp period.

Neotectonic activity along The Belt of Schuppen, in and around Niuland district, Nagaland, India: Insights from GIS-based morphometric analysis

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The NNE-SSW-trending imbricate thrust system of the Belt of Schuppen (BoS) follows the regional trend of the compressional strain developed due to the subduction of the Indian Plate below the Burma microplate. This has led to the development of WNW-ESE-trending normal faults, causing deformation of Quaternary sediments in parts of the Indo-Myanmar Ranges. Continuing tectonism has thus left its imprint on the rocks of the region. The westernmost unit of the BoS, the frontal Naga Thrust, is a narrow, elongated zone of imbricate thrusts, which extends about 200 km. Major lineaments trends parallel to the NE-SW regional thrust while some are perpendicular and oblique. The study area, situated in the western part of the BoS, is divided into four sub-basins. This region is tectonically disturbed and hence, the rocks are folded, jointed, faulted, thrusted, fractured, and sheared to great extents. The drainage pattern within the BoS is generally trellis to parallel, but is occasionally dendritic in the plains adjoining the hills. Up to 4^{th} order streams are observed in the study area. Morphometric analyses have been performed to investigate tectonic activity in the study area. The results indicate high channel sinuosity and low drainage density. Asymmetric factor (AF) values

indicate tilting of all the sub-basins. Low to moderate stream frequency is indicated. The stream length gradient index and steepness index display several spikes along the Dzüdza river profile; the knick-points indicate tectonic activity in the area. The study area consists of multiple strath terraces, ST1 at 221 m asl, ST2 at 224 m asl, ST3 at 227 m asl and ST4 at 255 m asl of the Dzüdza river. Tilted deposits of sand lens, pebbles and cobbles, bedrock with slickenside, fractures, and deformed sediments of the terrace deposits suggest that the area is tectonically active.

GLOF Risk Assessment using hydrodynamic modeling: A case study of Ladakh region

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Glacial lake outburst flooding (GLOF' s) are becoming a grave concern to the mountainous communities living in the various parts of the world due to the ongoing global warming and glacier mass loss. In the Indian Himalayan region, most of the past GLOF events (90%) have been witnessed in the Ladakh region, however less attention in terms of research has been paid so far in comparison to the other glacier and glacial lake bearing states of India. Recently, in 2014 a GLOF event occurred in the upstream region of Gaya village resulted into huge destruction of property and agricultural. Keeping, in view the high hazard level of the Gaya glacial lake particularly its rapid expansion, we have analysed the recent changes in the lake and associated glacier using high resolution satellite data. GLOF hazard assessment of the lake was assessed using the recent volume estimates (2022) calculated through the improved are-volume scale equation. Multiple hydrodynamic simulations were performed using HEC-RAS model for various scenarios with varied lake volume, breach width (bw) and breach formation time (bf). In the worst-case scenario, breach hydrograph with 75% of lake volume, 40 minutes of bf and 40 m bw was considered for GLOF routing through the channel up to the Gaya village. The depth of the Gaya glacier and bed over-deepening's were estimated using GlabTop (Glacier bed Topography) version-2 and consequently future lake sites were identified. Velocity of the glacier was also modelled through the Cosi-Corr software. Furthermore, geodetic mass balance of the glacier was also derived using DEM data for the years 2000 to 2020. The

potential GLOF impacts on the downstream area including various landuse classes were also evaluated by overlaying the final inundation map on the LULC map generated for the area. The results derived from these methods may help the decision makers to formulate the strategies to mitigate and reduce the risk associated with lake. We further recommend to carry out in-depth field-based studies to analyse the in-situ mass balance of the Gaya glacier and to investigate the geophysical and geotechnical properties of the moraine-dam which is holding the rapidly expanding volume of the Gaya Lake.

The correlation of morphometric and geomorphic parameters with the spatial distribution of landslides in Darma valley, Kumaun Himalaya

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A landslide is a downward and outward movement of slope-forming materials (rocks, soil, debris) due to the gravitational force that is occurring in most of the tectonically active mountains around the world. Numerous geological, geomorphological, hydrological, and anthropogenic factors cause landslides in an area. Amongst these, active tectonics play a major role in causing landslides in active mountain chains like the Himalayas. In this study, we aim to quantify the relationship between the spatial distribution of landslide occurrences and the tectonic regime of the Darma Valley of Kumaun Himalaya. The study area is located between longitudes 80°18′31″E &80°36′00″E and latitudes 30°31′15″N &29°57′20″N and covers a stretch of ~ 90 km along the Darma River between the Nasha Bugyal in the north and Tawaghat in the south. The area comprises various lithounits like phyllite, quartzite, schist, and gneiss and grouped into Tethyan Sequence (TS), Higher Himalaya Crystalline (HHC), and Lesser Himalaya Crystalline (LHC) and separated from one another by South Tibetan Detachment system (STDS) and Vaikrita Thrust (VT), respectively. An inventory of 256 landslides has been prepared by using high-resolution satellite images and field visits. In order to understand the active tectonics in the area, the morphometric indices have been measured at an interval of 300m along the Darma River; thus, a total of 300 measurements were made. These morphometric indices are the stream length gradient index (SL index), longitudinal profile, and the ratio of valley floor width to valley height ratio (V_f). Along with this, 15 geomorphic parameters of fifty-six fourth-order sub-basins were also extracted to prepare the erosion potential map of the area and correlate it with the spatial distribution of landslides. The high

values of the SL index and low values of Vf along Vaikrita Thrust and between Urthing in the south and Nagling in the north, with high to very high values of erosion potential in the vicinity of Vaikrita Thrust, indicate that the area around this thrust is relatively tectonically active. The elongated basins on the western side of the Darma River contribute to the presence of high to very high erosion potential values in that area. The spatial distribution of landslides is also clustered around this thrust and between Urthing and Nagling, indicating the role of the tectonic regime on the spatial distribution of landslides in the area.

A study on Palaeogene coal-bearing sediments from the Meghalaya, NE India: Implications on their source and depositional environment

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The Palaeogene coals of Meghalaya represent the primitive rainforest elements and one of the principal source rocks of the Assam Basin.The Palaeogene coal-bearing sediments from the Tura Formation, Meghalaya have been studied to uncover their source, depositional environment, and diagenetic and thermal alteration of biomolecules in terrestrial lipids. These coals-bearing terrestrial elements are mainly derived from the Bombacaceae and Arecaceae families of angiosperms, Araucariaceae family of gymnosperms, and pteridophytes of Osmundaceae and Schizaeaceae families, which are revealed by palynological and biomarker records. The late diagenetic to early catagenetic stage represents the thermal maturity of the coal in this area. The transformation of higher plant triterpenoids from parent lipid macromolecules is assigned to early diagenetic microbial changes in terrestrial environments and subsequent coalification. Furthermore, the palynofloras and stable carbon isotope results indicate that the Tura Formation was deposited in a marginal marine environment within tropical-subtropical latitudes, in humid and warm climatic conditions during the late Palaeocene-early Eocene.

Spatial variations in exhumation along the strike of the Karakoram Fault Zone, NW India: New constraints from zircon and apatite fission track thermochronology

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New zircon fission track (ZFT) and apatite fission track (AFT) thermochronological study has been carried out in the Nubra Valley region of SE Karakoram, India. The ZFT ages range from 8.7±0.7 to 11.3±0.6 Ma, and AFT ages range from 3.8±0.5 to 6.9±1.1 Ma. The calculated exhumation rates using ZFT ages vary from ~0.52 to 0.63 mm yr^{-1} during middle-late Miocene. and for AFT ages from ~0.58 to 0.65 mm yr^{-1} during late Mio-Pliocene. These rates are more than double as compared to that of Ladakh Batholith (LB) to the south and resemble the adjacent Karakoram Transpression Zone (KTZ) and Karakoram Batholith (KB) in the north. In the Nubra Valley, the deformation related to Karakoram Fault (KF) is moderate as compared to that of KTZ. The stretching lineations in the Nubra strand are subhorizontal; the transpression zone of the KF exhibits stretching lineations dipping at angles of up to ~40° SE-NW.Structural data along with the continuous decreasing trend of AFT ages from south to north in the Ladakh range and towards the KB, suggest the minimal or negligible role of local tectonics and point towards the regional tectonic or climatic control on the exhumation of this zone. Unlike the AFT ages, the ZFT ages show no systematic pattern from south to north. In the Nubra valley, the leucogranites have zircon U-Pb age of ~16-12 Ma. Young (~13-12 Ma) leucogranite show cross-cutting relationship with the foliation planes of the host rocks, old (~16 Ma) leucogranite has a fabric parallel to the foliation plane suggesting Early Miocene activity along the KF. There are evidences of south-directed thrusting of the Karakoram terrane over the northern Ladakh batholith during the middle-late Miocene (~12 Ma) in this zone, which also played the role in the exhumation of the rocks along the SSZ. In the Nubra Valley, the evidence of mantle-derived $^{3}He/^{4}He$ ratios of geothermal springs along the KF that are absent to the south of the KF within the Ladakh range suggests the role of the mantle related fluid in this zone. We suggest that the delamination induced high uplift during the early Miocene triggered early phase exhumation which later facilitated by south-directed thrusting of the Karakoram terrane over the northern Ladakh batholith during the middle-late Miocene (~12 Ma) in the Nubra valley. The discontinuous pattern in the ZFT ages denies the role of continuous post-India-Asia crustal thickening. The continuous increase in AFT exhumation rates during the late Mio-Pliocene suggests the role of the underthrusting of the Indian Plate below Karakoram.

Study of co seismic and post seismic deformation associated with the 2019 Mirpur earthquake using InSAR measurements

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An earthquake occurred near the Mirpur city of the Kashmir Himalaya on 2019 September 24 caused widespread damage including 34 deaths. Analysis of Interferometric Synthetic Aperture Radar (InSAR) data reveals coseismic and postseismic surface displacements associated with 2019 Mirpur earthquake, the largest instrumentally recorded event near the Main Frontal Thrust (MFT) in the North West Himalaya. Bayesian inversion of Coseismic InSAR data suggests that the earthquake ruptured a shallow (Depth ~ 5 km), near-horizontal (Dip~2.5°) up-dip portion of the décollement of the Main Himalayan Thrust (MHT). The distributed slip model predicts a compact rupture terminating the up-dip end at the base of the MFT with higher slip (> 0.4 m) around the hypocentre, equivalent to a moment magnitude of Mw = 6. We estimate a low effective coefficient of friction of 0.06 ± 0.02 from the slip model and suggest that high pore fluid pressures and/or a weak, lubricated portion of décollement could have caused a local, near-horizontal rupture at the base of the MFT. The 2019 Mirpur earthquake released a small fraction of the accumulated strain energy since the 1555 Kashmir earthquake. Coseismic Coulomb stress change analysis suggests a significant increase in stress on the locked, up-dip portion of the MHT and the frontal fold-thrust system. We build surface displacement time series from Sentinel-1 SAR data, enabling the estimation of postseismic deformation from the 2019 Mirpur earthquake. The displacement map generated from the interferogram stack suggests a positive LOS deformation of about ∼2 cm over six months towards the south of the earthquake rupture zone. It is challenging to separate post-seismic deformation of moderate-to-small earthquakes from the noise due to atmospheric phase delays. Our study emphasizes the need for having high resolution atmospheric models for retrieving subtle deformation signals caused by post-seismic processes.

Palaeoclimate and depositional environment of the Barail shale of Jouzangtek area, Tamenglong, Manipur (India)

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The present study attempts to understand the palaeoclimate and depositional environment of the Barail successions of the Jouzangtek area, the western part of Imphal Valley in Manipur. The presentation is based on the palynology, mineral composition and trace elements of the outcrop Barail shales. The palynotaxa present in the study area, such as *Hammenisporis multicostatus, Hamme-nisporis* sp., *Hammenisporis susassae,* cf. *Cyathidies minor, Monolites sp., Pinuspollenites crestus and Todisporites major indicates that the deposition environment of the* collected samples be a freshwater environment with tropical to subtropical conditions during an episode of the sedimentation. Based on XRD analysis, the occurrence of clay minerals viz., kaolinite, illite, and chlorite in all the XRD-analyzed samples supports the above palaeoecological conditions. The cross plot of redox indices of V/ (V + Ni) versus Ni/Co suggests that the study area was formed under dysoxic to anoxic environmental conditions. The Sr/Ba (0.28-0.46), Sr/Cu (1.47-2.90) and Rb/Sr (1.06-1.90) ratios of the study shale indicate the warm humid climatic condition during the deposition.

Geothermal Manifestation and Tectonic Interplay: Investigating Hot Springs and Out-of-Sequence Thrust Faults in Himachal Pradesh, India

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The presence of hot springs has long been of scientific and cultural interest, with Himachal Pradesh, India, standing out as a region renowned for its geothermal resources and picturesque

landscapes, attracting attention from Scientist, Researchers, Geologists, and tourists alike. This study presents an overview of a comprehensive study that delves into the intriguing coexistence of hot springs and out-of-sequence thrust (OOST) faults in this Himachal Pradesh region. The main objective of this study was to understand the relationship between the geothermal activity exhibited by the hot springs and the underlying tectonic processes responsible for the formation of OOST faults in Himachal Pradesh. Employing a multi-disciplinary approach, the investigation combined geological field surveys, analysis, and geochemical examination of water samples from the hot springs. Preliminary findings suggest a strong interplay between the hot springs and OOST faults, indicating that the migration of deep-seated fluids along these faults is a significant driving force behind the emergence of the hot springs at the surface. Geochemical analyses of water samples further support the geothermal origin of these springs, with elevated temperatures and mineral concentrations substantiating their connection to the geothermal system. The study also sheds light on the potential geothermal energy resources that can be harnessed in the region, offering valuable insights for sustainable energy development. By understanding the geological factors influencing hot spring occurrence, local communities and authorities can make informed decisions regarding the utilization of geothermal energy, taking into account both environmental impacts and economic benefits. In conclusion, this investigation significantly advances our understanding of the complex geological processes governing the coexistence of hot springs and OOST faults in Himachal Pradesh, India. The findings have far-reaching implications for geothermal resource assessment and sustainable energy development in the region, as well as contributing to the broader knowledge of geothermal systems and tectonics worldwide. Further research is required to fully unravel the intricacies of this captivating geological interplay in one of India's most geologically dynamic and culturally rich regions.

Landmark-based 2D and 3D geometric morphometry: a useful tool for taxonomic and phylogenetic studies of past life

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Morphometry is a well-established tool in palaeontological studies, to classify taxa, understand ontogeny, and create phylogenetic links. Landmark-based geometric morphometry is a relatively recent tool at the palaeontologists' arsenal that surpasses traditional morphometric methods, in terms of sophistication, complex taxonomic or phylogenetic analyses, and error reduction. The use of landmarks, both in a two-dimensional and a three-dimensional space, eliminates the problem of varying sizes of the anatomy in study. This is a common problem in traditional morphometrics, which is alleviated by marking the spatial distribution of anatomical features (i.e., using landmarks) and applying a Procrustes-generalized least squares (GLS) superposition. This allows for the shape of the anatomy in study to be compared directly, using statistical techniques, e.g., principal component analysis (PCA) and canonical variates analysis (CVA). A majority of uses of the landmark-based geometric morphometry is seen in quantifying the intraspecific or interspecific variations due to the abundance of shared anatomical features. Studies comparing anatomical features at higher taxonomic levels have also been conducted successfully. In this specific case study, we demonstrate the use of both 2D- and 3D-landmark-based geometric morphometry for evaluating the morphometric relationship of the enigmatic and extinct snake family Palaeophiidae with other Alethinophidian snakes. The CT-scan data of museum specimens of modern Alethinophidian snakes were obtained from the online CT-media repository MorphosourceTM. These scans were processed and the precloacal vertebrae of these snakes were modelled at an interval of 20% in order to incorporate the intracolumnar variation of the individuals and to eliminate the variation in vertebral count between species. Images of Palaeophid vertebrae were obtained from research papers for 2D morphometry. These images were used as the reference for the manual development of 3D models of these vertebrae by means of 3D-modelling software BlenderTM. A total of 11 landmarks were used for the 2D analysis, while 15 landmarks were ascribed to the models in the 3D analysis. With the use of CVA, the Mahalanobis distance between the snake families was obtained for both datasets. The Mahalanobis distance was used for hierarchical clustering of the snake families to understand their morphometric relationship. Both clustered dendrograms showed close similarity to the established phylogenetic relationships between the modern snakes, implying a degree of phylogentic influence. The family Palaeophiidae is placed closer to Boidae and Pythonidae in both datasets, thereby, implying that at least on the basis of vertebral shape, the Palaeophids have a stronger

morphometric affinity towards Boidae and Pythonidae than the Caenophidian snakes. This study demonstrates the power of landmark-based morphometry and is helpful in understanding the relationships between Palaeophids and modern snake families.

Neoarchean- Early Paleoproterozoic *UHT-HT* Metamorphism in KGB and its Importance in Early Geodynamics

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Charncokite rocks are composed of anhydrous minerals like orthopyroxene and garnet, indicating dehydrated granite intrusion or H2O-poor magma emplacement during a high-grade metamorphic event. As the high-grade metamorphic facies need eighter high-temperature or high-pressure conditions, the charnockite rocks provide insights into geodynamic processes. The Neoarchean- Early Paleoproterozoic evolution of charnockites from Karimnagar is very crucial to understand archean-Plaeoproterozoic ultra-high-temperature (*UHT*) metamorphism and early geodynamics. This work includes geochemical analysis, U-Pb zircon, monazite geochronology, and phase equilibrium modeling of charnockites from the Karimnagar granulite belt (KGB). Charnockites from Karimnagar (KC) contain quartz, orthopyroxene, feldspar, garnet, and biotite whereas Warangal (WC) charnockites are garnet absent. The major, trace, and REEs plots of studied charnockite indicate a protolith similar to Neo-archean East Dharwar craton (EDC) granites. The thermobarometry and *P-T* pseudosection result a counterclockwise P-T path. Prograde section of *P- T* path was constrained by the stability of dehydrated minerals, garnet, and orthopyroxene from biotite and feldspar while the retrograde section was constrained by the overgrowth of chlorite over biotite. The peak *P-T* conditions estimated from phase modeling and thermobarometers are, 0.55 GPa-800^{0}C and 0.7 GPa-830^{0}C for WC and KC charnockite, respectively. Magmatic zircons exhibit a concordance age of 2680 Ma and recrystallize zircon yield concordia age 2516 Ma in the U-Pb concordia diagram. Monazite grains in feldspar and garnet matrices show U-Th-Pb ages of 2508 ma and 2502 Ma, respectively. The Neoarchean magmatic ages indicate granite emplacement at EDC during accretion of Bastar Craton and Dharwar Craton as a part of expansion of the oldest suggested supercontinent Ur (Rogers & Santosh, 2003), followed by *UHT* metamorphism in a post-collisional extension ~2500 Ma, initiating its disintegration.

Paleoenvironment, and paleobiogeographyreconstructions of Late Triassic Tiki Formation, Rewa Basin, India; insights on Lepidosauromorphs and associated vertebrate faunal assemblages

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Tiki Formation has a rich varieties of vertebrate fossil assemblages comprises of cynodonts, archosaurians, and pisceans such as hybodonts, xenacanthids, and actinopterygians in Gondwana succession, India. In the study, we identify indeterminate Lepidosauromorpha and the indeterminate Sphenodontia from the Tiki Formation of Late Triassic age. The newly recorded early diverged lepidosauromorphs may fed on small vertebrates/insects and small invertebrates. The presence of early diverging lepidosauromorphs from the Tiki Formation suggests their geographic range from N. America, S. America, and Europe to the sub-continent India, during the Late Triassic age. Further, the records of the aquatic vertebrates and archosauromorph assemblages from the Tiki Formation might give additional clue to the idea of vertebrate affinities between Gondwana and Laurasia sub-continents of the Pangea.

Petrography and geochemistry of Neoarchean Gadwal Greenstone Belt of Eastern Dharwar Craton, India: tectonic implications

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The Gadwal Greenstone Belt (GGB) is among a series of N-S trending greenstone belts in the eastern Dharwar Craton which is of Neaoarchean age. The GGB has attracted lot of interest because of the diverse compositional range of the volcanic rocks which have been interpreted to form in a present-day-like subduction zone system. Here we exploit geoanalytical tools like XRF and ICP-MS to ex-tract whole-rock major oxides, trace and Rare Earth Elements (REEs), to understand the lithological complexity and tectonic setting of the GGB. Based on whole-

rock major oxides of the volcanic rocks of GGB, the rocks show varying composi-tional range of basaltic trachy andesite, basaltic andesite, andesite, and basalt. The basalts plot within the tholeiitic series. Detailed petrographic study of the basalts shows that they are metamorphosed and show well-defined foliation, dominated by amphiboles of hornblende composition with minor plagioclase, epidote, chlorite, pyroxene, sphene, magnetite, and biotite. The chondrite-normalized REE patterns of the basalts show two trends: (1) light REE (LREE)-enriched ((La/Sm) N > 1.5) pat-tern which resembles enriched-mid oceanic ridge basalt (E-MORB), and (2) Flat REE pattern ((La/Sm) N < 1.5) that resembles normal MORB. In the primitive mantle-normalized spider diagram both type of basalts show relative enrichment in Rb, Ba, Th, Sr and depletion in Nb and Ti indicating that these rocks formed in a subduction-related magmatic arc setting. We apply well-established dis-crimination systematics (built on immobile elements) of basaltic rocks of the GGB such as Zr/Y *vs.* Zr, Ti *vs.* V, and Th/Yb *vs.* Nb/Yb as our geochemical proxies to identify the tectonic environment of formation. These tectonic discriminant diagram suggests that the basaltic rocks of the GGB pos-sibly formed in an oceanic arc tectonic setting. Our geochemical study suggests that the tholeiitic basalts of the GGB formed in an oceanic subduction-related magmatic arc system which is also in agreement with previous studies from this region.

Deep Crustal Architecture of the Pranhita Godavari Basin: Insights from Gravity and Aeromagnetic data Interpretation

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Pranhita Godavari (PG) Basin is a NE-SW trending failed rift basin lie within the suture between the Bastar and Dharwar cratons. It stretches approximately 400 km in length and 50 km in width across south-eastern region of India. The basin is characterized by substantial accumulation of Proterozoic-Gondwana sediments as well as the granulite rocks along its northeast and southwest margins, indicating a complex history of evolution. Despite its importance in the Proterozoic reconstruction of India and East Antarctica, establishing the tectonic connection between PG Basin and East Antarctica remains challenging due to thick cover of sediments and overprinting of later tectonic episodes, especially the formation of

Eastern Ghat Mobile Belt (EGMB). The present study focuses on the detailed joint interpretation of gravity and aeromagnetic anomaly data of PG basin to delineate deeper crustal architecture of the basin, which further helps to develop more robust reconstruction model for the eastern Gondwana. Qualitative interpretation of Aeromagnetic and gravity anomaly maps of the region reveal the presence of two basement ridges, namely Bhadrachalam and Wamanpalli high. These two ridges are characterised by gravity and magnetic high, and divide the basin into three sub-basins, namely northern Chandrapura, the Godavari, and the southern Chintalpundi sub-basins. The 3-D gravity inversion study suggest that Moho depth varies between 40-44 km in the PG Basin. 2-D constrained potential field model along a transect cutting across the PG Basin reveal deep crustal Proterozoic intrusion in the northeastern side of the basin and abnormally deeper Moho depths in comparison with other contemporaneous rifted basins across the world. Furthermore, the present study supports different emplacement ages for Bhopalpatanam (~1600 Ma) and Karimnagar granulite belts (~2400 Ma) in the study area.

Spectral analyses of the Indian monsoon variability records from the ocean sediments for the past 20 kyrs

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The Indian monsoon system is a large land-ocean-atmosphere coupled system involving transportation and redistribution of substantial amounts of heat and moisture over the Indian Ocean and adjacent densely-populated Asian region (Webster et al., 1998). Almost all facets of societal and economic activities of the region critically depend on the monsoon including agriculture, which is the main source of income and livelihood (Gadgil et al., 2003). Even a slight change in its intensity leads to severe droughts, floods, and huge fluctuations in food production affecting gross domestic product (Gadgil et al., 2004). Therefore, reconstructions of past monsoon records from archives using proxies are critical for developing an understanding of the past, present, and future monsoon variability. Here, in this study, we selected and compiled some of the best high-resolution datasets (publicly available records of Mg/Ca-derived SSTs and δ18Osw for the past 20 kyrs from the Indian Ocean region) to perform REDFIT spectral and wavelet analysis using PAST program for a better understanding

of the embedded cyclicities and the forcing mechanisms of the Indian monsoon variability. Spectral analysis performed on the Mg/Ca-SST and δ18Osw records yielded some strong common cyclicities: 1). ~13kyr, ~330/~339yr, and ~259/~260yr for Core SK237-GC04 (Saraswat et al., 2013), 2). ~3975/~3964, ~201/~205, ~169/~170, ~160/~161, ~150/~152, and ~144/~145 years for Core SSD004-GC03 (Singh et al., 2022), 3). ~871/~898, ~213/~217, ~197/~198, ~185/~187, ~167/~169, and ~129/~130 years for Core SO189/2-039KL (Mohtadi et al., 2014), 4). ~513/~528, ~ 450, ~355, and ~335 years for Core ABP32-GC01R (Banakar et al., 2017), and 5). ~558/~583 years for Core SO188-KL342 (Weldeab et al., 2022). On the other hand, wavelet analysis performed on the above core datasets show generally higher energy bands mostly during the period of ~10-15 kyrs BP, suggesting that the period was more dynamic with higher intensities and dominance of smaller centennial to sub-millenial cyclicities in the Indian monsoon variability, which maybe linked to solar cycles and thermohaline circulation associated with atmospheric teleconnections.

Deformational history of Sendra Ambaji Granitoid and associated metasediments in Udaipur district, Rajasthan

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The Aravalli Delhi Orogenic Belt (ADOB) has undergone numerous regional deformational events which are accompanied by felsic magmatism thus making it an ideal area to study tectonic evolution of Precambrian Indian shield. NE-SW trending Delhi Fold Belt has been divided into North Delhi Fold Belt (NDFB) and South Delhi Fold Belt (SDFB). The Gogunda and Kumbhalgarh groups of SDFB in central and southern Rajasthan have been intruded by several phases of granite intrusion, the most prominent of them being the Sendra Ambaji Granitoid (SAG) which occur as a NE- SW trending, 360 km long belt extending from Sendra near Beawar, Rajasthan in the north to Ambaji, Gujarat in the south. In the entire length of the SAG, only the Chang Pluton near Sendra has been studied in detail in terms of geochemistry and geochronology. Detailed structure of the granitoid especially in relation with the surrounding metasediments has not been discussed and the significance of understanding the

deformational history in establishing the tectonic evolution of the SAG is less explored. To address this issue / gap areas, Sayra area of Udaipur district is studied which is located in the southern extent of SAG belt. The dominant rock types comprise of quartzite and quartz biotite schist belonging to Kelwara Formation of Gogunda Group, calc gneiss, impure marble, quartzite, bioite schist and calcitic quartz biotite schist belonging to Todgarh Formation of Kumbhalgarh Group of Palaeo to Mesoproterozoic Delhi Supergroup. The Phulad Ophiolite Suite (POS) occur as dismembered mafic to ultramafic rocks with a possible ophiolitic origin. The rocks of Kumbhalgarh Group are extensively intruded by the SAG. Planar structures such as gneissosity, schistosity, joints, fractures and shear planes as well as different linear features such as mineral lineation, intersection lineation, pucker lineation and fold mullions are studied. Major conclusions of the work are: (1) the rocks of Delhi Supergroup have undergone three phases of deformation. SAG as well as the POS are coeval. Presence of refolded gneissosity within SAG and POS suggest that both SAG and POS were emplaced during the D1 deformational event. POS was emplaced in the earlier stages of the deformation and SAG intruded in the later stages as felsic magmatism however, the intrusion of SAG continued post orogeny. (2) A prominent ductile simple shear zone (DSZ) is developed along the western contact of Kelwara Formation with Todgarh Formation post D1 but pre D2 deformation along the axial planar cleavage of F2 folds as observed by shearing of pegmatite/ quartz veins emplaced along S1 which are further folded however, pegmatite veins intruded along S2 do not show signs of shearing (3) The contact of SAG with the rocks of Todgarh Formation is sheared which is inferred to have occurred post D2 deformation along the S1 plane as no imprints of D2 deformation are observed within the shear related folds.

Geochemistry of granitoids in parts of Erinpura Granite Terrain, Sirohi region, Rajasthan

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The Delhi Fold Belt (DFB) in NW India is composed of two different segments referred to as North Delhi Fold Belt (NDFB) and South Delhi Fold Belt (SDFB) with different geological evolution (e.g. Sinha-Roy et al. 1998). Widespread granitic to granodioritic intrusions in the

SDFB and its western foreland are collectively named as Erinpura Granite (Coulson 1933). The granites are medium to coarse grained often showing foliated fabric. Quartz, microcline, orthoclase and plagioclase are the framework modes whereas biotite and hornblende occur as minor minerals. Major elements geochemistry suggests that the granitoids are metaluminous to peraluminous in nature. QAP diagram characterise Erinpura granitoids as granites and granodiorites. Geochemically, Erinpura granitoids are classified as granites to granodiorites in the TAS diagram. In Pearce et al. (1984) discrimination diagram, granites fall under Volcanic arc granites and Syn-collisional granites fields. In Whalen et al. (1987) discrimination diagram, granites plot in both S-type and A-type fields. The geochemical attributes of the granitoids indicate their magmatic and crustal origin and their emplacement in syn – post collisional tectonic ambiance.

Genesis of Y- and Th-zoned Monazite: A case study from the Alaknanda-Dhauliganga Valley, Garhwal Himalaya

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Significant progress has been achieved worldwide in monazite geochemistry, especially in the field of metamorphic geology, where it has been studied to understand the metamorphic processes under the crustal to the sub-crustal environment. The complexity in compositional zoning, particularly in the Himalayan monazite, has been used to decipher the complex tectonometamorphic evolution of the terrene. Recent investigations have been aimed at studying the partitioning behaviour of Y between monazite and other minerals in a way that the amount of monazite produced and utilized during chemical reactions is reflected in the form of chemical zoning patterns and, therefore, useful in finding the style of tectonic evolution. To understand the growth history and behaviour of monazite along multiple reaction pathways, the Alaknanda-Dhauliganga valley, Garhwal Himalaya, has been chosen for the research work. The area is known for its complex geological history, characterised by a low-high temperature and intermediate pressure metamorphism, with monazite occurring widely in metamorphic zones ranging from kyanite to sillimanite-K-feldspar zone. The geochemical analysis and compositional X-ray maps of Y and Th show the presence of three distinct zones: zone 1- high

Th, low Y; zone 2- low Th, low Y; zone 3- low Th, high Y. Zoning pattern typical of metamorphic monazite has been identified, where Y shows sympathetic to antithetic zoning with Th. The three generations of monazite formation have been suggested based on the distinct zones and their correlation with the possible metamorphic reactions. Generation 1 monazite is a rare inherited core in psammitic rock from the upper kyanite zone. Generation 2 is metamorphic monazite formed during the initial or later stages of garnet formation. Monazite of 3rd generation is characterized by high Y and has evolved from melt cooling and garnet breakdown reaction during the post-peak decompression path.

Study of olivine microfabric from the ultramafic rocks of the Nidar Ophiolite, eastern Ladakh: Preliminary results and implications for tectonics and seismic anisotropy

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The Nidar Ophiolitic Complex (NOC) is a remnant of the Tethyan oceanic lithosphere that lies in eastern Ladakh region of the NW Indian Himalaya. It is well exposed in Indus Suture Zone (ISZ) wherein, it shares thrusted contacts with the Zildat Ophiolite Melange (ZOM) to the south and the sedimentary Indus formation to the north. The NOC stands out as having the most classical and complete ophiolite section among all the ISZ ophiolites. The ~7 km thick ultramafic unit of the ophiolite preserves the most pristine, unaltered peridotites. This section is magmatically stratified with a lower mantle section consisting of chromite-harzburgite at the bottom and chromite-dunite at the top, showing varying degree of serpentinization. These are variably speckled with mineral inclusions. Scanning Electron Microscopy (SEM) based Electron Backscattered Diffraction (EBSD) technique helps delineate Lattice Preferred Orientation (LPO) patterns. LPO of olivine in turn, helps envisage the conditions and mechanism of deformation in terms of temperature, stress and fluid activity. Development of LPO in olivine results from viscous flow in the upper mantle. For the present set of samples, which compositionally vary from harzburgitic to cpx-bearing harzburgitic, we have identified 3 different LPO patterns (namely, A-, D- and AG- type). Each of these LPO patterns is associated with specific tectonic settings and deformation conditions. Presence of A-type fabric in 2 of the samples suggests their development in the pristine oceanic lithosphere, that is, the

Tethyan oceanic upper mantle. D-type fabric usually develops at modest temperature, low fluid content and higher stress conditions and presence of D-type fabric in 3 of the samples suggest LPO development during post-solidus conditions. This tentatively can be attributed to the stage of obduction and continental collision related to the Indo-Eurasian convergent tectonics. One sample having 'mesh' texture with presence of relict olivine within a dense network of serpentine veins, show AG-type fabric which can be attributed to non coaxial deformation and dynamic recrystallization. Seismic anisotropy obtained from the olivine LPO broadly suggests that S-wave anisotropy is proportional to serpentine content.

Evolution, Controls, and Impacts of Padam Proglacial Lake on Glacier Stability in the Doda Sub-Basin, Western Himalaya: A Comparative Analysis with adjacent Land-Terminating Glacier

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The dynamics of glacier situated within the Himalayas expanse have remained a realm of limited exploration, primarily due to formidable topography and adverse climatic condition. Consequently present study aims to provide a comprehensive evaluation of various glacier parameters including glacial recession, areal extent, ice velocity, proglacial lake development and geodetic mass balance using multitemporal observation derived from Landsat, Sentinel - 2A, SRTM DEM and Aster stereo pairs spanning from 1993 to 2022. The finding of study divulge a reduction in the area of Padam Glacier by 11% accompanied by retreat rate of 788 ±52 m, similarly Nateo Nala glacier shows a 4% area decline coupled with retreat of 368 ±204 m during the temporal span from 1993 to 2022. Glaciers lower ablation zones mean velocity decreased significantly from 33 ±6 during 2001-02 to 18 ±2 in 2014-15 and 15 ± 2 during 2021-22. Such a 57 % slowdown in glacier velocity in last two decades is due to less mass transfer from accumulation zone and increasing debris loading in ablation zone. The estimated geodetic mass balance shows degeneration of mass loss of lake terminating Padam and land terminating glaciers at the rate of 0.40 ± 0.29 and 0.56 ± 0.29 m.w.e per year. This dissimilarity in glacier dynamics is attributed to inherent distinctions in glacier characteristics, including the extent of their accumulation zones, the breadth of their ablation zones and frequency of ice cliff

formation with the Padam glacier displaying a relatively less negative mass balance in comparison to the Nateo Nala glacier.

Field Relationships and Petrogenetic Study of the Granitoids from the Nortern Margin of the Chotanagpur Gneissic Complex (CGC)

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The Chotanagpur Gneissic Complex is a Proterozoic belt of granite and granitic gneiss in the eastern part of Central Indian Tectonic Zone (CITZ). It predominantly comprises of granites, granitoid gneisses and migmatites displaying considerable variations in terms of structure, texture, and mineral composition. This complex is marked by the presence of intrusions like massif anorthosite, along with mafic, intermediate, and felsic rocks, within enclaves of supracrustal meta-sediments. This study focuses on detailing the geological relationships and the petrogenetic aspects of the granitoid rocks found in areas of Gaya district, Bihar. The rocks in question exhibit evidence of magma blending and intermingling, particularly within mafic, felsic, and intermediate (hybrid) rock varieties. Observable field indicators of mingling are evident, including features like partially engulfed boundaries of mafic magmatic enclaves, mixed regions at the interfaces of mafic and felsic materials, surfaces indicating reactions, streaked patterns known as schlieren structures, and the presence of mafic flows within the surrounding granitic host. These aspects strongly suggest the occurrence of significant magma mingling processes. Mafic magmatic enclaves (MME) offer insights into two distinct types of magma interactions. The granitoid rocks in question can be categorized into various types, such as grey, pink, and porphyritic granites, and are specifically grouped as GPG (grey and pink granites) and PG (porphyritic granites). The mineralogical composition of both the granitoids essentially consists of quartz+K-feldspar+ plagioclase+ biotite. Apatite+ ilmenite+ zircon+ monazite+ allanite occur as accessory phases and chlorite+serecite±microcline occur as

secondary minerals. Sieve and myrmekitic texture are common features observed in plagioclase feldspar. Intergrowth of quartz is also seen in a few K-feldspar grains representing micrographic texture. Exsolution lamellae of plagioclase occurring in orthoclase and microcline are also observed as indicated by perthitic texture. Enrichment in SiO_2, K_2O and Na_2O is evident in both the varieties of GPG and PG along with depletion in MgO, CaO and Sr. However, on an average PG have higher Al_2O_3, TiO_2, MgO and P_2O_5 content than GPG. All the samples fall to the ferroan A-type granites on Fe*[FeO^t/(FeO^t+MgO)] *vs.* SiO_2 diagram whereas on MALI (Na_2O+K_2O–CaO) *vs.* SiO_2, samples of GPG and PG mostly plot in calc-alkalic and alkali-calcic fields. The decreasing pattern of TiO_2, Fe_2O_3, MgO and CaO with increasing SiO_2 and that of selected trace show simple fractionation trends. The high concentration of Fe* and K along with the K_2O/Na_2O ratio (>1.5) is an indicative of peraluminous A-type granite. Geochemical trends imply a key role of fractional crystallization process during petrogenesis.

Extended finite fault simulation - Site effect correction and geometrical spreading optimisation

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Ground motion models (GMMs) are critical components in assessing seismic hazards and are the most important source of uncertainty affecting the hazard results. Such models provide median estimates of the amplitude of ground shaking based on factors like magnitude, distance, and site characteristics, with additional measure of expected (aleatory) variability. Empirical GMMs are generally used in data-rich regions (California and Japan), but for data-poor regions, such models are derived using simulation-based approaches.. Simulation approaches ensure reliable scaling with magnitude and distance while accounting for local seismological characteristics derived from limited recorded data. Our study uses the extensive California ground motion database to calibrate the overall model scaling behavior in magnitude and distance. We also employed GMSS 2.0, a Matlab-based tool capable of simulating seismic events, to assess the accuracy of geometric spreading. This allowed us to

effectively model the impact of near-distance saturation and comprehend how ground motion behaves across various scenarios. We used 4165 earthquake records for a moment magnitude, Mw ranges 3 to 7.4, recorded at an epicentral distance, R_{epi} of 100 km. To optimize geometrical spreading, we employed a grid-wise search approach that systematically investigates a spectrum of exponent values and assesses their influence on response spectra. Our analyses indicated the necessity for site-specific adjustments when comparing simulated ground motions to actual observations. We adopted the California-based site-response model proposed by Seyhan and Stewart (2014), which effectively enhances the precision of simulated ground motions by considering the geological and structural attributes of the site. Ultimately, the study determines that the optimal geometrical spreading exponent depends on the magnitude of seismic events. The study simulated 0.5-magnitude intervals, employing geometrical spreading exponent values ranging from 0.7 to 1.3. It was observed that for events with magnitudes between 3.2 and 5.7 and those between 6.7 and 7.3, an exponent value of -1 is found to be most appropriate. On the other hand, an exponent value of -1.1 provides a better fit for events with magnitudes ranging from 5.7 to 6.7. This observation suggests the interplay between geometrical spreading and the size of earthquake (magnitude), which is essentially related with the near-fault saturation phenomenon. Consequently, determination of geometrical spreading allows further inversion of other seismological parameters such as stress drop and kappa which will eventually be used for adjustment of California-based GMMs.

Exclusive Deformational Features in Carbonates of Gotan Limestone Formation and First Record of Fluid Inclusions, Marwar Super Group, Rajasthan.

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The Marwar supergroup falls in the Neoproterozoic era, this era was known to be the most revolutionary in Earth's history. Extending from 1000 to 541 million years. The Neoproterozoic Bilara limestone Group of the Marwar Supergroup, Rajasthan exposes metres thick layers of soft sediment deformation structures at different stratigraphic levels which could be traced over hundreds of metres on the outcrop scale. Gotan limestone Formation is

equivalent to Upper part of the Vindhyan Super Group but has been given separate status under Marwar Super Group. The definition for the *Soft-Sediment Deformation (SSD)* structures says, it develops at deposition or shortly after, during the first stages of the sediment's consolidation. And it means, sediments need to be "liquid-like" or plasma type for the deformation to occur. These structures have nicely depicted high deposition rates, which usually packs loose sediments. The Soft Sediment Deformation usually identifies by several marked structure namely convolute bedding, flame structures, slump structures, sole marking etc. In this study, several of such structures have been noticed, more prominent are, flame type, sand blows, and convolute fashion. The initial study of sedimentary structures, which have presumably identified in the Gotan formation and its beds, might show, it to be disturbed by the seismic waves from earthquakes. The fluid inclusions from Gotan rock samples. The fluid inclusions that have entrapped in the host phase, show variable size and shape, it is observed, most of the fluid inclusions change shape through a process referred to as "re-equilibration" that involves dissolution and re-precipitation of the host phase to reduce the surface area and produce many smaller inclusions from the original larger inclusion. Many of the tiny inclusions those contains fluids and vapour phases show irregular shaped, dis-oriented, and sometime not restricted within mineral grains, which might indicate the reflection of local disturbance, that possibly created by sudden shaking phenomenon like the earthquake, however to make so straightforward conclusion requires the correct assessment of the mineral-fluid relationship. The author is thankful to Prof. Vibhuti Rai and Prof. Dhruv Sen Singh for providing the working facilities of the department.

Detrital ages records from offshore sediments, sedimentary sequences and morainal deposits to understand the geological evolution of the Princess Elizabeth Land sector, East Antarctica

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The task of directly investigating rocks within the Antarctic Continent's interior is fraught with difficulty due to the formidable presence of a thick ice sheet. To surmount this challenge and glean insights into the composition of the continent's interior, researchers have turned to the

analyses of detrital sediments deposited along its offshore areas and margins (as moraine deposits). These sedimentary deposits are reliable proxies for the interior's geological makeup. Nevertheless, our understanding of the Princess Elizabeth Land-Amery Ice Shelf (PEL-AIS), East Antarctica, remains limited.

Numerous studies have sought to illuminate the mysteries of PEL-AIS by scrutinizing samples extracted from sediment cores obtained during various expeditions conducted along the offshore regions of Princess Elizabeth Land. The focus the ages of detrital Zircon minerals present within these samples. The results of these investigations have demonstrated remarkable consistency, revealing ages spanning from around 500 million years ago (Ma) to 700Ma. Intriguingly, a subset of ages extends even further, scattered upwards to 1000Ma.

Zircons reported from sedimentary rocks exposed at the continent's margins have yielded age ranges within 400Ma to 600Ma, with occasional instances of more advanced ages, reaching up to 1200Ma. Terminal moraines, left behind as markers of past glacial advances and retreats along the margins, have also played a pivotal role in uncovering insights into the interior's geological history. Focused investigations targeting detrital zircon ages from these moraine deposits have produced consistent results, aligning with the previously observed age range of 500Ma to 700Ma. A few scattered ages in the realm of 1500Ma have emerged from these analyses as well.

The geological tapestry at the continent's margins reveals a complex story. Among the exposed in-situ lithologies present, Archean rocks (sPCM) and Neoproterozoic rocks (PCM) feature prominently. Furthermore, mafic-felsic volcanism, spanning from approximately 1300Ma to 1020Ma, has left its mark, contributing to the mosaic of the region's geological history. Amphibolite facies metamorphism, a transformative process that occurred around 1020Ma to 940Ma, adds another layer to the narrative, particularly within the Fisher Terrain of North Prince Charles Mountain.

Interestingly, the ages derived from these geological features do not entirely correspond with the age data of detrital sediments. This discrepancy suggests the possibility of geological activity that was more prevalent within the continent's interior, but relatively absent from its margins. This nuanced understanding highlights the significance of studying both offshore sediments and terminal moraines to piece together the geological evolution of the enigmatic Antarctic Continent.

Abstracts Theme

Sophisticated Geoanalytical Tools

Lithological Mapping using ASTER SWIR Data: Case study from Vizianagaram area, Andhra Pradesh

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Lithological mapping is usually carried out by field evidences and petrographic studies.The mapping becomes debatable when the terrain is inaccessible. In view of this, it has been experimented to develop a semi-automatic approach to discriminate lithology through various methods such as Principal Component Analysis (PCA), Minimum Noise Fraction (MNF) on calibrated (orthorectified, cross-track illumination and atmospherically corrected) Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Shortwave Infrared (SWIR) data in the terrain of Vizianagaram area. The lithounits exposed in the area belong to Khondalite, Charnockite and Migmatite Groups belonging to Eastern Ghats Supergroup of Archaean to Palaeoproterozoic and Quarternary flood plain deposits of Pliocene age. Khondalite Group mainly comprises of quartzite, calc-silicate and khondalite (garnet-sillimanite gneiss /schist). Khondalite is exposed in Nilavathi, Vendram, Gantyada, Phulbagh Konda, Muddurukonda and Kovvudapeta. It is leucocratic to mesocratic, medium to coarse grained, banded and foliated. The proposed Band Combination (BC) derived from PCA and MNF has shown its effectiveness in lithological mapping. The RGB band combination derived from MNF image enhancement method shows better results over PCA transformation to discriminate various lithological units. The output derived from BC of MNF transform shows strong agreement with the published lithology map and field investigation. Hence, ASTER SWIR data coupled with advanced image enhancement technique like MNF are recommended as a fast and cost effective tool for lithological mapping.

Geochemistry of sediments of the Ganga River, Ganga basin: implication for provenance source-area weathering, and tectonic setting

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The Ganga River sediments were analyzed for their geochemical signatures, and mineralogical investigations have been carried out in order to understand the source of the sediments, the

degree of chemical weathering, and the tectonic setting of the basin. The geochemical data was then compared with the probable source rocks in the catchment area. The major element log values (Fe_2O_3/K_2O) vs. (SiO_2/Al_2O_3) and (Na_2O/K_2O) vs. (SiO_2/Al_2O_3) demarcate a lithology remarkably similar to that exposed in the catchment area. The chondrite normalized REE patterns of The Ganga sediment samples are similar to Post Archaean Australian Shale (PAAS) with LREE enrichment, a negative Eu anomaly and an almost flat HREE pattern similar to a felsic and/or cratonic sedimentary source. The La-Th-Sc plot of sediment samples falls in the granitic gneiss and mixed sedimentary domain, close to the Upper Continental Crust (UCC) and PAAS, suggesting various lithologies such as felsic and sedimentary source rocks for the Ganga sediments. The mineralogical characteristics, REEs pattern and high field strength elements (HFSE), together with heavy minerals such as zircon and monazite, indicate a more felsic source for the sediments of the Ganga. The CIA and PIA values of the sediment samples suggest low degrees of chemical weathering in the source region. The average ICV values of more than 1 and lower values of Na_2O/K_2O suggest chemical immaturity of the sediments. The plot between ICV and CIA values clearly indicates the weak weathering and immaturity of sediments. A plot between the SiO_2/Al_2O_3 ratio and Log(K_2O/Na_2O) suggests that Ganga River sediments have been deposited in passive margin setting. The petrographic characters and textural immaturity indicate a short distance of transportation for the Ganga sediments. The CIA and PIA values of sediments indicate weak weathering of the source rocks. Plots of the geochemical data on tectonic discrimination diagrams suggest that the sediments derived from the various lithologies of the LHS and HHCS exposed in the catchment area originated within a cratonic interior and were later deposited along a passive margin basinal setting.

Polycyclic Polyaromatic Hydrocarbons and their Geological Association: A Case Study from the Middle Rudramata Shale member of Jhuran Formation, Kachchh Basin, western India

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In the present study, geochemical and advanced spectroscopic proxies have been used to assess the distribution of polycyclic aromatic hydrocarbons (PAHs) in four shale samples from Rudramata Shale member of the Late Jurassic (Kimmeridgian–Tithonian) Jhuran Formation of Kachchh Basin, western India. The observations indicate that the most abundant PAHs present in the solvent-extracted fractions of the studied shale samples are PAHs with 3–5 ring structures, viz., phenanthrene, benzo[a]pyrene and perylene, identified from their respective excitation wavelength (λ_{ex}) values, i.e., 345, 409 and 433 nm, in their corresponding steady-state fluorescence emission spectra. Type IV and III, i.e., humic kerogen, were identified as the source organic matter for the immature to poorly mature shale samples. Presence of aliphatic sulphur, amine and carbonyls as NSO functionalities were correlated with the gradual change in thermal maturity. From the observations, it was possible to conclude that the studied shale samples contain certain combustion-derived PAHs viz. phenanthrene and benzo[a]pyrene. Presence of PAH such as perylene which is commonly present in marine sediments and shale, implies the predominantly terrestrial biogenic origin of its precursors and also indicates a diagenetic nature of perylene. Moreover, by confirming the presence of perylene in the studied samples, a faster rate of deposition in the deltaic sequence of Rudramata Shale member and hence the rise of anoxic condition can be assumed. The presence of benzo[a]pyrene and phenanthrene definitely associates the sediment source in Rudramata Shale with fluvial influence. It can be concluded from the present study that Rudramata Shale member of the Jhuran Formation might have been part of a river-dominated delta system with significant terrestrial contribution where the organic content was derived mainly from land biomass.

Geochemical and quality characteristics of some tributaries of the Jhelum River Basin, India

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Rivers are the primary sources of water for human activities and ecological balance in inland areas, however, they are vulnerable water bodies to pollution. This study attempts to understand the solute source mechanism and factors controlling the hydrochemical facies of some tributaries of River Jhelum in the Kashmir Valley. The results indicate that water from these

tributaries is alkaline (pH: 6.5 to 9.6) and moderately mineralized (TDS: 107-188 mg L^{-1}) with Ca^{2+}, Mg^{2+}, HCO_3^- and SO_4^{2-} dominate ionic budget. The study reveals that solutes exhibit seasonal pattern with higher concentration during low flow condition in winter months and lower concentration during higher during the summer months, this seasonal variance of major ions has been used to understand intensity of water-rock interactions and elemental source mechanism. Ionic ratios, Langliar-Ludwig, Gibbs, Piper trilinear, and scatter plots indicate that carbonate and silicate dissolution is a major solute acquisition mechanism controlling the stream water chemistry and water is Ca-Mg-HCO_3 type. The study further suggests that deterioration in surface water quality starts with the onset of the agriculture practice season, and higher concentrations of NO_3^-, Cl^-, F^-, and Fe^{2+} especially in the Liddar and Kuthar tributaries is a matter of concern. This study increases the understanding of sensitivity of these surface water systems, which is necessary for implementing water supply protection schemes within the region.

Geochemical characteristics of the Proterozoic metabasaltic rocks of the Banded Gneissic Complex,central Rajasthan: Implications for mantle source and geodynamic setting

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The Proterozoic Banded Gneissic Complexof central Rajasthan belongs to amphibolite facies andcomprises orthogneisses, metasedimentary (schists and paragneisses) and metabasaltic rocks. In this study, we present whole-rock geochemical data of metabasaltic rocks occurring near Jamola-Masuda regionto understand its mantle source and geodynamic setting. The metabasalts occurring as isolated bodies are sub-alkaline in nature excluding one sample, trachy-andesite in composition which occurs intercalated with the metasedimentary rock units. They have SiO_2 ranging from 46.21 wt% to 59.55 wt% (avg. = 48.71 wt%) and MgO from 3.68 wt% to 15.51 wt% (avg. = 9.61wt%). In the AFM (FeO^T-Na_2O+K_2O-MgO) ternary diagram, the samples show tholeiitic nature. The chondrite normalized rare earth element (REE) patterns of themetabasalts are characterized by flat to mild LREE depletion with $(La/Yb)_N$ ratio ranging from 0.42 to 1.47, and $(La/Sm)_N$ varying from 0.46 to 1.01. They exhibit almost flat HREE patterns with $(Gd/Yb)_N$ between 0.72 to 1.17. These signatures are similar to basaltic rocks

from mid-oceanic spreading centers (N-MORB like). The metabasaltic sample occurring as intercalated with metasediment shows enriched LREE, slightly depleted HREE and negative Eu anomaly indicating crustal contamination during the evolution. Further Sm/Yb vs Sm diagram suggests that the metabasalts originated from a higher degree of partial melting of the relatively shallower mantle except one sample which indicate very less degree of partial melting and greater depth of magma generation. The variation in Mg# (0.31-0.52; avg. 0.43) indicates evolved to primitive nature of the metabasaltic rocks. When plotted in the Nb/Th vs $(La/Sm)_N$ diagram, the samples show no effect of crustal contamination expect for one sample (supported by Chondrite normalized REE patterns). The binary plot of Ce/Y vs $(La/Sm)_N$ suggest these samples to be N-MORB type which are derived from Depleted Mantle except one sample which got assimilated with the crustal materials.Further, the mantle source characteristics were assessed using ratios of Th/Yb and Nb/Yb.The samples fall in the MORB-OIB array mainly near N-MORB indicating depleted sourceexcept one sample suggesting a contribution from the enriched source. Field observations reveal that these samples are exposed as isolated bodies and at some places they also outcrop in association with chert deposits while one sample occurs intercalated with the metasedimentary lithounits. Based on the field investigation and geochemical characteristics we suggest that these samples were formed in an extensionaloceanic environment and originated from a shallower depth. They represent the opening of the Mangalwar basin while one sample representssyn-volcanic sedimentation which is also supported by field evidences.

Spatial distribution of heavy metals in soils surrounding the Raniganj open-cast coal mines, India

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Coal serves as the predominant energy source for electricity generation in India, where 95.64 % of the coal extracted is being produced from open-cast mines. Coal mining and the associated activities (removal of topsoil, coal excavation, overburden dump of waste and discarded rocks, uncovered transportation of coals and waste rocks) have been identified as significant contributors to soil pollution. This pollution adversely affects soil quality, crop yield, plant, animal, and human health, and pollutes the sediments of water catchment areas. Open-cast coal

mining generates substantial volumes of solid waste (4.31–11.36 times greater than underground mining) containing elevated levels of heavy metals which are typically disposed to the open lands surrounding the coal mines. The mobile characteristics of these heavy metals lead to their accumulation and persistence in the environment exacerbating soil quality deterioration. In this study, the concentration of potentially toxic elements (As, Cd, Co, Cr, Cu, Ni, Pb, and Zn) were determined in surface soil samples (0-0.15 m) surrounding the Raniganj open-cast coal mines. The pH of the soil samples varied from acidic (4.3) to slightly alkaline (7.9) with a mean pH value of 5.8. Elevated levels of total organic carbon (7.19 %) were attributed to coal fines deposited over time from coal, temporarily stacked or stored on the land surface. Ternary plot indicated that the texture of soil ranged from sandy silt to less abundant silty sand and silt type soils, with low clay content. The mean concentration of heavy metals in the studied soil samples were as follows: As (9.56 ppm), Cd (0.92 ppm), Co (25.53 ppm), Cr (265.40 ppm), Cu (42.67 ppm), Ni (43.30 ppm), Pb (122.70 ppm), and Zn (54.61 ppm). These concentrations revealed that Cd, Cr, Cu, Co, Ni, and Pb exhibited the most substantial contamination degree when compared to the geochemical background values. Spatial distribution maps further supported these findings, highlighting the pollution concentration in the northern and western parts of the study area where extensive mining activities have been carried out over the years. Environmental indices (geoaccumulation index contamination factors, enrichment factors, and pollution load index) identified Cr as the most enriched heavy metal in the studied soil samples, followed by Pb, Co, Cu, Cd, Ni, Zn, and As. High positive Pearson and Spearman correlation coefficients and a strong exponential relationship between Zn and pollution load index ($r = 0.992$) were observed. Principal component analysis (PCA) results inferred that Cd, Co, Cu, Ni, and Zn share a common source originating from coal mining activities, and accounting for 37.14 % of the total variance observed in PCA factor F1. Conversely, PCA factor F3 was dominated by Cr and Pb, suggesting additional anthropogenic influences aside from primary coal mining and allied activities. The finding supports the need for implementation of comprehensive soil monitoring initiatives in close proximity to coal-mining regions, to isolate pollution hotspots and formulate effective strategies to alleviate and prevent environmentally detrimental soil contamination.

Mantle source characteristics and magmatic processes during the formation of the Nagaland-Manipur Ophiolites, NE India: Constraints from Chromite and platinum group elements geochemistry

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Ophiolites in Indo-Myanmar Orogenic Belt (IMOB) contain significant podiform chromitite deposits hosted by mantle peridotites in the form of massive, nodular, disseminated occurrences, exhibiting physical and chemical characteristics typical of Alpine-Himalayan type chromium deposits. The Nagaland-Manipur ophiolites (NMO), part of the IMOB, occur in the NNE-SSW trending Indo-Myanmar Orogenic Belt (IMOB), northeast India. The NMO hosts both refractory grade high-Al chromitites ($0.46 < Cr\# < 0.53$) and metallurgical grade high-Cr chromitites ($0.71 < Cr\# < 0.79$). These chromitite bodies are hosted in mantle peridotites and show various textures including massive, disseminated, nodular and granular. The high-Al chromite compositions in conjunction with the calculated $(Al_2O_3)_{melt}$ (15.66-16.39 wt.%), $(TiO_2)_{melt}$ (0.65-0.94 wt.%) and $(FeO/MgO)_{melt}$ (0.65-0.83 wt.%) values indicate that they were derived from the tholeiitic melt that forms at the mid-ocean ridge centre through low-degree partial melting. In contrast, the high-Cr chromitites, coupled with the $(Al_2O_3)_{melt}$ (11.24-12.99 wt.%), $(TiO_2)_{melt}$ (0.21-0.33 wt.%) and $(FeO/MgO)_{melt}$ (0.58-1.54) values show similar geochemical affinities to those derived from boninitic melts produced by partial melting of already depleted mantle due to the subduction of oceanic crust in a supra-subduction zone environment. The total PGE content (60-190 ppb) of the high-Al chromitites is less as compared with the total PGE content (118-2341 ppb) in high-Cr chromitites. Chondrite-normalized PGE patterns in high-Al chromitites are flat from Os to Rh and negatively sloping from Rh to Pd, whereas high-Cr chromitites show a high (Os + Ir + Ru)/(Rh + Pt + Pd) with strongly fractionated chondrite-normalized PGE patterns. Total PGE contents and low Pd/Ir ratios (0.02–0.64) of chromitites are consistent with typical ophiolitic chromitites. Mineral chemistry and PGE systematics suggest that NMO chromitites were generated in two separate tectonic settings. The distinct gap observed between the chemical compositions of high-Al and high-Cr chromitites, together with the estimated compositions of the parental magmas for high-Al chromitites and high-Cr chromitites, indicates that these chromitites did not crystallize by differentiation of the same magma source. The high-Al chromitites are associated with tholeiitic melts that formed at the mid-oceanic ridge tectonic environment through low-degree partial melting. Following the change of tectonic regime to subduction, advanced partial melting triggered by the subduction of oceanic crust into previously depleted upper mantle

generated boninitic magmas; with the removal of these melts, the extensively depleted mantle was left behind, and the high-Cr chromitites crystallized from the melts. Thus, it is suggested that the Nagaland-Manipur ophiolites of northeast India is a fragment of oceanic lithosphere initially formed in a mid-ocean ridge setting that had been modified at a supra-subduction tectonic environment.

Field relationship and geochemical signatures of metabasalts from the Mahakoshal basin, Central Indian Tectonic Zone (CITZ): Implications for mantle source and tectonic setting

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The Central Indian Tectonic Zone (CITZ) is a suture zone that separates the North Indian Block (NIB) and South Indian Block (SIB). These two blocks amalgamated during the Proterozoic Eon. The CITZ consists of three supracrustal basins from north to south i.e., Mahakoshal, Betul and Sausar, respectively. The Mahakoshal basin is situated in the northern most part of the CITZ and lies between the Son-Narmada north fault (SNNF) and the Son-Narmada south fault (SNSF). The study of the metabasalts from the Mahakoshal basin is important to understand their petrogenesis and geodynamic setting.

In this study, we conducted a thorough field investigation, petrography and geochemical study to understand the petrogenesis of the metabasalts and the tectonic setting in which they were emplaced. The metabasalts are intercalated with metasedimentary rocks and show pillow structure, indicating that syn-sedimentary volcanism occurred under an aqueous condition in the Mahakoshal basin. These metabasalts are associated with andesite, dacite and rhyolite (BADR association), indicating their proximity to the arc. Mineralogically, these metabasalts consist of chlorite, actinolite and plagioclase. Epidote occurs as an alteration product. Chlorite and actinolite are elongated in nature. Based on the mineralogical association, we conclude that metabasalts are metamorphosed up to greenschist facies. Geochemically, metabasalts are characterized as being subalkaline in nature. In the $FeO^T + TiO_2 – Al_2O_3$ - MgO ternary diagram, they fall in the high Fe-tholeiite field. The chondrite normalized rare earth element patterns (REE) show two different types of patterns. Some metabasalts show a slightly enriched light rare earth element (LREE; La_N/Yb_N ranges from 1.44 to 1.72) and others show a more

enriched LREE pattern (La_N/Yb_N ranges from 5.77 to 7.31). The primitive mantle (PM) normalized multi-element diagram also shows two different gradients of the slope of large ion lithophile elements (LILE) and LREE, which further endorse their different degrees of partial melting. This is because LREE and LILE are more sensitive to the degree of partial melting than heavy rare earth elements. The Nb/Nb* values range from 0.7 to 1.3. The Ce/Y vs $(La/Yb)_N$ bivariate diagram indicates their E-MORB (enriched mid ocean ridge basalt) type source. Furthermore, to understand the tectonic setting of the Mahakoshal basin, we employed the V vs. Ti/1000 tectonic discriminant diagram, which indicates metabasalts are emplaced in the MORB + BAAB fields (mid oceanic ridge basalt + back-arc basin basalt). Hence the field, petrography, and geochemical evidence indicate that the Mahakoshal basin opened as a back-arc rift basin in which metabasalts are formed by different degrees of partial melting at different depths of an E-MORB type source.

Application of Electrical Resistivity Tomography (ERT) for the Evaluation of Slope Susceptibility

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Landslides are complex geological event leads to a serious socio-economic impact for the society as they create huge amount of economic loss as well as loss to the mankind lives. Due to steep slopes and severely sheared, crushed, and deformed rocks in the Himalayan region, mass movement, tectonic activity, and slope instability frequently occur. The formation of Himalaya orogeny undergone severe deformation having major discontinuities such as Himalayan Frontal Thrust (HFT), Main Boundary Fault (MBT) and Main Central Thrust (MCT). Instability of slopes in the Himalayan terrain appears to be aggravated by rising anthropogenic activities in the recent years such as widening of roads, deforestation, unplanned urbanization and construction, mining activities, hydroelectric projects, improper waste disposal, quarrying and excavation, unplanned tourism, improper sewerage and water supply system etc. Joshimath town in Chamoli district of Uttarakhand state is the living example of land subsidence which affected more than 40% of the area leads to 181 buildings marked as

unsafe and 868 buildings as cracked. A total of 217 families migrated to another places with total number of habitants as 810 (report by District Disaster Management authority, Chamoli on March 02, 2023). Another town in the district are also undergoing in same situation like Gopeshwar, Karanprayag etc. Hence the study of surface and subsurface is essential for the analysis of stability of such slopes. A promising geophysical tool, Electrical Resistivity Tomography (ERT) is a non-invasive method to investigate the stability of the natural as well as hill cut slopes rockfall to debris flow and to produce high resolution subsurface resistivity distribution models. The lithological, hydrological, and geotechnical parameters of the subsurface can all be indirectly measured using this technique. ERT is beneficial in the investigation of landslides because of its high sensitivity to water saturation in bedrock and colluvium which is a critical factor behind landslides. In order to reconstruct the slope body shape, identify potential sliding surfaces, pinpoint weak zones, estimate the thickness of the sliding materials, and locate places with high moisture content, ERT approach has been utilized. This technique for measuring subsurface geometry is quite promising for such areas like Joshimath Chamoli which are vulnerable to land subsidence and potential landslides, so that the future development of such places will be planned taking care of all the aspects with the essence of these areas remaining intact as they share strategic boundaries with Tibet China and are equally important in the field of tourism and pilgrimage.

Zircon separation from the northwest Himalayan mafic rocks: a potential method for U-Pb dating

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Uranium-Lead (U-Pb) dating of zircon has extensive applications in stratigraphic correlation, timing of magmatic and metamorphic events, source rock characterization, sediment transport and dispersal patterns in almost all the orogenic belts and cratons for tectonic interpretations and paleogeographic reconstructions. Zircon is the most prevalent and easily recovered in intermediate to felsic rocks (granitoids), making dating them easy; nevertheless, dating in mafic rocks is problematic because zircon mineral extraction from the mafic rock remains a difficult task. To overcome these challenges, we performed a zircon mineral separation from the mafic

rocks of the northwest Himalaya at the Central Laboratory-Wadia Institute of Himalayan Geology, Dehradun using a combination of physical and chemical heavy mineral separation techniques. First, petrographic studies were carried out, which revealed that the studied rock is a medium-corase grain, melanocratic gabbroic dyke made up of subophitic to ophitic texures with plagioclase, olivine, and clinopyroxene as the essential minerals and accessary mineral phases such as biotite, hornblende, apatite, and opaque. After petrographic screening, ~5-10 kg of the rock sample were crushed to a fine powder using a sledge hammer, a jaw crusher, and a disc mill. Powdered samples were sieved in a sterile 60 mesh size sieve, gravity separated using the Holman Wilfley water table, collected the heaviest fine particle, and then maintained within a 60°C oven for proper drying. Since mafic rocks still contain an abundance of magnetic minerals, dried samples are then further separated for lighter and magnetic minerals using an isodynamic magnetic separator, followed by chemical heavy liquid separation using bromoform and diodomethene. Finally, 40 to 50 zircon (>25 micron size) grains were manually picked under a binocular microscope, mounted in per-fluoro-alkoxy alkane (PFA®) Teflon, and then sequentially polished to reveal the zircon core-rim section using 8, 5, 3, and 0.25 _m diamond paste. Using a Zeiss EVO 40 EP scanning electron microscope and Zeiss Everhart-Thornley SE and Chroma UV CL2 detectors, cathodoluminescence (CL) images of the well-polished zircon grains were captured. The CL images provide easier to observe the internal features of zircon grains, which makes it quicker to locate the perfect spot for laser ablation by LA-MC-ICP-MS. Conclusion: Using the aforementioned techniques, we were able to successfully recover and separate the zircon grains from the medium-coarse grain gabbro, and it is currently being prepared for U-Pb dating analysis at the Wadia Institute of Himalayan Geology. Using the final zircon U-Pb data, it will be possible to constraints the new age, petrogenesis, and tectonic evolution of mafic rocks of the northwest Himalaya.

Geochemical characteristics of lakes sediments and abandoned channel deposits of Ganga River in parts of upper Ganga Plain: Implications for Provenance, Paleoweathering and Tectonic Settings

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The sediments of the lakes and abandoned channel deposits of Ganga River were studied for major, trace and rare earth elements (REEs). These are compared with Higher Himalayan Crystalline Series (HHCS), metasediments, Leucogranite and Lesser Himalayas Series (LHC) which is probable source in the Himalaya. The various indices of weathering (CIA, CIW, PIA) of oxbow lake sediments and abandoned channel deposits of Ganga River suggest low to moderate chemical weathering of the source rock. This indicates low to moderate chemical weathering in the source area and derivation of the sediments from the upper continental crust. Moreover, the average Th/U ratio (mean = 4.40) is also consistent with above explanation. However, the plot of chemical index of alteration (CIA) vs. index of compositional variability (ICV) shows that most of the lakes sediments and abandoned channel deposits are geochemically mature and a few are immature and were derived from low to moderate weathered source rock. The sediments were deposited dominantly in humid to semi-arid condition. Tectonically, these analyzed sediments sample are found to have affinities towards both the passive margin (PM) and the active continental margin (ACM) settings, which further implies existence of multiple tectonic activities during their deposition. Moreover, the elemental ratios of Eu/Eu*, La/Sc, Th/Sc, La/Co, Th/Co, Th/Cr and chondrite normalized REE distribution pattern suggest their derivation from sources of felsic composition. The high ratio of Zr/Sc indicates the enrichment of heavy mineral zircon supplemented by sediment recycling.

Identification of Land use and Land cover Impacts on Groundwater Quality in Kodavanar Watershed, A Part of Amaravathi Basin, Tamil Nadu, India

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Groundwater is the prime source of fresh water present in the globe which supports human life on the earth and is also significant for agriculture. In India, since from 1970s almost 60 percent of the total area of agricultural land is irrigated by groundwater throughout the country. In addition, around 85 percent of the rural people drinking water supply is also met from groundwater sources. In general there are numerous natural factors such as rainfall, quality of

permeable surface water and subsurface geochemical processes that can affect the quality of groundwater. In recent years the groundwater quality has been deterioyting primarily dueto the anthropogenic (non-geogenic) activities. Changes in the land use pattern resulting an alternative effect on the groundwater. Notably in few areas, the land use prevails over there has a dominant impact in altering the chemical quality of the groundwater. In precise, the change can affect water channels, quality and quantity of water and decline in the ecosystem. The present study is carryout in the study region of Kodavanar watershed, which is situated between 10° 11' 37" to 10° 27' 30" North latitudes and 77 °37'46 to 78° 01' 10" East longitude. The total geographical extent of the study area is around 2254 sq.km. The study area is mostly depend on seasonal rainfall for the usage of fresh water resource, so in the rest of the non-monsoon month and especially during the monsoon failure the people should totally depend on groundwater resource for their basic needs which includes drinking. So it is important to identify the impact of land use on groundwater quality. Hence, to carry out this study, a total of 42 groundwater samples were collected from bore wells and wells with cosidring the underlying geology and spatial distance, for the post-monsoon season (January 2022). The samples were analysed for Ca, Mg, Na, K, HCO_3, Cl, SO_4, F, NO_3, pH, EC, and TDS by using American Public Health Association standard procedures. The Piper tri-linear diagrams, USSL diagram have also been prepared by using Aqua chem software to discover the major cation, anion and to assess the sodium hazard, salinity hazard for the study area. The Inverse Distance Weighted (IDW) interpolation method was used to map the spatial distribution of each parameters. The Water Quality Index (WQI) has been calculated to examine the drinking suitability. The Land use has been mapped using Sentinel 2A and the values of land use and WQI have been extracted using systematic random points. Finally, the relation between land use and groundwater quality has been identified and resulted that the agricultural land use has adverse effect on groundwater quality. Thus, the region identified with poor water quality from the WQI and agricultural land use has major impact on that, the high priority has to be given to control the impact of agricultural based sources of pollution in groundwater to bulit a sustainable future.

Petrochemical study of Sendra plutonic suite of Ambaji – Sendra arc terrain, Sirohi – Banaskantha districts

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In the NW Indian shield, the western of central Aravalli orogen consists of numerous Neoproterozoic (990–970 Ma) granitic intrusions, which are considered to have formed during the assembly of the Rodinia Supercontinent (Deb et. al. 2001; Pandit et al., 2003; Singh et. al. 2010; 2021; Zhao et. al. 2018). These granitic plutons, along with subordinate rhyolites exposed around Sendra, are collectively termed as Sendra Granitoid Suite (Agrawal & Srivastava, 1997; Tiwana, et. al. 2020). The limited geochronological data (zircon U–Pb) suggest that the emplacement of these plutons took place between 990 and 970 Ma (Deb et al., 2001; Pandit et al., 2003; S. Singh et al., 2021). Nevertheless, there is a lack of comprehensive petrological and geochemical data on these rocks. This inadequacy of such data led to inconsistent interpretations about the tectonic setting of the Sendra granitoids. For example, Pandit et al. (2003), consider Sendra granitoid as I-type granites emplaced in Andean-type convergent settings whereas Tiwana et al.(2020) interpret these as magmatic post-collisional extensional A-type granites. The comprehensive petrochemical data of Sendra granitoids generated in the present study suggests their complex genesis and diachronous emplacement. The Sendra granitoids possess two types of granites. One variety is peraluminous with high total REE abundances coupled with low CaO and high HFSE concentrations. The Fe-number, and Ga/Al ratios classify this variety as A-type and its Y/Nb ratio (>1.2) categorizes it as A2-subtype, signifying its derivation from crustal sources in a post-collisional setting. The second variety of granites is magnesian (low Fe- number) and has low total REE, HFSE, and Ga/Al ratio. These granites plot in volcanic arc field in Y+Nb vs Rb plot. The primitive-mantle normalized multielement plots of the granites of both varieties show prominent but variable negative anomalies for Ba, Sr–Eu, and Nb which are likely to be related to the fractionation of K-feldspar-biotite, plagioclase, and rutile respectively. The present data suggest that Sendra Granitoids owe their magmatic as well as crustal origin, that they were initially emplaced in an arc setting and subsequently in the extensional back-arc setting.

Geochemical assessment for hydrocarbon source rock potential of Jaintia Hill coals, Meghalaya, India

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India possesses extensive coal reserves, yet it imports approximately 80 percent of its liquid hydrocarbons to meet the growing demand. In recent decades, there has been significant interest in exploring the potential of coal as a source rock for petroleum. Specifically, low-rank coal with a high hydrogen content and a maceral group capable of generating hydrocarbons (such as liptinite) is considered promising as a hydrocarbon source rock. The low-rank Tertiary coals of Meghalaya were chosen for this study. Sixteen coal samples were collected from active coal quarries in East Jaintia Hills and subsequently subjected to Ultimate analysis. According to early theories, liptinite was thought to be oil-prone and vitrinite was gas-prone, while inertinite had little to no potential for producing petroleum. Many researchers focused on liptinite and set a minimum percentage (15% to 20% of liptinite) level of liptinite macerals in coal as a criterion for considering it a potential hydrocarbon source. Studied coal contains just 5.63% of liptinite, which is far less than the estimated number to produce liquid hydrocarbon; however, recent studies show that coal rich in liptinite and/or perhydrous vitrinite (hydrogen-rich maceral) has the potential to produce liquid hydrocarbons. Perhydrous vitrinite, in particular, may contribute significantly more to hydrocarbon generation than other maceral groups. In some cases, perhydrous vitrinite may contribute the most to hydrocarbon generation compared to other maceral groups. Vitrinite can be classified into perhydrous, orthhydrous, and subhydrous based on its hydrogen and carbon weight percentage. Perhydrous vitrinite, with over 5.5% hydrogen by weight, has been identified as a source material for liquid hydrocarbons in certain sedimentary basins. The hydrogen and carbon percentages of the study samples were plotted on the diagram given by Diessel (1992). The results show that the data points spread over a large area ranging from perhydrous to subhydrous, but their concentration in the zone of perhydrous vitrinite indicates that these coals have the potential to generate liquid hydrocarbons upon maturation. Van Krevelen's plot, based on H/C and O/C atomic ratios, suggests that the study samples belong to a mix of Type II and Type III kerogen, indicating a combination of oil and gas-prone characteristics in these coals. The aforementioned analysis suggests that this coal can be considered as a source of hydrocarbon.

Hydro-chemical characteristics and water quality evaluation of natural freshwater wetlands in Doon Valley

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Global Climate Change (GCC) threatens ecosystems in both developing and developed countries. Freshwater habitats occupy about 0.8% of the earth's surface and are a lifeline of species diversity per unit area and nurturing around 6% of the earth's species. The GCC, rapid urbanization and anthropogenic stresses are the major and direct drivers to make an impact on the global wetland ecosystems and water pollution. Wetlands cover 5% of the total area in India and 75 freshwater wetlands have been listed in the Ramsar sites of International importance on the 75th Independence Day (2022). Wetlands are generally sandwiched between a terrestrial ecosystem and open water bodies. There are 116 wetlands including one Ramsar site (Asan wetland) situated in Uttarakhand state. Apart from the Ramsar site, seven freshwater wetlands are supporting the habitat of many endangered biotas of Doon Valley, where rapid and uncontrolled urbanization is taking place. The water quality parameters that include temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), major ions (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, HCO_3^{-}, Cl^{-}, F^{-}, SO_4^{2-}, NO_3^{-}), trace elements (Zn, Sr, Fe, Ni, Li, Cr, Cu, Cd, Mn, Co) were measured in the wetlands of Doon valley (impacted by anthropogenic activities in recent times), Uttarakhand, i.e., (Asan Left, Asan Right, Asan Central, Asan Ramsar site, Dakpathar, Nakronda, and Virbhadra) and Manu swamp. The Doon Valley is NE-SE trending one of the largest intermontane valleys (~ 80 km long and ~25 km wide) between the Lesser Himalaya to the north and the Siwalik ranges in the south. An intensive work has been conducted throughout the calendar year (2021-2022). The results show average pH, TDS, DO, and EC of 7.7 ± 0.6, 170 ± 113 mg L^{-1}, 6.70± 2.9 mg L^{-1}, 378.3 ± 242.9 µS cm^{-1} for the summer, and 8.2 ± 0.4, 172 ± 90 mg L^{-1}, 8.6 ± 3.8 mg L^{-1}, 327 ± 171 µS cm^{-1}, for the winter seasons, respectively. Geochemical facies of the wetlands are characterized by the Ca^{+2}:Mg^{+2}:HCO_3^{-} type for both seasons. This suggests a similar lithological setup (carbonate weathering) of all the wetlands in the Doon Valley. We have observed that the water quality of all the wetlands in the Doon Valley is badly affected during the summer. The newly developed water pollution index (WPI) approach was used to calculate the pollution load or water quality. Among all the wetlands in the study area, the elevated dissolved nitrate (NO_3^{-}) concentration in the Nakronda and Manu swamp may be attributed to Human intervention. WPI offered four classifications for water quality: WPI 0.5 denotes

excellent quality, 0.5 > WPI < 0.75 denotes good quality, 0.75 > WPI < 1 represents water with moderate pollution. Whereas, WPI > 1 denotes extremely polluted water. We report here the WPI ranging from 0.16- 0.43 with a mean value of 0.25 and 0.13- 0.51 for the winter and summer seasons, respectively, and an average value of 0.25. This indicates that the water quality in the wetlands of Doon Valley falls under excellent water quality except the Nakronda which falls under the good water category.

Equation of state and high-pressure phase transitions in Mg_2GeO_4 forsterite

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(Mg, Fe)2 SiO4 olivine is one of the most abundant minerals in the Earth's upper mantle. With increasing pressure and temperature, forsterite (α-olivine) undergoes a series of phase transitions that is, wadsleyite (β-olivine)-ringwoodite (g-olivine)-perovskite+ magnesiowustite –post-perovskite. Although, post-perovskite is the last observed silicate phase in the Earth, under conditions equivalent to super-Earth mantles (>1 TPa pressure and 4000 K temperature) it may no longer be stable. However, to test this hypothesis we have to use analog materials like germanates because we can observe the same phase transitions at lower pressures (Dutta et al., 2022). Mg_2GeO_4 forsterite was synthesized by heating stoichiometric proportions of MgO and GeO2. High-pressures were attained using Diamond Anvil Cell device. Double sided laser heating was used to generate high temperatures. Synchrotron X-rays at the Advanced Photon Source, Chicago, USA were used as the x-ray source for probing the sample. Computations based on density functional theory have been used to complement diffraction experiments. We have shown that forsterite (Mg_2GeO_4) is stable up to 30GPa, above which the phase changes to a novel Forsterite III structure, which remains stable up to 73GPa. This is in contrast to previous work which suggested a pressure-induced amorphization between 25GPa and 30GPa (Nagai et al.,1994). We have calculated the lattice parameters of both the phases up to the peak pressure. A third order Birch Murnaghan fit to the DFT data yielded the values V0: 316.8 (3), K0: 111.2 (13) and Kp: 3.86(5), where V_0, K_o and K_p are ambient pressure unit

cell volume, isothermal bulk modulus and its pressure derivative respectively. This was found to be in very good agreement with the experimental data V_0: 305.1(3), K_0: 124.5(14) and K_p: 3.85.

Assessment of groundwater quality in vicinity of coal mines of Northern Coal field Limited (NCL), Singrauli, Central India

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The main objective of the study is to evaluate the water quality of groundwater and its suitability for drinking purposes. Attempt has been made to understand hydrogeochemical processes controlling the groundwater quality of Singrauli area. In this study, 20 groundwater samples were collected from hand pump, bore well in June 2022 and were analysed. The pH, electric conductivity (EC), TDS and temperature were measured in situ and major ions are analysed in the laboratory at NIH Roorkee. The pH of groundwater samples varies from 5.5 to 7.3 with an average of 6.7 which indicate acidic to alkaline nature. The TDS value of groundwater varied from 172 mg/L to 900 mg/L (avg: 519 mg/L). The dominant cation and anion series of groundwater samples of the area is given by $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+}$, and $HCO_3^{-} > SO_4^{2-} > Cl^{-} > NO_3^{-} > CO_3^{2-} > F^{-}$ respectively. The anion and cation chemistry of ground water is dominated by HCO_3^{-} with average value (226.4 mgL^{-1}) and Ca^{2+} with an average value of (65.1 mgL^{-1}) respectively. Most of the groundwater samples are characterized by Ca^{2+}- Mg^{2+}-HCO_3^{-}, and mixed Ca^{+2}-Mg^{+2}-SO_4^{-2}-Cl^{-} type of water facies. The result of Weighted Average Water Quality Index (WAWQI) indicates 34% groundwater samples are unsuitable for drinking purposes. The Chemometric and classical bivariate analysis results indicate that silicate weathering and ion exchange are the key hydrogeochemical processes controlling water chemistry. Out of total samples 15% of the water samples have more NO_3^{-} ion concentration than the permissible limit. The results of the chemical analysis and chemometric method indicate that rock weathering and anthropogenic activities have the greatest influence on groundwater composition.

Development of earthquake early warning scaling relations for the Kumaon Himalaya using both simulated and observed datasets

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The Kumaon region lies in the NW Himalaya India, is one of the most seismically vulnerable parts of the Uttarakhand Himalaya. The Kumaon region lies in the central seismic gap and this region is one of the most likely locations for future earthquakes. Rapid urbanization, man-made structures and population grow, suggesting increased seismic risk in the near by regions. This strongly requires an earthquake early warning (EEW) system, which will improve the region's seismic risk assessment and mitigation. These technologies are able to quickly identify earthquakes after they happen and send out alerts to the most vulnerable regions before the seismic waves that might cause damage arrive. This work aims to develop region-specific scaling relationships for the Kumaon region using both observed and simulated datasets. We first modified the semi-empirical technique for P-wave simulation for the 2011 Indo-Nepal earthquake (M 5.4). We then simulate seven future earthquakes (M 6.0-7.5) using MSET. Afterwards, we estimated EEW parameters: Average Period (τ_c), Peak amplitude displacement (P_d) and Peak ground velocity (PGV) are extracted from 53 cataloged events (M 2.7-5.4) and seven simulated events (M 6.0-7.5). Using a hybrid (observed and simulated) dataset, we suggest new earthquake magnitude relations with τ_c and P_d in addition to the P_d-PGV relation. The developed regression relations are then used to predict magnitude and PGV using average values of estimated EEW parameters. In addition, for 15 densely populated cities close to the study's area, lead time estimation using the proposed relation ranges from 18 to 90 seconds.

Geochemical characterization of lateritic profiles in Garbeta, West Bengal

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Laterites are mainly found in stable cratons and are the products of chemical weathering under warm, humid climates of the tropics. A typical lateritic profile consists of three major horizons

namely the saprolite, the ferruginous nodular layers and the bioturbated surface soils. Laterites occupy a sizeable portion of the Chotanagpur Plateau, mainly in West Bengal and Jharkhand. They occur at two topographic levels: the 'primary' laterites formed by in-situ weathering of rocks along the plateau fringe and 'secondary' laterites formed by the reworking of the primary laterites. The secondary laterites span across the length of Rarh region, from Jhargram to Birbhum districts of West Bengal. Of these, those exposed along the scarp faces at Gangani badlands, near Garbeta in Paschim Medinipur district are perhaps the most well-known. Here, the secondary laterites are exposed along the gully walls, and are, unlike most other lateritic profiles in the Rarh, profoundly horizonated. Even though there have been a number of studies on the gullies at Gangani, these lateritic profiles have not been systematically documented. Therefore, this study presents preliminary results from an ongoing characterization of the geochemical changes occurring within lateritic profiles at Gangani due to the progression of lateritisation. Combining major element data with grain size analysis, assessments of the geochemical nature of the laterite was done while also ascertaining the degree of weathering-related changes within two secondary lateritic profiles, situated in the eastern and western parts of the Gangani badlands. Two weathering indices, Chemical Index of Alteration (CIA) and Mafic Index of Alteration (for oxidising environments- MIAo) were used, along with the Index of Lateritisation (IoL), to discern these changes. Results suggest that both profiles are composed of coarse to very coarse sands (average Mz = 1.0 in the western profile and 0.059 in the eastern profile), but the proportion of gravels is higher in the eastern part, especially in the lower layers. The sediments are mostly poorly sorted, fine to very fine skewed and are platykurtic to leptokurtic in nature. Geochemically, they are characterized by loss of SiO_2 and accumulation of Fe_2O_3 andAl_2O_3 in the upper layers, resulting in the formation of hard crusts. Both profiles are highly weathered, with mean CIA and MIAo values of 85% and 87% respectively, but show variable degrees of lateritisation, with the eastern profile having a higher IoL value (~ 44%) than its western counterpart (~40%). The dominance of coarse grained, poorly sorted and platykurtic to leptokurtic sediments in both studied profiles points to their deposition under moderate to high-energy conditions. Furthermore, most of the samples are yet to be fully kaolinitized, suggesting that they are presently at incipient stages of chemical weathering. Together, the data indicates that the lateritic profiles at Gangani are composed of river-borne sediments, which are undergoing re-lateritisation. Since this re-lateritisation process involves in-situ transformation of dominantly allochthonous materials, the lateritic

exposures at Gangani should be considered as 'ferricrete alteration profiles' (*sensu* Widdowson, 2007) rather than lateritic weathering profiles, by which they are usually referred.

High-temperature behavior of Pb-ZnS

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Galena (PbS) and sphalerite (ZnS) are often associated and considered the most important ore minerals for the extraction of lead and zinc, respectively. The Indian Bureau of Mines, in its latest report, estimates the total reserve of Pb and Zn to be ~750 million tonnes [3], with ~85% being classified as "remaining resources." The constant demand from lead-acid battery and galvanizing industries is expected to increase the mining and extraction of these metals. Studying them under extreme temperature conditions will help us understand the stability of these phases during ore extraction processes. Here, we report the temperature phase relations in pure PbS, pure ZnS, and a natural sample with intermediate composition. Initially, we began with synthetic PbS and ZnS. We performed XRD and Raman spectroscopic measurements at temperatures up to 1000°C in increments of 100°C. Our findings

revealed that PbS transforms into novel phases at high-temperature. Our specially designed Raman system allowed us to measure low-wavenumber peaks as low as 38 cm-1. In pure PbS and ZnS, new Raman modes were observed at temperatures > 500 °C and 600 °C, respectively. The x-ray diffraction data supports the above mentioned observation, showing new peaks above the same temperatures. The natural galena sample was first characterized using Field Emission Scanning electron microscopy (ZnS: 4-5%, PbS >93%). In this case, the phase transition commenced at temperatures > 600°C, which is 100°C later than the synthetic PbS. We also observed distinct color changes in all three samples at different temperatures. ZnS shifted from yellowish white to whitish yellow, synthetic PbS changed from black to whitish yellow, while the natural sample transitioned from black to pale yellow.

Abstracts Theme

Artificial Intelligence in Geosciences

Source rock properties, depositional environment and hydrocarbon generation potential of lower Gondwana shales and coals from Talchir and Godavari basins of Eastern India

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The Gondwana Basins of India account for nearly 99% of the coal resources of the country. These also host organically-rich and thermally mature shales interbedded with the coals and are a potential source for the gaseous hydrocarbons. This study presents the source rock characteristics, depositional environment, and quantitative hydrocarbon generation potential of the Permian Barakar shales and coals from the Talchir and Godavari basins of Eastern India. The organic richness, measured in terms of total organic carbon (TOC) content; the type of kerogen, characterized by the organic provenance and its thermal maturity are important criteria to evaluate a source rock for its hydrocarbon generation potential. The TOC content of shale and coal samples from the Talchir Basin is in the range of 1.8 - 3.6 and 41.3-46.8 wt%, respectively; whereas the Bhupalpally coals of the Godavari basin show a higher TOC content of 11.4-65.5 wt%. Majority of Barakar coals exhibit Type III kerogen, sourced dominantly from terrestrial organic matter, with minor input of Type IV. In comparison, Godavari coals belong to Type-II and admixed Type-II & III sources, suggesting input both from terrestrial as well as shallow marine, particularly from estuarine environment. Coals of both basins are characterized by thermally immature to early mature kerogen (pyrolysis T_{max} = 417 to 432^{0}C). The artificially simulated kerogen decomposition kinetics indicate broad activation energy distribution of Barakar samples from the Talchir basin, suggesting higher organic heterogeneity, compared to that from the Godavari basin. Kerogen transformation and hydrocarbon generation occur at lower temperatures with faster rates for the samples from both basins. This study reveals a significant difference in the hydrocarbon characters in terms of source rock potentiality, organic maturity and depositional environment for Talchir and Godavari basins. Our results indicate that the shales and coals from Barakar Formation from

Godavari are promising for gas prospects, whereas the equivalents from the Talchir sub-basin are suitable for their liquefaction to oil.

Enhancing Spatial Resolution and Understanding Temporal Variability of Terrestrial Water Storage Anomaly in Peninsular India: A Case Study of Krishna Basin and Andhra Pradesh

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The peninsular region of India has long been grappling with freshwater scarcity issues. The Peninsular rivers largely exhibit ephemeral nature as they rely exclusively on monsoonal precipitation for their water supply. The prevalence of hard rock formations having limited porosity and permeability limits the potential of groundwater resource, which further amplifies the water scarcity in the region. Although greater attention has been directed towards the North Indian states due to a high negative trend observed in the Terrestrial Water Storage Anomaly (TWSA) derived from GRACE satellite, the south Indian regions have been largely ignored because of slightly positive or insignificant trends. Studying the spatial and temporal variability of TWSA can help understand and mitigate the water scarcity issues of the region. This study offers a thorough examination of TWSA in two regions of peninsular India namely Krishna Basin and Andhra Pradesh. First, we employ the coarse-resolution (~1°) GRACE TWSA data along with fine-scale hydroclimatic variables to enhance the spatial resolution of TWSA values up to 0.25°. We use the Long Short-Term Memory model to obtain a spatially detailed and temporally continuous overview of TWSA. The model results are validated through a novel approach and have shown excellent capabilities in representing TWSA at higher spatial resolution. The higher resolution (downscaled) product is then used to calculate the groundwater Storage Anomaly (GWSA). The GWSA thus obtained is compared with in-situ data and Community Land Surface Model simulated GWSA values. The comparison indicates that, in contrast to the Krishna basin, Andhra Pradesh uses larger quantities of deeper groundwater storage. We used Dominance Analysis to identify the hydrologic factors that can better explain the dynamics of TWSA. The analysis recognizes soil moisture, Normalized Difference Vegetation Index (NDVI), and Evaporative Stress Factor (ESF) as crucial factors in explaining the spatio-temporal variability of TWSA in a region. These critical insights

provide a foundation for predicting future groundwater depletion patterns and offer essential guidance for freshwater monitoring and management strategies.

Coal as a Resource of Rare Earth Elements (REEs): Benefits and its Impacts on society

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In the present scenario rising demands for E-gadgets, E-vehicle, making permanent magnets, renewables, the defence industry, making alloys; we need massive amounts of REEs (REE+Sc+Y) elements to fulfill the needs. Primarily REEs is extracted and exported from China to other countries of the world, so it has significant control over the global market. Complete dependency on China for REEs is a matter of concern regarding political insecurity worldwide. Literature indicates that carbonatite (0.5%) and per-alkaline rocks are the primary sources of REEs, but their abundance is very low in India. So, we must look up non-conventional sources for the beneficial recovery of REEs. Research studies indicate that coal ash and fly ash can potentially produce REEs. Traditional methods of REY extraction using harsh acids are dangerous to the biotic world. China has produced huge chemical waste from REY extraction in the last few decades. The dumping of chemical waste in an anthropogenic lake created one of the most polluted sites in China, among the top 10 polluted sites in the world. So, there is a need to generate noble ideas for more accessible and cheaper extraction methods and extraction of REY with non-conventional sources. Coal is made up of Organic and Inorganic parts. The inorganic part of coal always remains a problem for thermal power plants, which is the cause of pollution in the form of ash and fly ash. Ash and fly ash have been dumped for many years, and it has minimal usage. Researchers have found that REY and trace elements are associated with the Inorganic part of coal in many countries like the U.S., China, and India. So, if we start to extract the REY from coal ash and fly ash, this will be like we are producing something worthy from waste (Waste to wealth). There is a need for the types of equipment that we can install in thermal power plants at the last stage of thermal processing so that we can harness the REEs from the same thermal power plants. It has many advantages-

1) the cost of ash dumping will be reduced,

2) we will harness the REEs from the same thermal power plant, so there is no need to install new plants at the new location

3) it will reduce the problem of groundwater contamination by leaching of elements, and

4) it will reduce soil and atmospheric pollution due to the presence of heavy elements in ash and fly ash.

Extracting REEs from ash and fly ash will make coal-based industries more profitable and reduce its environmental concerns.

Prediction of Landslide prone areas in Dima Hasao District of Assam, India using Random Forest model

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Landslides are one of the major hazards in mountainous areas, impacting human life and infrastructure. To minimize losses and prepare mitigation plans, the identification of landslide prone area is a fundamental requirement. Therefore, landslide susceptibility mapping (LSM) was conducted in the Dima Hasao district of Assam state, India using Random Forest model (RF). In this process, fifteen landslide controlling factors were identified and used to predict the landslide prone areas. These factors were initially undertaken for the multicollinearity test for enhancing the model's prediction ability. Afterwards, seventy percent of the dataset, consisting of landslide and non-landslide pixels, was used for model training, and the remaining 30% was used for model validation. Subsequently, the landslide susceptibility map of the area was generated. The success and prediction rate curves based on the area underneath the receiver operating characteristic (ROC) curve were used to assess the efficacy or performance of the RF model utilised in this study. A success rate of 0.917 and the prediction rate of 0.923 was achieved in the present study. Finally, the predicted LSMs were divided into five classes using equal interval classification methods: very low, low, medium, high, and very high. It was found that the about 42.45 % of the area fell within the moderate landslide susceptibility zone, while

28.22 % of the area was prone to high landslide susceptibility. The region with a high susceptibility to landslides was approximately 3.86 %, primarily concentrated in the southern and south-eastern parts characterized by hilly topography. Furthermore, the estimation of the contribution of the selected factors in landslide susceptibility revealed that distance from the road was the most important factor, which was followed by distance to the river, slope angle, and lithology. Conversely, Curvature was found to be the least contributing factor followed by Aspect. The study may be used for the development of district disaster management plan for better disaster governance.

Disaster Risk Exposure to Social Well-Being and Resilient in Kodaikanal Environ, Tamil Nadu Using GIS Techniques

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Hilly areas are particularly prone to natural disasters such as landslides, flash floods, and earthquakes. It is imperative to have disaster preparedness plans and strategies in place to support the recovery of affected communities and mitigate the impact of disasters on hilly areas. Research on social well-being recognizes that physical and socioeconomic factors are important in influencing individual and community access to resources, opportunities, and social support systems. Socioeconomic factors such as income, education, and employment opportunities have a significant impact on an individual`s ability to access resources, and social networks, and participate in activities that promote well-being. It is therefore imperative to have preparedness plans and strategies in place to mitigate its impacts and assist affected communities in their recovery. Kodaikanal is the study area located in a geographical extension of 10° 14' 17' 21" north latitude and 77° 29' 21" east longitude. The study area extends over an area of 1747 Sq.km. During summer (from March to May), the temperature stays between 30°C to 20°C, while in winter (from December to February) the temperature ranges between 17.3°C to 8.3°C. Monsoon could, however, be seen during the months of June to September annual rainfall is 239.19 cm. The Kodaikanal town extends over an area of 21.45 Sq.km with a population of 45,232. This study aims to map the physical and socioeconomic vulnerable areas with the help of a Geographical Information System (GIS). The first stage analysis makes use

of the thematic layers in combination with environmental factors such as Geology, Geomorphology, slope, aspect, relief, NDVI, rainfall, LST, wind speed, TWI are parametres leading to support for the second stage analysis using weighted overlay in geospatial analysis. According to physical considerations, the final map reveals that the majority of the disaster-prone locations are Kodaikanal, Mannavanur, Adukkam, Pannaikadu, and sections of Melachokkanathapuram, Vadagounchi, Poolathur, and Panrimalai, while the rest places are non disaster-prone. The Landslides may be caused by steep hills, severe rainfall, roads, buildings, and other factors. Heavy rains during the monsoon season in and around Kodaikanal can loosen the soil and render it unstable. This renders the slope prone to landslides. This area's foothills are made up of a mix of hard and soft rocks, which can cause varying weathering and erosion. This process can weaken the soil and rock layers, making them more prone to landslides. Moreover, weighted overlay analysis was used for detecting vulnerable areas in Kodaikanal environments. Strengthening infrastructure is also important to protect communities from physical vulnerabilities such as natural disasters.

Machine Learning approach for attenuating random noise in land seismic data from Ganga Valley Basin, India

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Seismic exploration plays a pivotal role in the oil and gas industry and in various geological and environmental studies. However, the quality of seismic data can be compromised by the presence of various noise sources, such as ground vibrations, equipment malfunctions, and environmental factors. These random noises appear on reflection seismic data, shows high frequency spikes and high-amplitude having low velocity, which can affect the signal-to-noise ratio (SNR) of seismic data. Accurate interpretation of subsurface structures relies on effective noise attenuation techniques. Therefore, in land seismic data processing, estimation and attenuation of these random noises are essential to enhance the signal-to-noise ratio (SNR) and improve the subsurface seismic image quality. Conventional random noise reduction techniques such as statistical filters, median filters, or wavelet denoising are applied to suppress random noise, which often appears as high-frequency spikes or irregular fluctuations in the data. Therefore, machine learning techniques, including neural networks and deep learning

models, have been increasingly employed for noise attenuation in post-stack seismic data. These models can learn complex noise patterns and adapt to different geological settings. In recent years, self-supervised machine learning has emerged as a powerful tool in seismic noise attenuation, offering the potential to enhance the quality and reliability of seismic data. In this study, self-supervised blind spot networks were used to attenuate random noise energy in the post-stacked land reflection seismic data acquired in the Ganga Valley Basin, India. The primary goal of post-stack seismic noise attenuation is to improve the signal-to-noise ratio (SNR) of seismic data. Reducing random noise makes the geological features and subsurface structures of interest more pronounced and easier to interpret.

Impact of projected precipitation under climate change on the landslide susceptibility in the Upper Beas Valley (Himachal Pradesh)

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Landslides and related phenomena account for the loss of life and damage to property worth millions of dollars every year and are a cause of concern. These are mainly attributed to steep slopes, fragile lithology, high topographic relief, complex geological-physiographical characteristics, and climatic conditions of the terrain. Out of these, rainfall has been accounted as the major factor responsible for the highest number of landslide occurrences. India alone contributes ~ 16% of the world's total rainfall-induced landslides. These numbers are expected to increase in the future as climate change can exacerbate the rainfall intensity that may lead to landslides. The present study assessed the impact of climate change on the landslide susceptibility in the Upper Beas valley, Himachal Pradesh. To accomplish this, 11 independent variables including slope aspect, distance to drainage, elevation, lithology, land use and land cover, plan curvature, profile curvature, distance to road, slope angle, distance to thrust, and rainfall, and an inventory of landslides were taken into consideration. Rainfall projections for the years 2040 and 2070 were prepared using the CMhyd (Climate model data for hydrologic modelling) under the principal shared socioeconomic pathway (SSP) scenario SSP5-8.5 based on MIROC6 CMIP6 model bias-corrected by the method of Equidistant Cumulative Distribution Functions. Three susceptibility maps were prepared considering the present and future rainfall scenarios for the years 2040 and 2070 using an artificial intelligence method

random forest (RF). The results indicate that with the projected climate there is a pronounced shift in the landslide susceptibility zones with time. The RF model using the worst scenario of CMIP SSP5-8.5 observed the rainfall shifting pattern and predicted that the proportions of the very-high landslide susceptibility would increase gradually from 2022 to 2040, and 2070. The predictive power of the model was assessed using the area under the curve (AUC) which is around 89.2%.

Seismicity pattern of Andaman-Sumatra region – Study of Seismic Quiescence and b-value as possible precursors

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Objectives: a) To analyze the long-term seismicity and understand the potential of seismic quiescence study to use it as a reliable seismic precursor b) To estimate b-value and understand the variation in b-value as earthquake precursor in seismically active region.

Methods: The present study analyses the seismicity pattern from the Andaman-Sumatra region for a period of 1964 to 2020. The area has been divided into 7 epicentral blocks. Earthquakes preceding and succeeding a major earthquake with different seismic phases of quiescence and pattern of seismicity have been studied carefully. All quiescence periods are characterized by high b values and period of major shocks has a low b value. Main shock events for each epicentral block with different phases of quiescence (Q1, Q2 and Q3) and active seismicity have been identified and analyzed.

Findings: The study suggests that there is generally approximately 6-12 years of gap between major earthquakes. But combined analysis of blocks 5 and blocks 6 reveals that the area was comparatively quiet for a long period of around 28 years before the megathrust earthquakes of 2004, suggesting that long-term quiescence leads to great earthquakes. Magmatic pulsations can result in earthquake swarms in volcanically active areas such as Off -Nicobar region. Our analysis shows that the northern segments are comparatively quiet since the megathrust earthquake, which can lead to a major earthquake in the near future. Based on the mapping of co-seismic ruptures of the Eastern boundary thrust of Andaman over the last 2000 years scientists suggest an increase in slip deficit which can lead to a large magnitude earthquake in the Andaman- Nicobar region. A thorough analysis of long-term seismicity and seismic quiescence can be used as an earthquake precursor, though with limitations. The latest post

seismic quiescence period Q2 after the greater events of 2004 and 2005, may yield an impending event of 6.5 Mw or even greater. The study suggests that a proper study of the long-term seismicity and seismic quiescence can be used an effective earthquake precursor. All quiescence periods are characterized by high b values and period of major shocks has a low b value. Such studies can help in preparing a mitigation plan of seismic hazard.

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