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National Conference
on

GEODIVERSITY AND GEOHERITAGE OF INDIA AND ITS SUSTAINABLE DEVELOPMENT

Delhi, 6-7 October, 2025

Abstract Book

Mahabaleshwar Deccan Traps, India
Second 100 IUGS Geological Heritage Site

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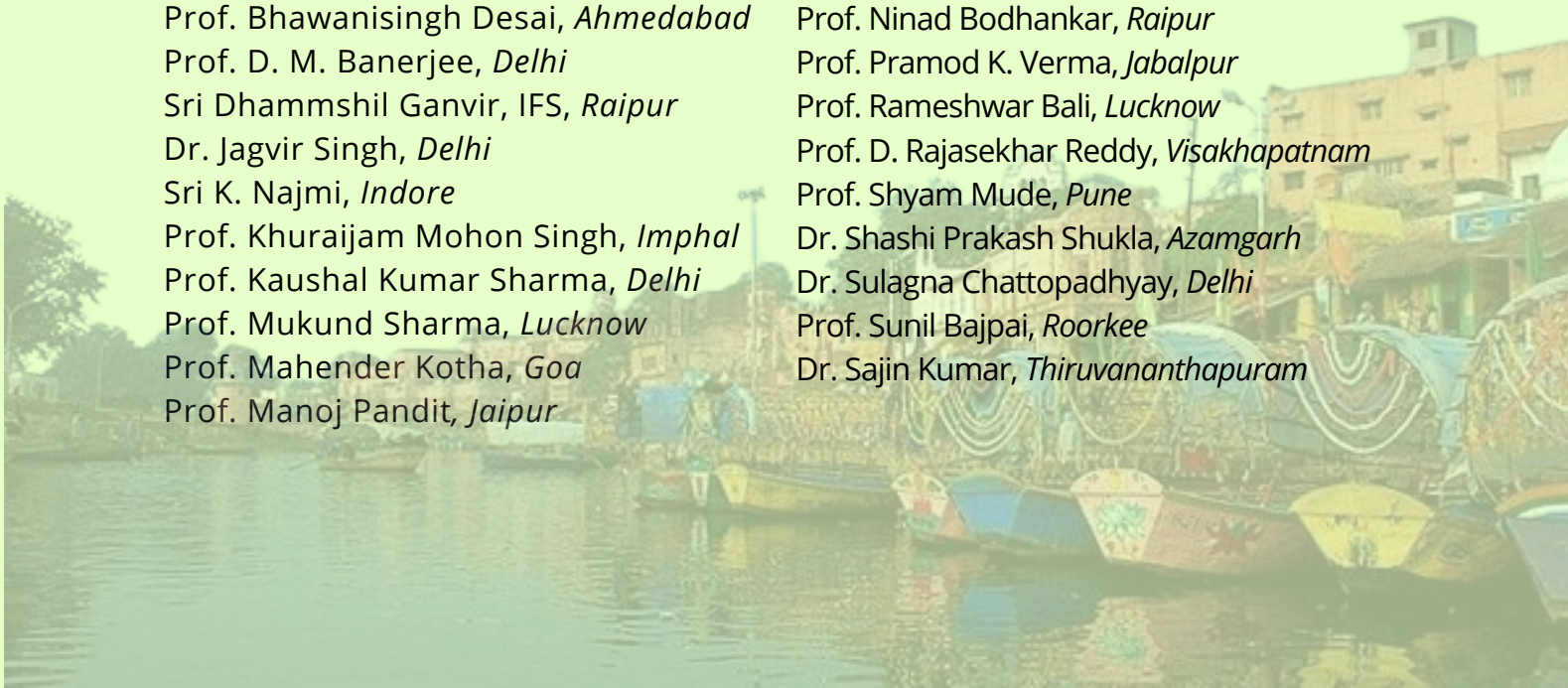

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Content

Geoheritage at the Crossroads: India's Legal Landscape and International Best Practices

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ABSTRACT

India, endowed with exceptional geological diversity- from Precambrian cratons and fossil-rich Gondwana basins to the Deccan Traps and the tectonically active Himalayan orogeny- remains underrepresented in global geoheritage conservation frameworks. This underrepresentation is largely due to the absence of a dedicated, enforceable legal structure for geoheritage protection. Despite the identification of numerous nationally significant geosites, many remain critically vulnerable to degradation, encroachment, and neglect, owing to fragmented governance, weak statutory mechanisms, and limited integration with environmental regulations.

This study underscores the urgency of India's geoheritage being at a critical crossroads, where rapid urbanization, unregulated mining, and infrastructural development continue to erode valuable geological assets. The unsuccessful efforts to protect classical geological sections in regions such as the Kachchh Basin, Rajasthan Shelf, and Bagh basins in western India, provide stark case studies, revealing the limitations of administrative notifications in the absence of legal enforceability, structured site management, and community engagement. These experiences highlight the broader challenges facing geoheritage conservation in India.

The paper critically evaluates the India's current policy landscape, including recent draft legislation, state-level initiatives, and heritage site declarations. It further presents a comparative analysis of established geoheritage laws from countries such as the United Kingdom, Australia, Brazil, and China, identifying key international best practices. Based on this analysis, the study proposes a framework for integrated, legally binding geoheritage protection in India. By framing India's geoheritage discourse within a global context, this work aims to provide actionable insights for legislators, conservationists, and geoscientific institutions committed to sustainable heritage stewardship.

★★★

Deccan Traps:A Recognised Geoheritage Region and its Nascent Geotourism Potential

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ABSTRACT

The recognition of the Deccan Traps under Second 100 IUGS Geological Heritage Site in 2024 is apt and timely. Spread across more than 0.5 million square kilometres in parts of western and central India, this region has numerous popular tourist spots, which are visited by an estimated 20-30 million tourists annually. Such spots include a wide spectrum of hill-stations, beaches, cultural and historic places amongst others.

Unfortunately, this geoheritage region suffers from two contradictions. In those tourist spots, which have well developed tourist infrastructure, the awareness of the geoheritage importance is nearly zero. For example, in hill stations like Mahabaleshwar-Malshej (in Maharashtra), Amarkantak–Mandu (Madhya Pradesh), Saputara–Girnar (Gujarat) known for their scenic beauty or at World Heritage sites like Ajanta – Ellora (Maharashtra) there is not even an iota of information regarding the geoheritage of those locations. On the other side, some locations with an exciting geoheritage potential (Aneghat, Bagh, Bharudpura, Lonar, Manawar, Potla, …) and are akin (if not better than) globally recognised geoheritage sites have negligible to no tourist infrastructure.

Besides official certifications from global agencies, the success of any geoheritage site or region lies in its capacity to attract tourist footfalls, without which it is only a paper-certification, notwithstanding any global agency documentation. Unless the geoscientific world reaches out, understands the commercial dynamics of evolving tourism and interacts proactively with the local administration, potential investors and local population (for their active involvement), geotourism in the Deccan Traps will remain an untapped opportunity.

★★★

Trans-border Geoheritage Conservation in South Asia and Geopolitical Concerns for India

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ABSTRACT

South Asia has a distinct identity. India, Pakistan, Nepal, Bhutan, Sri Lanka, Bangladesh, the Maldives, and Afghanistan are part of this sub-continent. India has a central position in this region. The country has a 14,103 km land boundary and shares this with Bangladesh, Bhutan, Myanmar, China, Nepal, and Pakistan. It also has a long coastline. Transborder geoheritage sites in South Asia are geological and geomorphological features that extend across national borders, often showcasing unique geological formations or processes. While the concept of transboundary geoheritage is gaining recognition, specific sites that are officially recognized as transboundary geoheritage sites in South Asia are still emerging. Examples of such sites, or areas with potential for transboundary recognition, include regions like the Himalayas, the Indus Valley, and areas with volcanic or karst landscapes that cross borders, Zanskar region in Ladakh. These sites can be developed as collaborative Geopark sites for the development of scientific research, sustainable tourism, economic development,and peace building.

In South Asia, the most common approach to geoheritage sites management to date has been through an in-situ management system. Therefore, geoheritage crossing national boundaries in South Asia faces a variety of threats. For this reason, there is a growing realization that transboundary conservation cooperation in geoheritage management can serve the purpose of sustainable development of these sites. Moreover, many examples in world geoheritage sites give insights that such cooperation is possible despite bilateral problems existing among the countries ofthe region. However, despite a strong rationale for cooperation, the extent and nature of it in the effective sense have been quite minimal because of geopolitical constraints

In this context, the study will provide a detailed analysis of existing and proposed trans-border Geoheritage projects along with geopolitical concerns. It will also examine the linkages between geoheritage concerns and the national security paradigm of South Asian nations.

★★★

The Geoheritage of Saheed Dweep– an Approach to Sustainable Development

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ABSTRACT

Shaheed Dweep, erstwhile Neil Island, forms a part of the Andaman Island chain that has recently been popularized among tourists for its spectacularly beautiful sea beaches and the two enormous limestone arches developed as part of a karst topography. These are accessible over rock pools only during low tide.

Geological and palaeontological studies carried out so far in Shaheed Dweep suggests that major part of the island is constituted of coralline and foraminiferal limestone of Miocene to Pliocene age. Long-term marine erosion, through wave action and dissolution of these limestone formations in a tropical coastal setting, has led to development of the two towering naturally developed limestone arches in Laxmanpur Beach II area. While these geomorphological features are considered principal tourist attractions of the island, the numerous rock pools that are left behind at low tide and are filled with an intriguing variety of marine life also add to the lure of the site. In these pools are sea cucumbers, sea hares, sea slugs and other nudibranchs, sluggish star fish, fleeting crabs, tiny fishes, molluscs and hermit crabs amidst live brain and boulder corals.

The local settled community is predominantly dependent on tourism for livelihood. Women are primarily engaged in the trade of marine shells and wooden decorative items, while many young men serve as guides, escorting tourists to the natural arches and caves and showcasing the rich marine fauna inhabiting the rock pools. However, the same tourism that sustains local economy is gradually degrading the fragile littoral ecosystem. Frequent tourist foot traffic over intertidal rocks en route to the limestone arches causes significant damage to algae and corals. This disturbance has, over the years, contributed to a marked decline in coral cover and a concomitant surge in hermit crab populations, reflecting an imbalance in the coastal ecosystem.

A holistic management policy is therefore urgently required encompassing conservation, educated tourism and sustainable development, ensuring preservation of balanced ecological and geological heritage of the island. One immediate approach may be to provide a single narrow wooden plank bridge, raised on wooden poles and with safety handholds, as an approach over the rock pools to the natural arches. The structure will have multiple implications. Being on poles, the bridge will allow tourists to approach the limestone arches even during high tide. Simultaneously it will restrict tourists to one single path thereby minimizing damage to the brittle ecosystem and yet allowing for a good view of the rock pools. Use of binoculars by the guides will help. Additionally, the poles will allow free flow of water below the plank bridge and thereby help in rejuvenation programs for the corals and marine life. Development of small interactive 3D videos for the tourists on geological processes operative at this site and on marine ecosystem will help in development of eco-conscious educated tourism. Such measures will be in line with UNESCO denfied 'Ecotourism best practices' that focus on responsible travel, minimizing environmental impact, promoting sustainable eco-system and benefiting local communities in the process.

★★★

Sustainable Development of Geoheritage in India with Special Focus on Ramgarh Crater, Rajasthan

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ABSTRACT

The Ramgarh Crater, situated in Baran District, Rajasthan, is one of India's rare circular geological structures, widely believed to be the remnant of a meteorite impact. Its distinctive geomorphology, archaeological features, and ecological importance give it significant potential to be recognized as a National Geoheritage Site and developed into a UNESCO Global Geopark. Despite its scientific and tourism value, the site faces severe threats from unregulated human activity, quarrying, degradation of its geological features, and the shrinkage of its crater lake due to neglect. The main objective of the study is to develop a sustainable geotourism-based conservation model for the Ramgarh Crater by integrating geo-spatial analysis with community participation. To achieve this, the study applies an integrated methodology combining remote sensing and GIS-based spatial analysis for mapping geological features, monitoring land use/land cover changes, and identifying zones of ecological sensitivity. Landsat 8 OLI imagery with maximum likelihood classification is used to detect degradation patterns. Primary data were gathered through structured questionnaires from 300 randomly selected residents of Ramgarh town and nearby villages, supplemented by field surveys, photographic documentation, and secondary data from the Geological Survey of India and published research. Findings indicate that the crater possesses substantial geoheritage potential, including its well-preserved circular morphology, varied lithology, biodiversity pockets, and cultural landmarks such as the 10th-century Bhand Deva Temple. However, significant challenges persist, including land degradation, insufficient interpretive infrastructure, and minimal public awareness. Local residents express a willingness to engage in conservation and tourism development if provided with capacity-building and livelihood opportunities.

Geomorphological and Geoheritage Sites in Mulugu and Jayashankar-Bhupalpalli Districts, Telangana- A Potential Geotourism Corridor

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ABSTRACT

This paper presents geomorphological and geoheritage sites of Mulugu and Jayashankar-Bhupalpalli districts, Telangana that deserve to be developed as geotourism sites. The geomorphological features, developed in limestones and dolomites of Proterozoic age, are situated at Mylavaram exhibiting huge caves and caverns extending for a length of several kilometers. A variety of shapes and forms of stalactites and stalagmites offer an eye feast to the visitors in Mylavaram caves. These caves are wide-spread than the well-known Belum or Borra caves of adjacent state, Andhra Pradesh. As no karst caves are known in Telangana, Mylavaram caves deserve to be developed as a tourism place,which can be useful for geoscientists, speleologists and common visitors. Several other places of geological and geoarchaeological importance include Pandavulagutta landforms, Devunigutta temple, Laknavaram waterfalls, Bhupathipur fossil-wood site, Ramappa temple, Ganapesewaralayam temple and Mulugu dolomite mines. The Pandavulagutta is endowed with geomorphological landforms in sandstone, which is recently developed as a tourist place by the Forest Department, Government of Telangana. The newly discoveredfossil-tree area of Bhupathipur spread over an area of ~5 Sq.Km., which is largest in the state. The fossil woods range from 10 to 25 metres in length, along with other species suspected to be Palmoxylon and Castanoxylon and presence of many other fossils that need to be explored and examined. The site warrants to be preserved as a Fossil Park similar to Waddam Fossil Park of Maharashtra, as the state has no such park yet. The ancient temple at Devunigutta is observed to be in Khmer architectural style similar to the Angkor Wat temple of Cambodia, however, it was built much earlier than the latter. The historical architectural marvel, Ramappa temple, which is recently recognized by the UNESCO as a World Heritage Site is situated 38 km from the Mylavaram caves. Yet another not-much popular historical picturesque stone-carved temple namely Ganapeswaralayam at Ganapeswaram displays finest stone sculptures that warrants proper maintenance to attract more tourists. The waterfalls at Laknavaram lake and Bogatha are already popular as weekend resorts. Next to Kumbh Mela of river Ganges, the annual Medaram Festival attracts a huge number of devotees and visitors which can add to the tourism potential of this area. All these places exist within a range of 50 km radius and reachable in short travels. A SWOT analysis stceflerthat all these sites are eligible for development as geosites. Therefore, developing these sites as a geotourism corridor would not only bring the hidden geological sites into limelight and inculcates geotourism awareness but also generates local employment and revenue for the government.

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From Ancient Ports to Fortified Towns: Geoheritage Narratives from Gujarat's Past

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ABSTRACT

The western Indian state of Gujarat hosts a rich repository of geoarchealogical sites that chronicle millennia of human-environment interactions shaped by shifting climate, hydrological regimes, and landscape evolution. This presentation synthesizes evidence from three culturally and and geologically significant locations to highlight their value as geoheritage landmarks. At a major coastal Harappan settlement, multi-proxy sedimentological and geochemical evidence reveals a regional sea-level fall beginning around 4200 BP, aligning with the onset of the Meghalayan Age. This regression likely disrupted maritime trade, contributing to the broader urban decline of the Indus civilization. A complementary inland site provides parallel insights into changing palaeoclimate conditions and their effects on settlement sustainability. Further north, a fortified early historic town preserves remarkable evidence of human ingenuity and adaptive strategies in the face of environmental challenges, including earthquake-resistant construction practices centuries ahead of their time. By integrating geomorphological, archaeological, and geochemical approaches, this study underscores the potential of these sites not only as windows into past cultural resilience but also as key nodes in developing sustainable geoheritage and geotourism frameworks for India's future.

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Tso Kar Basin: A Planetary Geoheritage Resource for Mars Analogue Research and a Test Case for High-Altitude Conservation Policy

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ABSTRACT

The Tso Kar basin (33°180N, 78° E), situated at ~4,527 m above sea level in the Zanskar Range of Ladakh, India, is a high-altitude intermontane depression of exceptional Geoheritage value. Containing the hypersaline Tso Kar and freshwater Startsapuk Tso, the Tso Kar fault bounds the basin to the west and the Tso Morari strike-slip fault to the east. Late Quaternary tectonic activity, coupled with Holocene fault reactivation, reorganised palaeodrainage systems, creating the present twin-lake configuration. The basin receives seasonal glacier-melt inflows from the Pulong Kha Phu River and perennial input from the Nuruchan Lungpa, with hydrological connectivity maintained via a narrow conduit. Strong conductivity contrasts (5.59 mS cm-1 in Startsapuk Tso vs. 1,134 mS cm-1 in Tso Kar) reflects this separation.

Geomorphologically, the basin preserves a suite of periglacial and lacustrine features of planetary significance. Well-developed thermokarst depressions, frost mounds akin to pingos, and salt-encrusted lacustrine sediments record active permafrost processes. Multiple palaeoshorelines and prominent terminal moraines document Holocene hydrological oscillations and past glacier advances of up to 15 km from current ice margins. These landforms, together with hypersaline chemistry and high-UV, low-pressure environmental conditions, render Tso Kar an important terrestrial analogue for Martian lacustrine basins, where similar periglacial morphologies, evaporite deposits, and shoreline assemblages are hypothesised.

Ecologically, the Tso Kar Wetland Complex was recognised as a Ramsar site in 2020. It lies within the Changthang Wildlife Sanctuary and hosts many types of vegetation, such as desert-steppe, scrub-steppe, and subnival cushion plants. It is a vital breeding site for the Near Threatened Black-necked Crane and is part of the Central Asian Flyway, attracting numerous migratory waterbirds. The area also supports animals like kiang, bharal, and Tibetan wolf. These biodiversity features are at risk due to the expanding tourism infrastructure, vehicle traffic, and unregulated waste. The basin's extreme environment has also attracted technological interest. Tso Kar has been used for planetary-analogue research, including habitat module trials and rover mobility testing, due to its permafrost, saline soils, and geomorphic complexity. Such field deployments provide operational data for future Mars exploration systems while enhancing understanding of biosignature preservation in cold, arid settings.

From a governance viewpoint, Tso Kar is protected under India's Wetlands (Conservation and Management) Rules, 2017, and the Wildlife (Protection) Act, 1972. However, effective Geoheritage conservation requires specific strategies. These should include zoning to separate key ecological and geological areas from tourist zones, seasonal limits on visitors, strict waste management practices, community-led ecotourism initiatives, and research permits linked to environmental monitoring.

Tso Kar's geological significance, ecological sensitivity, and planetary-analogue potential make it a site of global scientific relevance. Its preservation is essential not only for high-altitude biodiversity and paleoclimate records but also for sustaining a unique natural laboratory that bridges Earth system science and planetary exploration.

Geoheritage and Geotourism Potential of the Columnar Basalts of Angadimogar, Kasaragod: A Case for Geosite Recognition in Southern India

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ABSTRACT

India hosts a wealth of geological heritage, characterised by significant rock formations, distinctive landforms, and varied landscapes, which continue to engage geoscientists, nature enthusiasts, and the wider public. These landscapes embody distinctive scientific, educational, and cultural significance, meriting acknowledgement on national and global platforms, alongside their protection as geoheritage sites and development into geotourism attractions. This study seeks to document and highlight the columnar basalts of Angadimogar, representing the first recorded occurrence of such a feature in Kerala's Kasargod district, and to propose its recognition as a national geosite. Columnar basalts are igneous formations characterized by the development of regular, polygonal columns, typically hexagonal, resulting from contraction during lava cooling and solidification. These basalts exhibit features akin to internationally recognized sites such as the Giant's Causeway in Northern Ireland, alongside nationally prominent locations like St. Mary's Island in India, highlighting their significance within the geological record.

The columnar basalts at the Angadimogar quarry are nearly horizontal, and what distinguishes these structures from other renowned sites is the presence of a rosette structure across the central part of the quarry, along with secondary mineralization including zeolites such as natrolite, stilbite, and apophyllite. The Angadimogar syenites serve as the basement rock beneath these columnar structures, with an age of 638 ± 24 million years, whereas the newly identified basalts have a crystallization age of 137 Ma.

Field observations, petrographic studies, and whole-rock geochemical analyses indicate that these basalts are tholeiitic and correspond to an Early Cretaceous magmatic event, potentially associated with the Kerguelen plume, as corroborated by recent geochronological data. To evaluate the geosite potential of the area, we applied the framework proposed by Brilha (2016), which assesses sites based on scientific, educational, and touristic relevance, as well as susceptibility to degradation. In parallel, a global inventory of columnar structures and their compositions was compiled for the first time, facilitating a comparative assessment of the Angadimogar site's significance. The study also presents a detailed action plan for the protection of these columnar basalts, outlining potential threats and strategies for their conservation to support both geotourism and educational activities.

The columnar basalts of Angadimogar quarry are visually remarkable and geologically significant, featuring well-formed and systematically arranged columns. These characteristics satisfy the essential criteria for geoheritage and geotourism, supporting their designation as a geosite and potential inclusion in the geosites recognized by the Geological Survey of India.

★★★

India's Field and Museum Palaeontological Collections: An Untapped Geoheritage Potential

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ABSTRACT

India provides a diverse range of geoheritage in terms of rock records and/or fossil records from the Precambrian to the Holocene. Fossil discoveries from India have demonstrated global ecnacfiingisin developing an understanding of the origin and evolution of different biotic groups, apart from reconstructing past ecosystems in varied palaeoclimatic settings. However, geoscientists have witnessed neglect of the country's geoheritage (i.e., fossil sites and/or geological assets) as a consequence of a lack of legal support to protect the geoheritage and weak repository policies. In the past decade or more, UNESCO's 'Global Geopark' concept has gained a lot of popularity amongst the public and the geoscientific community as it conforms to a holistic approach for the protection of geoheritage, education, and sustainable development. Thus, the geoscientific community is making concerted efforts to highlight various geologically significant regions in India as potential contenders for UNESCO Global Geoparks/Geosites via print and electronic media, apart from outreach activities. Geoscientists are also actively participating in the conceptualisation and/or development of Museums at the regional/state (e.g., Mandhro Fossil Park, Jharkhand) and at the national level (e.g., TIME). Limited research surveys (from India) do support the geoscience communities' efforts towards increasing public engagement and preserving India's palaeontological wealth. According to research surveys, museums offer socioeconomic benefits to the populace by fostering employment possibilities and boosting domestic and international tourism. The importance of industrial-academic relationships is also critical in light of technological advancements and for increasing the footprint. For instance, virtual reality (VR), augmented reality (AR), interactive exhibits, mobile apps, gamification and artificial intelligence (AI) can be integrated rapidly and may be affordable for enhancing a museum's exhibit experience. Additionally, Micro-Computed Tomography (Micro-CT) with 3D printing technologies can be very helpful in preserving museum collections, facilitating data exchange among geoscientists, and perhaps expanding the social reach and appeal of geoscience. Overall, an inclusive approach with citizens as the stakeholders is the best way to move forward. It is also evident that various agencies of the government, private sector institutions, non-government organisations, various geoscience societies, the geoscience community at large, and research and academic institutions can play an active role in protecting and sustainably developingthe untapped geoheritage potential of India.

★★★

From Sacred Sites to Geosites of the Amarkantak Plateau: Geogodism for Advancing Geoconservation

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ABSTRACT

The Amarkantak Plateau, located at the eastern margin of the Deccan Volcanic Province in Central India, represents a rare confluence of geological diversity and cultural heritage. It hosts scientifically significant geosites such as rare compound lava flows, columnar basalts, intertrappean fossil beds, natural CO_2 sequestration zones, and lava tubes, alongside geoheritage monuments including temple complexes, cave shrines, and sacred water bodies. Despite this richness, most visitors engage with the region for its spiritual significance, with little awareness of its geological value.

To bridge this gap, this study advances the concept of 'Geogodism' a culturally rooted geoconservation approach that integrates spiritual reverence for sacred landscapes with scientific interpretation of their geological rarity. Geogodism aims to harness the appeal of religious tourism to promote geoeducation, community stewardship, and sustainable heritage management. Field surveys (2022–2024) in Madhya Pradesh across Amarkantak-Rajendragram-Badargargh transect in Anuppur, Dindori, Mandla, and Jabalpur districtsidentified ongoing threats including unregulated quarrying, infrastructure expansion, and lack of interpretation at key sites such as Nagapahar (natural CO_2 traps), Sahajani (world-class columnar basalts), and Kundam–Niwas (stratigraphic transition zone). Simultaneously, pilgrimage sites like Kapildhara, Doodhdhara, and Mai Ki Bagiya draw millions annually, presenting untapped potential for geoscience outreach. By positioning Geogodism as the fifth pillar within the expanded "5G" framework Geoheritage, Geotourism, Geoparks, Geoconservation, and Geogodism, this study demonstrates how the Amarkantak Plateau can serve as a model for integrating cultural beliefs with geological awareness. This approach aligns with Sustainable Development Goals 4 (Quality Education), 11 (Sustainable Cities and Communities), 13 (Climate Action), and 15 (Life on Land), offering a replicable strategy for heritage preservation in culturally rich landscapes worldwide.

★★★

Geoheritage Values of Goa with Special Reference to Geoconservation

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ABSTRACT

The coastal state of Goa is marked by a wide variation in the topography, starting from beaches to headlands (forming pocket beaches), the central table lands with vast cover of laterites and to the east of the state lies the enormous Western Ghats. The rock types and rock structure in the region, which result in deposition as well as erosion, has responsible for the present-day topography and scenery. The state of Goa has been serving as a major tourist destination for people world over. Main stream tourism of the state has been already saturated and industry is looking for an alternative. Over the decade, ecotourism has swiftly entered the tourism arena. Geotourism can be another easy alternative to increase the tourism capacity of the state. Visitors from all over the world have long been drawn to unique geological structures. However, geotourism is a relatively recent notion. The main objective of the study is to identify and categorize the potential geosites of Goa based on based on the preexisting geological maps, satellite images, toposheets and Ground truth verification through detailed field work. The selected sites are then categorised based on the factors like Structural, Petrological, Geomorphological, Physical Geology, and Archaeological importance depending upon their genetic character.The present work is carried out to enhance the knowledge of geotourism resources and provide a deeper understanding of awareness and appreciation for the geological heritage of these regions.

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Geoheritage Conservation in India: Challenges, Gaps, and the Role of GSI in a Federal Framework

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ABSTRACT

India's geodiversity is remarkably vast, encompassing nearly the entire span of the geologic time scale and expressed across a range of geological features, from a wide spectrum of rock types and outcrops to landscapes. However, not every element of geodiversity qualifies as geoheritage.

In India, the distinction between geodiversity and geoheritage remains denfied yltneicfifusniand inconsistently understood. Post 2016, when Geological Survey of India released the compilation named Geological Hotspots of the Subcontinent, during the 35th IGC, it was eyeing, bringing to fore, all exciting destinations having potential for encouraging geotourism. Hitherto, while GSI identified 34 geological heritage sites and 56 geotourism locations, only two sites have received international recognition from the International Union of Geological Sciences (IUGS). Many scientifically significant type and reference sections, outcrops, and landscapes remain unprotected, endangered, and lack formal recognition, as endeavours by individuals or institutions to create awareness about a few of them have succeeded only as piecemeal efforts. Institution-driven mechanisms for systematic, site-specific geodiversity assessments, clearly identifying uniqueness, extent, and vulnerability, are largely not in place, impeding strategic planning and effective governance.

The lack of structured assessment and policy support leads to major implementation gaps. Disparities between states are also pronounced: despite heritage sites being reported from 28 Indian states, only one or two show progress towards integrating geological heritage into sustainable local development frameworks. Additionally, fragmented institutional engagement on common sites often results in conflicts or redundant initiatives, further weakening conservation outcomes.

The situation calls for a national, system-driven, and inclusive approach with certain laws that are binding on the conservation of geo-locales. It is proposed that a standardized methodology for evaluating geodiversity elements must be developed and uniformly applied across the country. As a follow-up reinforcement to the first step, inter-institutional coordination, integrating geology with culture, education, entrepreneurship, and skill development, involving the nuance of forest, environment, and climate change, and with an eye on rural development, tourism, encompassing tribal welfare (women and child welfare in particular), etc., is essential. It comprehends that improvement in geoheritage development in isolation may not augur well for its overall visibility and desired socio-economic impact.

What appears as an imminent strategy and way forward would be to contemplate and establish a ,defiinumultidisciplinary platform under India's federal framework. This platform should function with subject experts, with an interface of key stakeholders from central and state governments, ensuring inclusivity across regions and sectors. Equal opportunities for training, capacity building, and research must be extended to all states, doing away with a selective or ad hoc approach. Such a platform should also champion public awareness and policy advocacy on geoheritage conservation.

Apropos above, GSI is well-positioned to anchor this initiative, owing to its historic legacy, pan-India presence, and enriching information base as requisites to nurture collaboration with state governments. With its recognized expertise in geoscience and geoconservation, and for representing India's interests at UNESCO, GSI can play a leading role in creating a collaborative structure that brings together research and academic institutions, government departments, and civil society to promote site-specific development strategies rooted in sustainability and aligned with global best practices.

★★★

Sacred Rocks, Living History: Conserving the Pavagadh-Champaner Geoheritage Landscapr, Western India

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ABSTRACT

The Pavagadh–Champaner Geoheritage Landscape in Gujarat, India, embodies a rare confluence of igneous volcanism, structural geology, arc haeological heritage, and sacred traditions, qualifying the Pavagadh–Champaner Geoheritage Landscape as a distinctive candidate for recognition within UNESCO Global Geopark and international geoheritage frameworks. Rising as a volcanic outlier of the Deccan Volcanic Province (DVP), Pavagadh preserves an igneous succession of picrites, ankaramites, mugearites, basalts, rhyolites, ignimbrites, and rootless cones. These lithologies record the dynamics of continental dooflbasalt volcanism- alternating explosive-effusive eruptions, assimilation–fractional crystallization, and mantle-crust interactions-with direct implications for the Cretaceous–Paleogene environmental crisis. Despite its long research history, Pavagadh's volcanic record is far from exhausted, offering fresh opportunities for advanced investigations and serving as a classical classical field site for geoscience education. Complementing the volcanic record is the Proterozoic Shivrajpur–Bhat manganese mining belt, a classical structural–mineralogical archive where abandoned underground workings and excellent outcrops of folded metasedimentary outcrops display spectacular S-, Z-, and M-type ptygmatic folds along with structurally controlled mineralization (saddle reefs, fissure veins, boxworks). This setting provides a unique opportunity to establish a Field Structural Geology Museum, fostering experiential learning in tectonics, ore geology, and mining sustainability.

The foothill settlement of Pavagadh–Champaner, a UNESCO World Heritage Site, represents an outstanding Indo-Islamic cultural landscape characterized by for defiitarchitecture and ingenious water-harvesting systems. At the summit of Pavagadh, the Kalika Mata shrine—revered as a Śakti Pītha has elevates the volcanic hill into a living sacred landscape, integrating geological prominence with spiritual and cultural traditions. Archaeological records extend the temporal depth of this landscape, from Palaeolithic–Mesolithic rhyolite tool industries to medieval Jain temples, Rajput fortifications, and Sultanate architecture, attesting to an unbroken continuum of human–landscape interactions spanning over 200,000 years.

We propose an integrated framework recognizing Pavagadh–Champaner as a Geoheritage site and potential UNESCO Global Geopark, uniting its volcanic archives, structural–mining heritage, archaeological ensembles, early human imprints, and sacred dimensions. Recognition of this kind would protect vulnerable geo-cultural records and simultaneously establish Pavagadh–Champaner Geoheritage Landscape as a field laboratory where geology, archaeology, and cultural heritage intersect. In doing so, it underscores the role of hybrid landscapes in shaping global geoheritage research and pedagogy.

★★★

Integrating Participatory Alternative Dispute Resolution into Policy Frameworks for Sustainable Geotourism and Geoheritage Conservation in India

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ABSTRACT

India possesses a rich geodiversity and geoheritage with tnacfi ingispotential for sustainable geotourism and the establishment of UNESCO Global Geoparks. While a draft Geoheritage Sites and Geo-relics Bill seeks to address this, the current governance landscape remains fragmented and contentious, lacking a cohesive policy mechanism to effectively manage the multi-stakeholder disputes that frequently arise. Conflicts over land use, benefit-sharing, and conservation priorities between local communities, conservation authorities, tourism operators, and developers often escalate into protracted litigation or administrative stasis, a challenge underscored by the very controversies surrounding the proposed legislation.

This paper proposes a novel policy framework that embeds participatory Alternative Dispute Resolution (ADR) mechanisms, specifically mediation and arbitration, within India's geoheritage governance structure. The framework is informed by a comparative analysis of international models, including the extensive geopark management strategies of China, participatory conservation practices in the European Union, and successful environmental mediation experiences in Indonesia and New Zealand. It demonstrates how structured ADR can serve as a proactive governance instrument to reconcile competing environmental, cultural, and economic interests in geotourism contexts.

The proposed framework operates on two interconnected levels:

1. Policy-Level Integration: It advocates for amendments to national and state-level geotourism and conservation policies to mandate early-stage mediation for stakeholder conflicts and to establish specialized environmental arbitration for unresolved disputes.
2. Community-Level Mechanisms: It proposes the creation of local mediation councils comprising trained community mediators, supported by expert panels in geoscience, tourism economics, and heritage law. This structure ensures that dispute outcomes are both technically informed and culturally sensitive.

Methodologically, the study employs a comparative legal-policy analysis, stakeholder mapping, and thematic synthesis of global dispute resolution models. It categorizes recurring dispute typologies-such as land-use stciflnoc, over-tourism

pressures, and gnirahs-tfienebdisagreements-and evaluates the suitability of ADR interventions at various stages of governance.

By positioning ADR as a core component of geoheritage governance rather than a post-dispute remedy, this research offers a replicable framework for managing multi-stakeholder conflicts. The model is designed to align conservation imperatives with local economic aspirations, enhance stakeholder participation, and strengthen policy coherence. It aims to accelerate consensus-building, safeguard cultural and environmental values, and establish the institutional conditions necessary for sustainable geotourism development and successful geopark designation in India.

★★★

The Deltic Mangrove Landscape of the Sundarban is Fading Away: Sustainable Conservation Strategies

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ABSTRACT

The coastline of India has tnacfiingisinstances of geological heritage, including coastal cliffs with geological formations and characteristics. The Indian Delta coastline stretches 7500 km and is characterised by varied landscapes, including sandy beaches, muddy shores, mangroves, and tidal networks (SAC, 2003).The Sundarbans and its mangrove forest are one of the major deltaic features, covering areas in India and Bangladesh. The region is a highly dynamic deltaic landscape shaped as the Ganga, Brahmaputra, and Meghna rivers converge in a very deeply sedimented, erosive, ever-changing natural landscape. It includesthe largest continuous mangrove forest in the world and is a UNESCO World Heritage Site (since 1987) because of its high biodiversity and ecological importance.

On a geological time scale, the Sundarban landscape comprises Pleistocene terraces that were developed throughout glaciation periods when the sea level was 100 to 150 m below the current levels. In the Holocene, the sea levels rose due to glacial melting, and this created an inundation of the region. The rivers, Ganges-Brahmaputra-Meghna (GBM), also help in deltaic growth to a tune of about 15 km annually. In the last 5,000 years, as a result of sea-level stabilisation, the accumulation of sediments was possible, resulting in elevated older deltaic plains. In the presentday, the most stable terrains (1-3 m above sea level) are the Older Deltaic Plain and Older Flood Plain, which are composed of mature mangrove forests with little human development. In the Younger Deltaic Plain, continued deposition is ongoing, and there has been more recent colonisation by mangroves, though this is also tidally affected. The Younger Coastal Plain is composed of eroded sands and salt flats its outskirts, which were formed by waves. It is mostly identified by the existence of the Active Flood Plain, the overall part of an elaborate system of tidal canals and sandflats which are daily submerged and keep the largest mangrove ecosystem on earth. Scattered off-shore landmasses take the form of temporary sediment deposits, and interconnected waterways (rivers, estuaries, creeks) could penetrate all these units and be viewed as biological corridors. Surprisingly, one of the most important anthropogenic unclassified terrains is poldered cropland, embankments, and reclaimed terrains, indicating the alteration of land forms by human beings, especially when they are concentrated in the old plains. The Sundarban deltaic landscape includes landforms such as island sandbars (forested in the case of Sundarban), tidal sandbars, mstafldu, levees, tidal deltas, and more.

Previously titled as a UNESCO World Heritage Site, the geological history of the Sundarban landscape formed over the domination of the rivers, then modified by tidal forces and is currently being affected by the anthropogenic climate forcing. The region is facing sea level rise rates as much as double the global rate (~3–8 mm/yr in some locations), and some islands have already sunk underwater. The rare Mangrove Forest landscape has also started to deteriorate under climate change and rising sea level, and hence has been declining since 2006.29 km2 (in 2017) to 1930.41 km2 (in 2024), which shows the coastal regions are exposed to tsunamis and cyclones.

Our observations indicate that many of these highly diverse locations of geoheritage interest lack protection. To date, no cfiicepsmanagement plans have been established under the national policy guidelines to address the anticipated effects of present and future climate change and variability, whether regionally or nationally, on the geoheritage interest of the Sundarban deltaic landscape. These climatic variations include the rise in sea level and the increased frequency of coastal storms and wave activity. Disturbed weathering and erosion cycles due to higher temperatures and a probable decline in precipitation or more variation in rain. Increased insights into the connections between geological, geomorphological, natural, and cultural heritage could lead to a greater appreciation of the landscape and geoheritage at the Sundarban deltaic landscape. To save these mangrove forest it should be considered as geoheritage sites as no other places have this kind of forest.

★★★

Karst Heritage Formation, Processes, Characteristics, Landforms in the Tapeshwar Cave, Dehradun, Uttarakhand: A Case Study for Tourist Attraction

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ABSTRACT

Geotourism is a form of scientific, cultural, learning about natural phenomenon by tourism that emphasizes the geoheritage characteristics of a particular place. Karst landforms, topography and associated structures are one of the most imperative eye-catching aspects of the geological theme of nature-based tourism. The geomorphological, stratigraphical, structural regionalization of the karst landforms contributes to a better understanding of behavior of carbonate rocks in continuous interaction with water for longer geological time periodand provides the important provincial knowledge for resource utilization, ecological protection, and general economic improvement. To achieve this objective, an integrated geological structural approach for inventorying, appraising, and evaluating geosites of karst geoheritage within the framework of geomorphosite assessment method convoyed by SWOT analysis has been performed in the Tapkeshwar Cave, Dehradun, India. Tapkeshwar Cave, located near Dehradun in Uttarakhand, is a notable example of karst topography in India. Formed in limestone rock, the cave was shaped by the chemical weathering and dissolution of carbonate minerals through mildly acidic groundwater. A distinctive feature of this karst system is the natural dripping of water onto a Shiva Lingam, creating both geological and spiritual interest. The cave's structure, along with underground passages and water seepage, stceflerclassic karst processes. Tapkeshwar Cave highlights the interaction of geology, hydrology, and culture, making it an ideal site for geotourism and geo-heritage education in the Himalayan foothills. Tapkeshwar cave is famaous due to sacred association with Lord Shiva, This cave is revered as one of the oldest Shiva temples in the region, with a naturally formed Shivalinga (symbol of Lord Shiva) enshrined within the cave. The name Tapkeshwar is derived from the Sanskrit root “tapak” (to drip), signifying the unique geological feature where water droplets naturally drip over the Shivalinga from the cave ceiling- an ongoing phenomenon that blends geoscience with spiritual symbolism. Furthermore, the mythological connection of the cave is associated with Guru Dronacharya, the legendary teacher from the Indian epic Mahabharata. It is believed that he meditated here, and hence the cave is also known as Drona Cave. Such narratives deeply embed the site in Indian cultural consciousness, attracting not only pilgrims but also those interested in mytho-historical tourism. In terms of pilgrimage and festivals the importance of this cave, during Mahashivratri and Shravan month, the cave becomes a hub for thousands of devotees who perform rituals and offer prayers, creating an immersive spiritual atmosphere. These events also offer opportunities for geotourists to experience the cultural landscape shaped by geological formations. The natural features reinforcing spiritual belief, the continual dripping of water from the cave ceiling onto the Shiva Lingam is seen as a divine phenomenon, though geologically it results from seepage through porous limestone or fractured rocks. This natural process lends itself to geo-spiritual interpretation, where geological formations are seamlessly integrated into

religious beliefs. The Scocio-economic importance enhancing Geotourism through spiritual significance play a a vital role towards spiritual value of Tapkeshwar adds a unique dimension to geotourism, where visitors engage not only with physical landscapes but also with the intangible cultural heritage tied to those landscapes. It serves as a textbook example of sacred geosites, which highlight the intersection of geology, mythology, and faith.

Interpretative potential of the cave is providing the integration of scientific explanations (e.g., cave formation, hydrology) with religious narratives, which can be leveraged to create engaging interpretive signage, guided tours, and cultural storytelling to the visitors. The sacredness of the site encourages community-based conservation, as local stakeholders have a vested interest in preserving both its physical integrity and spiritual sanctity. The aim of this study to provide the importance of socio cultural awarness of Tapkeshwar cave among the visitors and local community to do the pramostion of the site in public to improve the Infrastructure and enhance the tourism promotion and providing platforms for educational outreach about geology.

Assessment and Monitoring of Sendra-Granite Geoheritage Site for Geotourism Development in Rajasthan using Geospatial Technologies

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ABSTRACT

The Sendra-Granite landscape of Rajasthan represents a significant geoheritage site with unique geological and geomorphological features ideal for education, research, and sustainable geotourism. This study examines the use of geospatial technologies such as Remote Sensing (RS), Geographic Information Systems (GIS), and Global Positioning Systems (GPS) for the assessment, documentation, and monitoring of this geosite. Multispectral satellite imagery, GIS mapping, and GPS-based field surveys were used to delineate site boundaries, evaluate landscape conditions, and identify vulnerable zones requiring conservation. The findings provide valuable datasets for geoscientists, conservationists, policymakers, and tourism planners, supporting informed decisions for sustainable geotourism development. GIS-based digital tools further enhance public awareness and visitor engagement. This research illustrates how integrating technology with conservation strategies can preserve geological heritage while fostering responsible tourism. The approach can be replicated for similar geotourism destinations across India.

★★★

Step Wells of Jodhpur of Western Rajasthan: Implication for an Innovative Concept of Hydro-geosites and Hydro-geotourism in India

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ABSTRACT

Geodiversity is denfiedas the variety of geological, geomorphological, pedological and hydrogeological phenomena. Step wells in India are tnecfiingam groundwater bodies characterized by their greater values of hydrogeological geodiversity. Step wells of Jodhpur situated in the Thar Desert of western India are locally known as Jhalra and Baori which are good practices of ground water harvesting, conservation and management system of medieval period. Furthermore, these are magnificent artifacts showcasing historical-cultural (archeological), Architectural and civil engineering geo-monumental heritage of India. In absence of any methodology and guidelines, the hydrological heritage aspects of step wells are least understood and were not adequately explored for their geoheritage values in Inda. The present study explores in light of their potential to characterize and recognize them as hydro-geosites of hydro-geoheritage values to promote hydro-geotourism in India. Based on the proposed methodology, out of 134 inventoried step wells of Jodhpur eight are qualified as hydro-geosites. The qualified hydro-geosites are characterized to be utilized them for educational and hydro-geotourism purposes. Among these eight step wells, five are Jhalra type (Tunwarji, Rajmahal, Gulab Sagar, Ranisar and Bijolai), and three are Baori type (Raghunath, Navlakha, and Najarji) hydro-geosites. Very less number of qualified as hydro-geosites clearly reveals that most of them are in pathetic stage due to their negligence since long time that needs urgent conservation. For their conservation, these hydro-geosites should be protected as an important geoheritage sites similar to National Geological Monument (NGM) and Monument of National Interest (MNI) in India. Further, the self-sustainable economic development through awareness and associate them with in the framework of Geopark to promote hydro-geotourism would be the best tools for their conservation, and for socioeconomic developments of the region.

★★★

Geopark Potential of Baratang Island, Middle Andaman, Union Territory of India

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ABSTRACT

This study evaluates geoheritage, biodiversity, and cultural significance of Baratang Island, Middle Andaman, Union Territory of India with an objective to assess its potential as a UNESCO Global Geopark (UGG). UGG are single unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development. Baratang Island- a part of the Andaman-Nicobar Island chain- has been identified in context of geotourism development on account of its exceptional aesthetic-scientific-educational values as geoheritage. Present study attempts to analyse natural diversity of Baratang Island including its biodiversity, geodiversity, and cultural diversity, in perspective of its prospect to be designated as a UGG. Methods adopted include fieldwork and interaction with local administration, residents, tourists to look for prerequisites of a UGG in Baratang Island as per the UNESCO operational guidelines.

Geodiversity of Baratang Island embraces mud volcanoes, being the only active ones in India, karst topography hosting the biggest underground cave complex of Andaman-Nicobar Islands,and Baludera Beach. Erupting sporadically, the mud volcanoes have been already declared as a geoheritage. Located along a NE-SW trending fault zone that forms a part of the imbricated thrust sheets parallel to trench axis of the Andaman-Java subduction zone, these volcanoes feature diapiric ascent of enfisediments of mud or clay accompanied by methane gas and sporadic angular sub-surface rocks. The mud volcanoes, aligned along regional fault systems in accretionary complexes may be caused through leakage of sub-surface hydrocarbon along tectonically active zones. The karst topography presenting development of stalactites, stalagmites, pillars, clefts, tunnels, surreal limestone lattice on cave walls and the beachenvironmentpreserving different wave- and tide-dominated sedimentary structures are ideal for study of sedimentary milieufor both carbonate-siliciclastic domains.

Ecosystem evolved around the Baratang karst topography supports a unique biodiversity among limestones, gullies, and sinkholes. Being a part of the Indo-Burma global biodiversity hotspot, this tropical rainforest with mangrove ecosystem house rare flora and fauna including edible-nest swiftlet, Andaman horseshoe bats, barn owls,wood pigeon, treepie, serpent-eagle, drongo and many other avian species. Small, uninhabited Parrot Island near Baratang is famous for its large parakeet population. The mangrove creeks are host to salt water crocodiles.Apart

from its bio- and geoheritage aspects, Baratang Island is also home to the Jarawa tribe, one of the rarest indigenous tribes of the Andaman-Nicobar Islands signifying its rich cultural heritage.

Present study advocates Baratang Island to be a potential UGG. If designated, a holistic management should be adopted here encompassing conservation, educated tourism and sustainable growth, ensuring preservation of balanced ecological, geological, and cultural heritage. Recognition as a geopark will also raise awareness about not only the intriguing geological processes that have shaped the Andaman Islands, but will also address aspects like conservation of natural diversity, mitigation of impacts of natural hazards especially coastal erosion and storms, climate change, sustainable resource, evolution history and culture, involving local communities and thereby stimulating new sources of revenue generation through geotourism.

★★★

Loktak Lake: A Potential Site to become UNESCO Global Geopark in India

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ABSTRACT

The Loktak Lake in Bishnupur District of Manipur is the largest freshwater lake in the entire north-east of India, covering an area of 246.72 sq. km. The lake is located in the middle of Imphal valley between 24°25"N to 25°42" N and 93° 46" E to 93°55" E. Most geoscientists believe that the origin and evolution of Loktak Lake coincided with the origin and genesis of Imphal Valley. The evolution of the Imphal valley is attributed to transtensional tectonic movements that occurred in the microtectonic setting of the region due to dextral shear coupling driven by oblique subduction of the Indian Plate below the Myanmar microplate and further assisted by the easterly motion of the Shillong-Mikir Massif, which lies farther in the northwest. The Lake was primarily formed during the Quaternary period and particularly lies on the Eocene rocks of the Disang Group. Presently, the Loktak Lake possesses a- fluvial-lacustrine environment and it is dotted with beautiful islands like Sendra, Thanga, Karang, Pabotching, Ithing, Mandaching, Chingthi, Mukapching, Chaobaching, Chingdompok and Pabotching etc. These islands provide majestic views of Loktak Lake and its surrounding areas. The Loktak Lake is economically vital for Manipur, serving as a crucial source of water for various purposes and supporting numerous livelihoods. The most unique and valuable feature of Loktak Lake is the floating islands (swamps or mats), locally called "Phoomdis' that are the heterogeneous masses of soil, vegetation, and organic matter in different stages of decay. Now, the largest single mass of 'Phumdi' is located in the south-eastern part of the lake, occupying an area of almost 40 sq. km. This mass is recognised as the only floating National Park in the world, named the Keibul Lamjao National Park. Moreover, this park is the only natural habitat of the famous and most endangered brow-antlered Sangai deer (Rucervus eldi eldi), popularly known as the 'Dancing' deer. Considering its ecological uniqueness, the lake achieved the designation as a wetland of international importance under the Ramsar Convention in 1990. Besides, the story of human attachment to this lake is praiseworthy. The lake is best known for being the place of origin of the ancient epic legend of Khamba and Thoibi, one of the seven epic cycles of incarnations of Meitei mythology and folklore. Therefore, from the above discussion, it is evident that Loktak Lake has immense international importance in terms of geological as well as ecological points of view. Moreover, the aesthetic view of Loktak Lake attracts thousands of tourists from all over the world to visit it and enjoy the majestic beauty that has made it an important tourist destination of North East India. Hence, the site is ideal to promote geoeducation as well as geotourism. Therefore, considering its exceptional geoscientific, ecological, aesthetic, cultural, and economic values Manipur government and the Government of India should follow the proper modalities to make it a UNESCO Global Geopark.

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Banni Grassland, Western India: Integrating Geoheritage, Biocultural Linkages, and Sustainable Development for a Potential UNESCO Global Geopark

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ABSTRACT

The Banni Grassland, situated in the peri-cratonic Kachchh rift basin of western India, represents a unique convergence of geological, ecological, and cultural heritage. Spanning ~3800 km² between the Kachchh Mainland Fault and the Island Belt Fault, Banni records Late Quaternary tectonic, sedimentary, and climatic processes while supporting one of Asia's most distinctive tropical grassland ecosystems. Its geoheritage attributes include inland mangroves, meteorite impact structures, earthquake-induced liquefaction features, and a sedimentary archive revealing Holocene climatic transitions. Coupled with this geodiversity is a rich biocultural legacy- the Maldhari pastoralist communities-whose traditional ecological knowledge underpins sustainable grazing, indigenous water harvesting systems, and climate and seismic-resilient architecture (bhungas). However, the region faces severe threats from invasive species (Prosopis roflilula), altered hydrology, salinity ingress, land-use change, and unregulated tourism. While the "Rann Utsav" festival has demonstrated geotourism potential, it also underscores the need for responsible, community-led models. This paper synthesizes multidisciplinary evidence to advocate for the recognition of Banni as a potential UNESCO Global Geopark, aligning geoconservation with livelihood enhancement. It proposes a participatory geo-eco-cultural management framework integrating traditional knowledge, scientific monitoring, and sustainable tourism. Such an approach can preserve Banni's fragile geosystem while meeting socio-economic aspirations, offering a replicable model for linking geodiversity conservation with the Sustainable Development Goals (SDGs 11, 13, and 15).

Recognizing Banni as a Geo-Ecosite would not only safeguard its unique geological and ecological assets but also ensure the intergenerational transmission of its living cultural heritage-transforming this "Land of Endless Possibilities" into a global exemplar of holistic geoheritage stewardship.

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Geodiversity Assessment of Jodhpur Region of Western Rajasthan, India using an Innovative Approach of Geospatial Technologies

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ABSTRACT

In recent decades, significant advancements have been made in the quantitative assessment and mapping of geodiversity utilizing various remote sensing and GIS techniques. The innovative grid overlay method, in particular, has proven effective in generating Geodiversity Index (GI) maps, which facilitate the spatial noitacfiitnediof geodiversity-rich zones or "hotspots". These outputs are instrumental in formulating and prioritizing conservation strategies with promoting sustainable geotourism, particularly in the frameworks of the UNESCO Global Geopark and IUGS Geoheritage Sitesinitiatives. Despite India's rich, diverse and varied landscapes, research on noitacfiitnauqof geodiversity remains limited and largely unexplored, with few studies and an absence of a standardized methodological framework to recognize geodiversity Hotspots. To address these gaps, the present study proposes an innovative GIS-based grid-overlay approach for the assessment and spatial mapping of geodiversity, using Jodhpur region, Rajasthan as a case study. The methodology incorporates four partial indices-geology (stratigraphy, lithology, mineral-fossil occurrences, and structural features), geomorphology (relief and landforms), hydrogeology (drainage patterns and water bodies), and soils-derived from thematic spatial layers. These indices were integrated to generate GI maps that depict the spatial variability and richness of geodiversity elements across the study area.

This study generated GI maps, identified and delineates key geodiversity hotspots in Jodhpur region by integrating high Geodiversity values with geoheritage significance. These findings demonstrate the applicability and effectiveness of the GI approach in the Indian context that underscore its value in supporting conservation prioritization, sustainable land management, and Geopark development strategies. Despite India's remarkable geodiversity, the absence of any UNESCO-designated Global Geopark highlights the need of such research, which offers a crucial foundational framework for identifying high geodiversity hotspots to promote nature-based geotourism with long-term sustainability potential. The present GI methodological approach is both scalable and adaptable, making it suitable for replication across diverse regions of India. Its wider application can contribute to the development of a comprehensive national geodiversity inventory, which can support land-use planning, environmental management, education, and sustainable tourism. Further, present study provides a practical framework for integrating geodiversity into national development strategies by aligning with long-term socio-economic and conservation goals.

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Why a People-Centric Approach is Crucial in Geosite Conservation: A Case Study from Rajmahal Hills, Sahibganj, Jharkhand, India

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ABSTRACT

The Rajmahal Hills of Jharkhand house one of India's most scientifically significant palaeontological sites, designated in 2014 by the Geological Survey of India (GSI) as a Geoheritage Site. The pyroclastic deposits of the Rajmahal Formation (Upper Gondwana Group) exposed at Mandro in Sahibganj District preserve an extraordinary record of plant life dating back 118-115 million years. Rich in fossils of Ptilophyllum flora and other Jurassic-Cretaceous taxa, these volcanoclastic units serve as geological testimony to India's northward drift from Gondwana and the subsequent evolution of the subcontinent's terrestrial ecosystem.

GSI has meticulously mapped an area of 1.62 sq. km between Gurmipahar and Tara villages using DGPS, identifying at least 15 fossiliferous locations with a wide variety of specimens of petrified wood and floral impressions. Despite partial preservation efforts by the Forest Department, Government of Jharkhand, including the establishment of a Fossil Park on an approximate 0.1 sq.km area at Gurmipahar featuring both in-situ and relocated fossil specimens with basic infrastructure to facilitate public engagement, the broader fossiliferous landscape remains critically vulnerable. Numerous fossil wood trunks and leaf impressions, particularly those embedded in the slope wash or scattered across agricultural fields and grazing lands, are largely unprotected. In areas such as Tara and Basgobedo, several significant mega fossil trunks have already suffered damage or been illicitly removed. The wider fossil-bearing terrain continues to face threats from natural degradation, unregulated extraction, and anthropogenic interference. These challenges are exacerbated by a combination of factors, including limited awareness among local communities and tourists, the rising public interest fueled by social media coverage of recent local finds, and the perceived economic value of the fossils. Without a more comprehensive, community-informed, and scientifically guided conservation strategy, irreversible damage to this geologically significant heritage appears imminent.

The area is home to socio-economically marginalized and culturally distinct tribal populations, including Particularly Vulnerable Tribal Groups (PVTGs). The prevailing socio-economic conditions oflow literacy, limited livelihood opportunities, and weak institutional engagement compound the threats to geoheritage. Fossil removal from its original context not only damages the site but also undermines critical scientific research into its natural preservation, paleoecology, and stratigraphic context.

This scenario underscores the urgent need for a community-engaged conservation model that integrates cultural sensitivity, economic inclusion, and

scientific stewardship. The success of geoheritage preservation in such a tribal and ecologically sensitive region with a complex land ownership system depends on embedding conservation within broader community development frameworks thatrecognize indigenous values and social sentiments, foster local ownership, and build capacities for geotourism.

We argue that top-down conservation policies alone are inadequate. Instead, a decentralized, participatory approach combining institutional support, local governance, and sustainable tourism is imperative. Initiatives like interpretative trails and stays by tribal-led fossil guides, school outreach, and culturally contextualized awareness campaigns can transform local communities from passive observers to active custodians.

In conclusion, conserving the Rajmahal fossil heritage is not only a scientific necessity but also a socio-cultural imperative. Aligning geo-conservation with tribal empowerment and sustainable tourism can create resilient landscapes where heritage is protected, livelihoods are improved, and communities are meaningfully involved in preserving Earth's legacy.

★★★

Analyzing Landscape Transformation through LULC Change Dynamics in Bagh Region, Madhya Pradesh Using Geospatial Technologies

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ABSTRACT

The integration of advanced geospatial technologies with machine learning algorithms has emerged as a critical approach for monitoring geodiversity and managing geologically significant sites. In regions of unique geodiversity and geosites like Bagh, India, spanning approximately 3,019 sq. km, a potential Geopark containing fossil-bearing formations, volcanic outcrops, and ancient cultural sites co-exist, rapid land use transformations pose a growing threat to geodiversity. This study presents an integrated approach of combining advanced remote sensing, Support Vector Machine (SVM) classification, and Geographic Information Systems (GIS) to assess and monitor spatio-temporal LULC dynamics in the Bagh region, Dhar district, Madhya Pradesh, India. With the use of latest multi-temporal satellite imagery from Landsat platforms from 2003, 2014 and 2024, this research employed Support Vector Machine classification integrated with with Geographic Information Systems to quantify landscape transformations and assess their implications for geoconservation strategies. The methodology integrates radiometrically corrected satellite data with extensive ground-truthing surveys, applying SVM classifier to achieve superior classification accuracy (overall accuracy >90% and Kappa coefficients >0.88) compared to traditional maximum likelihood approaches. The derived LULC maps not only reveal substantial land use transitions including progressive expansion of built-up areas, but also identify geosites that are exposed to anthropogenic pressures. Through integration of these innovative geospatial technologies, the study demonstrates a methodological framework suitable for replication for high-resolution assessment and monitoring of geodiversity sites within rapidly changing landscapes. The monitoring results reveal built-up area expansion from 59.34 sq. km in 2003 to 215.23 sq. km in 2024, accompanied by a notable decline in open land from 2,186.32 sq. km to 1,927.46 sq. km. Agricultural land remained relatively stable, while vegetation increased by 68.57 sq. km, and waterbodies nearly doubled. Buffer analyses at 1 km, 3 km, and 5 km from geosites indicate concentrated urbanization pressure particularly around Bagh Caves, Dinosaur National Park, and Padlya posing ongoing risks to geodiversity. This study contributes to the emerging field of digital geoheritage management by demonstrating the efficacy of innovative geospatial technologies for geodiversity assessment and geosite monitoring. The findings provide crucial insights for developing comprehensive strategies that balance heritage preservation with sustainable regional development, particularly relevant for areas with rich geodiversity, particularly in regions aspiring for geopark status.

★★★

Bhanpura Geo-Rock Art Landscape in Chambal Valley: A One-of-A-Kind Geo-Rock Art Heritage Marvel in The World

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ABSTRACT

The Bhanpura region, located in the Chambal River Valley of Madhya Pradesh, represents a unique ecneuflnocof geological diversity and prehistoric cultural expression. Geologically, the area encompasses Vindhyan Supergroup formations—primarily sandstones and quartzites—overlain by the Deccan Trap basalts of the Malwa Plateau. This stratigraphic juxtaposition can be seen at Sangram Ghata, and is dramatically exposed at Rawali Phanta, where the decomposed basalt visibly overlaps the Vindhyan strata. The region's geomorphology is marked by the deep Chambal gorge, a major geological fault in the region, rift valleys, lateritic crusts, palaeochannels, and fluvial terraces, making it a dynamic geoscape shaped over millions of years.

Of exceptional ecnacfiingisis the area's geo-cultural landscape, wherein Stone Age cultures nodehsiruoflBhanpura plateau, and natural rock shelters were transformed by early humans into one of the world's unique known rock art galleries, manifesting the development of human constructs of reality. Sites such as Daraki-Chattan Cave, located in the quartzite buttresses of the Indragarh Hill, offer Lower Palaeolithic petroglyphs, tentatively placed in the middle Pleistocene on archaeological grounds. These are among the earliest rock art indicators of cognitive and technological development in prehistoric humans, and marking the origin of symbolic artistic behaviour. Chaturbhujnath Nala, the longest rock art gallery in India, and Chibbar Nala—showcases a range of compositions from the Mesolithic to early historical periods, and rare depictions of extinct fauna,transition from hunting foraging life to pastoral economy, early Buddhist symbols, and inscriptions.

Georesources were instrumental in the cultural development of the area. Iron oxide nodules from denuded laterite were processed to obtain pigments for rock paintings, while the hard quartzite cobbles from a palaeochannel at the junction of Indragarh and Chanchalmata Hills served as hammerstones for the production of early cupules. The region also bears evidence of fossilized megafauna, along with ostrich eggshells (those from Chandresal identified as Struthio camelus molybdophane by Ashok Sahni), highlighting its palaeontological significance. The cultural continuum is further illustrated by Chalcolithic habitations, Buddhist and Brahmanical caves cut into laterite crust at Dharmrajeshwar, and early temple architecture and forts at Indragarh and Hinglajgarh.

The geo-rock art heritage of the Bhanpura region represents a rare and possibly singular instance where geological formations of significant scientific value have been actively utilized by early humans for symbolic expression. This

convergence of geoheritage and cultural heritage provides critical insights into the evolution of human cognition, technology, and symbolic behaviour. As such, Bhanpura stands as a globally tnacfiingissite for understanding the intertwined trajectories of Earth's geological history and humanity's intellectual evolution. Given this rare intersection of geoheritage and cultural heritage of universal value, the Bhanpura region is an outstanding candidate for recognition and development as a Geo-Rock Art Heritage Park. Its scientific, educational, and tourism potential aligns strongly with India's growing emphasis on heritage conservation, sustainable development, and geo-tourism promotion under national geodiversity frameworks.

★★★

Geo-Rock Art Heritage of the Bhanpura Region, Chambal Valley: Systems Approach Towards Sustainable Development

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ABSTRACT

The Bhanpura region represents a globally tnacfiingislocus for examining the intertwined trajectories of Earth's geological evolution and the development of human cognition and symbolic expression. This rare convergence of geoheritage and cultural heritage—manifested through its exceptional geological formations and one of the world's unique rock art assemblages—renders Bhanpura an outstanding candidate for designation as a Geo-Rock Art Heritage Park. Its considerable scientific, educational, and geo-tourism potential aligns closely with India's strategic priorities for heritage conservation, sustainable development, and geo-tourism promotion under national geodiversity frameworks.

This paper advances a sustainable development approach for the Bhanpura Geo-Rock Art Heritage Park using a System Dynamics (SD) modelling framework. Sustainable development inherently demands the reconciliation of environmental integrity, economic viability, and social equity within complex, interdependent systems. SD provides a rigorous methodology for representing these interconnections, enabling the simulation, visualization, and evaluation of long-term impacts arising from alternative policy and management choices.

In this context a decision-support model was developed incorporating stock–flow diagrams to represent critical system components: in terms of Environment, Economic and Social dimensions. The scenario building within the SD framework facilitates the exploration of alternative development pathways under varying policy, technological, and environmental assumptions. These dynamic simulations highlight feedback loops, delays, and non-linear effects that traditional linear models often overlook. By integrating real-time and historical datasets, the approach strengthens managerial decision-making, enabling the identification of leverage points for maximum sustainable impact.

The proposed methodology is exemplified through a decision-support model applied to a representative regional context, where economic growth goals are balanced against environmental carrying capacities. The results underscore how SD-based scenario analysis can guide policy formulation, optimize resource allocation, and anticipate unintended consequences, thereby aligning strategic actions with global sustainability goals. This integrative, data-driven approach positions system dynamics as an essential tool for 21st-century governance, offering actionable insights for building resilient, adaptive, and inclusive development strategies for Sustainable Development of heritage.

★★★

Integrating Geoheritage and Geotourism into Undergraduate Curriculum: Advancing Sustainable Education under NEP 2020

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ABSTRACT

Geoheritage and geotourism are emerging areas in the field of geoscience education as they promote scientific and environmental education, cultural and aesthetic value, community development, public awareness. They have implications toward local economic benefits and sustainable development. Geoheritage site allows us to learn about Earth's history, and geotourism gives visitors an educational, recreational, and enriching experience. Several papers have been published on geoheritage sites, emphasing the importance of geological and geomorphological sites and geotourism opportunities in India.They emphasise the importance of geoheritage conservation and the development of geotourism to promote economic well-being and community involvement. Landscapes, ecosystems, and cultural identities are all built upon geodiversity, geoheritage, and geotourism. Globally, a growing body of research, specialised university courses, and integration into UNESCO frameworks reflect their academic and societal relevance. However, these topics are noticeably missing from Indian undergraduate/postgraduate courses barring a couple of institutions. This gap creates an obstacle to the growth of geo-literacy while also impeding the study of geotourism and conservation-focused livelihoods. In contrast, many universities abroad, particularly in Europe, provide specialised courses on geodiversity, geoheritage and geoconservation at both undergraduate and postgraduate levels, often incorporating a mix of theoretical studies, fieldwork, and including aspects on UNESCO frameworks and sustainability principles. Equivalent undergraduate level course(s) in India is required to inculcate and enhance awareness among students about the value of abiotic resources, the role of geoheritage in sustainable development, and the opportunities for geotourism and conservation-related livelihoods. Based on the need, the School of Sciences at IGNOU, utilising its extensive national reach and flexible learning, is creating a separate value-added course (VAC) on specifically on Geoheritage and Geotourism for the four-year undergraduate programme (FYUP) offered in open and distance learning mode as per NEP 2020. The curriculum aims to bridge academic gaps, meet global standards, create awareness and prepare students for careers in geosciences/geoheritage, covering geodiversity, geoheritage, geoconservation, sustainability, and potential sites. This initiative will also allow India to be more involved in worldwide projects like UNESCO's Geoparks.

★★★

Enhancing Public Awareness and Youth Engagement through Geoheritage of Chhattisgarh

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ABSTRACT

Geoeducation plays a vital role in promoting a sustainable relationship between society and the Earth's dynamic systems. In a geologically diverse state like Chhattisgarh, with its unique geoheritage sites such as the Gondwana Marine Fossil Park and the Kailash-Kotumsar Cave system, there lies immense potential to transform these natural assets into active centres for education, conservation and community development. Kailash-Kotumsar Cave system formed in Proterozoic limestone holds evidence of prolonged geological processes. Its speleothems and cave sediments can aid in reconstructing paleoclimatic conditions and understanding the biogeographic adaptations in subterranean ecosystems. The troglobitic species found in Kotumsar Cave is uniquely endemic in nature. Likewise, Marine Fossil Park at Manendragarh contains marine fossils from the Permian period (~250 million years ago), offering vital clues about ancient marine environments, continental drift and the paleogeographic evolution of the Gondwana Supercontinents. Preserving geoheritage sites is not just about protecting rocks and fossils, other way it also benefits the society in cultural, ecological and economical aspects. In light of the escalating pressures from human activities and climate change, it is more crucial than ever to increase awareness and bolster conservation initiatives for Earth's invaluable natural geoheritage sites. Geoeducation initiative is a multi-pronged approach towards sustainable development. This includes interactive awareness lectures in schools and colleges, guided field visits to geoheritage sites and mobile exhibitions in collaboration with the education Department of State aimed at engaging both students and the common people. These activities can spark curiosity about Earth sciences, raise awareness of geological conservation and inspire younger generations to become responsible stewards of natural resources. To amplify outreach, collaborations with the State Tourism Department are proposed for developing interpretation facilities and promoting geotourism. With the widespread use of digital platforms among all age groups, tools such as social media and short educational videos offer an effective medium for disseminating geoscientific knowledge. Encouraging local participation in conservation efforts, through volunteer programs, citizen science initiatives or geotourism, can boosta sense of ownership and responsibility towards the sites. Geoeducation is holistic approach to connect people with earth sciences by integrating formal education, community engagement, geotourism and digital communication to promote the long-term sustainability and preservation of India's rich geological historyfor future generations, rather than being lost to time and infrastructure development.

★★★

Women as Champions of Geodiversity Conservation

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ABSTRACT

Women play a vital, yet often understated, role in geodiversity conservation, acting as guardians of biodiversity, possessing unique knowledge, and driving community-based conservation efforts. Their traditional knowledge, gathered from years of interacting with the environment, is invaluable in understanding and managing natural resources sustainably. Deep Knowledge of Ecosystems: Women often have intimate knowledge of local ecosystems, including plant and animal species, water sources, and soil conditions, due to their daily interactions with the environment for gathering resources like firewood, water, and food. Resource Management: Women are often responsible for the sustainable use and management of natural resources like water, forests, and land, ensuring the long-term availability of these resources for their families and communities. Community Leadership: Women are increasingly taking on leadership roles in conservation initiatives, forming grassroots organizations and advocating for sustainable practices. Need for Empowerment: Empowering women through education, access to resources, and participation in decision-making processes is crucial for effective and sustainable conservation.

★★★

Geoheritages Sites and Women Empowerment- A Case Study from the Geoheritage Sites of West Bengal, India

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ABSTRACT

Geoheritage sites refer to Geological features and landscapes of significant scientific importance along with educational and cultural value. Geo-heritage sites can be a focal point for preserving and promoting local culture, traditions, and knowledge, which can be led by women within the community and can be a powerful tool for women's empowerment through Geo-tourism and community engagement. By integrating women into the planning, management, and promotion of Geo-heritage sites, communities can foster economic opportunities, preserve cultural heritage, and promote gender equality.

Geo-heritage sites can support women's entrepreneurship through the development of small businesses of selling local handicrafts, food and souvenirs along with creating diverse job opportunities for women in areas like guiding and hospitality and raising awareness among the mass about the importance of conservation of Geoheritage sites. Training programs focused on geo-tourism, sustainable practices, and business development can empowerlocal women with new skills and knowledge. This approach ensures that women's voices are heard and their perspectives are considered in the development of the Geoheritage sites.

The geoheritage sites of West Bengal and a step forward towards women empowerment:

Gangani River Gorge, Midnapore District, West Bengal: Gangani, River Gorge is a natural riverine gorge or canyon on Silabati river and also called Grand Canyon of West Bengal which is formed from the weathering and erosive activity of the river over time. This locality is famous for the handicraft's products of Sabai Grass, brass and bell metal, terracotta products and Goyna bori. The women from this locality can be engaged in selling of these products and also can be trained in hospitality sector and as guide, to cater the tourist and peoples visiting these places and made them aware about the formation of the river gorge and importance of its conservation.

Amkhoi Fossil Wood Park, Birbhum District, West Bengal: This Geo-heritage site is an Angiosperm Wood Fossil Park which is proof of the presence of vast dry deciduous forest which prevailed 15- 20 million years back. It is only 20 kms from Shantiniketan, which is declared UNESCO World Heritage site in the year 2023. It is a university town under the legacy of Kabiguru Rabindranath Tagore and major cultural hub of West Bengal. This locality is famous for handmade Kantha stitch, handmade Batik print, art inspired by famous painter Sh Abanindranath Thakur and Ghee. Gramin co-operatives could be formed in this area led by women who will educate the people about the geoheritage site along with promoting the rich cultural heritage of this area and selling of the handicraft products thus making them self-

reliant. Sundarbans Delta, South 24 Parganas district, West Bengal: Sundarbans Deltais world's largest river delta with a cluster of 102 low-lying islands and home to world's largest mangrove forest locally known as Sundari tree. It is core part of tiger reserve and biosphere reserve and UNESCO World Heritage Site. The area is famous for its local honey and sea and fresh water products. The women in this area can be trained in hospitality sector and as guide who can cater to the large number of tourists who visit Sundarbans every year and create awareness among the masses about conservation of the mangroves. Apart from that they can sell the local produce. There are many women led NGO's working in the Sundarbans area like Champa Mahila Society, Mukti, Sabuj Sanga to name a few and many more women led NGOs and co-operative can be formed for overall development in the area.

Thus, the geoheritage sites of West Bengal can promote women empowerment for an inclusive development in the area. Also to mention, UNESCO Global geoparks recognize the importance of women's empowerment as a crucial aspect of sustainable development and work towards creating a more equitable and inclusive environment for Women.

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Geodiversitical Signatures of Subterranean Flows in Bundelkhand Region of India Oozing as Saraswati River at Prayag

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ABSTRACT

The unseen River Saraswati at Prayag (modern-day Prayagraj) is often considered mythical, yet it holds deep religious and cultural significance in Indian society. Despite centuries of debate, its actual presence and flow path remain scientifically unverified due to the absence of any surface water flow. Some geologists hypothesize that the invisible river at Prayag could be a subterranean extension of the Vedic mighty Saraswati River, which once flowed from the Himalayas to the Arabian Sea but is believed to have vanished over 4000 years ago due to major tectonic events. These events are thought to have caused significant gradient shifts and created large subterranean cavities, redirecting the river underground. However, the presence of the Aravalli geological system has led many researchers to question this hypothesis.

This study presents the findings of hydrogeological and geophysical investigations conducted in the Bundelkhand region of Madhya Pradesh using vertical electrical sounding (VES), earth resistivity tomography (ERT), and drilling. The study identifies multiple geodiversitical signatures—such as unexplored sinkholes and water-filled subterranean cavities (e.g., Pandajhir, Patalganga, Arjunkund, Bhimkund, and Sadwa Caves)—along an elongated prominent limestone formation sandwiched between granite bedrock. These features display typical karst characteristics, suggesting a well-developed subsurface drainage system capable of transmitting significant volumes of groundwater.

Satellite imagery and topographical analysis of study area revealed a prominent southwest–northeast trending lengthy geological lineament originating from a remote forest tiny village Pandajhir (432 meters above mean sea level) and terminating at Prayag (100 meters amsl). Along this corridor, several hydrologically active and culturally significant karstic features—such as the Pandav Caves near Panna and the Gupt Godavari caves at Chitrakoot—exhibit evidence of perennial water flow. These features are aligned with zones of carbonate enrichment and geological fractures, supporting the hypothesis of a continuous subterranean hydrological system that may extend to the Ganga-Yamuna confluence.

Groundwater occurrence and water level monitoring data suggest that this inferred underground flow is primarily sustained by local recharge and the regional groundwater gradient, with water moving through deep-seated limestone channels and cavities. These flows eventually emerge, albeit subtly, at Prayag, giving rise to the belief in the underground Saraswati. The study proposes that during a historical period of tectonic upheaval and subsequent climatic desiccation, the original Vedic

Saraswati River—originating from the Himalayas—disappeared due to changes in gradient and loss of surface connectivity. As flow in the Ganga and Yamuna rivers diminished temporarily, water observed seeping from the subsurface at the confluence may have been interpreted by ancient observers as the reappearance of the lost river from the underworld ("Patal Lok").

By integrating geological, hydrological, geophysical, and satellite imagery data, this research provides a scientifically grounded explanation for the longstanding cultural assertion of Saraswati's presence at Prayag. While it does not establish any direct link with the Vedic Saraswati of the northwest Indo-Gangetic plains, it identifies a separate but significant subterranean hydrological system within the Bundelkhand region that may have informed the myth. The study highlights the importance of combining geoscientific tools with historical-cultural perspectives to decode ancient environmental narratives and calls for further in-depth investigations to better understand these hidden hydrogeological networks for both scientific knowledge and water resource management.

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Making of a Geopark for Conservation, Sustainable Geotourism and Livelihood Generation: A Case Study from Pithoragarh District, Uttarakhand, India

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ABSTRACT

The present paper is based on an ongoing Geopark project sanctioned by Ministry of Environment, Forest & Climate Change (MoEF&CC) and monitored by National Mission on Himalayan Studies (NMHS). Through a comprehensive geological and geomorphological study followed by identification and subsequent development of Geo-sites, the project aims to bring out geological uniqueness of the project area to obtain UNESCO Global Geopark status. Pithoragarh, the focus area of the research cum action project, is a strategically located border district of Kumaon Himalaya and represents one of India's most distinctive and underexplored geodiversity hotspots. The region is bestowed with exceptional geological heritage, encompassing striking fluvial, glacial, and lacustrine landscapes, alongside significant Proterozoic stromatolitic colonies representing invaluable indicators of early life. The varied geomorphology of the region, shaped by the dynamic interplay of active tectonics and climatic forces, sustains a mosaic of habitats, thereby forging strong functional linkages between geodiversity and biodiversity, and creating a living natural laboratory for geoeducation, research, and experiential learning. In addition, the integrated potential of Pithoragarh and surrounding districts of Kumaon Himalaya makes it a model region for development of holistic geotourism, as an effective measure for conservation of geoheritagein Himalayas.

Additionally, as the initial dlefisurveys have revealed, the area is enriched with archaeological and anthropological sites, viz. natural caves, rock shelters, prehistoric rock paintings and abandoned historic copper mines to name a few, testify existence of early human habitation and provides opportunity to observe their evolutionary realm. Early ethnographic investigations suggest that the indigenous tribal communities inhibiting the project area host rich cultural legacy interwoven with the mountain landscape.

The initial studies and preliminary surveys have given enough indication that the project area has high potential to meet requisite conditions of a UNESCO designated Global Geopark. The current study showcases the effort made so far by the project proponents inassessing and initiating a sustainable geotourism model, incorporating geoexcursion sites and geo-cultural- archaeological hubs of tourist interest with active involvement of the local community in selected locations of Pithoragarh and adjoining Districts.

★★★

Hermit Cave System in Lakhamandal Valley, Upper Yamuna River Basin, Northwestern Himalaya

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ABSTRACT

The Himalaya are the most evolving terrain, featuring a few important geological and geomorphological heritage sites. This study assesses one of the hermit cave complexes in the Lakhamandal valley, located in the Northwest Himalaya within the Yamuna River basin. It consists of alluvial deposits, and the valley is home to a hermit cave complex created by sages and the locals. The cave complex of this hermit is seen over several terrace levels, and one- or two-story houses, have been carved into the Quaternary deposits through a narrow opening. The Lakhamandal valley has a rich history as a pilgrimage route, boasting a cultural and historical reputation that is reflected in various historic books on the Indian subcontinent. The rapid growth of infrastructure in the valley has attracted both local and foreign tourists over the past few decades, resulting in the unscrupulous excavation of hermit caves in the region. We have proposed the Lakhamandal valley hermit cave complex as a geoheritage site to capture its unique geological and historical attributes. A preliminary SWOT analysis provides an overview of the site's severe issues and recommendations, and we aim to have it identified as a geoheritage site.

From Stone to Symbol: the Role of Historical Monuments as Catalysts of Nation's Cultural Integration in Contemporary India

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ABSTRACT

Historical monuments in India transcend their architectural magnificence to serve as powerful catalysts for cultural integration and national identity formation in contemporary society. This research examines the transformation of monumental structures from mere archaeological sites to vibrant symbols of national unity and cultural synthesis. Through an analysis of different significant monuments like the Konark Sun Temple in 10 rupees note (representing ancient Indian architectural excellence), Ellora Caves in 20 rupees note (showcasing religious harmony), Hampi in 50 rupees note (demonstrating South Indian architectural grandeur), Rani Ki Vavin 100 rupees note (symbolizing cultural synthesis), etc. The Taj Mahal stands as the most prominent example of symbolic transformation. The Red Fort in Delhi has evolved from being a Mughal palace to a powerful symbol of Indian independence and sovereignty in 1947. The Somnath Temple, having been destroyed and rebuilt multiple times, symbolizes the perseverance and revival of Indian cultural traditions. Similarly, the Qutub Minar represents the architectural innovation and cultural synthesis that marked India's medieval period. The Ashoka Stambh represents one of India's most significant transformations from a historical monument to a paramount national symbolto become India's national emblem and a symbol of sovereign authority. The chakra (wheel) beneath the lions, derived from the Dharma Chakra, has been adopted in India's national flag. The adoption of the Lion Capital as India's national emblem has given it new dimensions which are appeared on all official documents, currency, and government communications. The transformation of these monuments into symbols has been further reinforced through educational curriculum that emphasize their historical and cultural significance. Digital media campaigns that promote these monuments as symbols of India's rich heritage. Conservation efforts that engage communities in preserving these symbols for future generations. This research provides crucial insights for heritage administrators, policymakers, and cultural organizations in leveraging historical monuments for strengthening national unity while preserving their architectural and cultural significance in an increasingly globalized world.

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Cultural and Ethical Dimensions of Geoheritage: A Case Study of Ardhanari Nateshwar Temple, Velapur, District Solapur, Maharashtra, India

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ABSTRACT

Geoheritage sites tend to be comprehended in terms of their geological characteristics first and foremost; yet, most such places are richly embedded within the cultural, spiritual, and moral life of neighbourhood communities. The present paper examines the Ardhanari Nateshwar Temple in Velapur, Maharashtra- a rare instance of a heritage edifice combining spiritual symbolism, conventional architecture, and geodiversity. Built by the area-relevant Deccan Trap basalt and consecrated to the uncommon Ardhanarśvara God, the temple is a quintessential example of geoheritage in cultural terms. It is assessed by this research for its suitability as an official geoheritage site while taking into consideration the ethical dilemma of protecting such environments during active religious worship.

★★★

Culturally Aligned Conservation of Geodiversity- Role of Sacred Spaces for Interconnectedness and Sustainable Futures

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ABSTRACT

Sacred groves are traditionally the areas of religious and cultural significance. They are often associated with unique geological features or landforms. However, there is general paucity of research that acknowledges the interconnectedness of natural and cultural heritage. It has been a belief that certain trees are the abode of sacred deities and ancestral spirits, many communities set aside sanctified areas of forested land and establish rules and customs to ensure their protection, prohibiting felling of trees, killing animals, and vandalising rocks, etc. The sacredness, religious beliefs and taboos play a significant role in promoting sustainable utilization and conservation of flora and fauna of the such sacred spaces.

A noticeable gap in studies is observed that yllacfiicepsfocusing on the geological features located within the sacred groves and their ecnacfiingiswithin these cultural sites. Such interconnectedness of Cultural and Geological Heritage is elaborated in the present contribution that records the occurrence and preservation of two major notified National Geological Monuments (NGM)– the Eparchean Unconformity (the boundary is between sedimentary rocks of the Cuddapah Supergroup, 1600 million years in age, and underlying Archaean rocks comprising granites, gneisses and dolerite dykes that are more than 2100 million years old). Second NGM is the Natural Arch, is one of the most popular natural tourist sites in Andhra Pradesh. Locally it is called Silathoranam, literally meaning 'a garland of rocks'. It is a naturally formed arch at the Tirumala Hills in Andhra Pradesh. This natural structure is the result of natural weathering and formed in the quartzites of Cuddapah Supergroup of Middle to Upper Proterozoic age (1600 to 570 Ma) due to natural erosive forces operative for the last 2.5-million-year. This Natural Arch is also linked to mythology and may have a divine connection. This may be because the arch is located in the famous Tirumala Hills, which is home to the famous temple of Lord Venkateswara or Lord Balaji or Vishnu. The entire area around the Tirumala Hills is forested, also known as Dev Bhumi (abode or home of gods). It is protected as a sacred forest and in parts developed into well-curated and nurtured gardens hosting a variety of medicinal and aromatic plants by the Tirupati-Tirumala Devasthanam (TTD). Such dispensation not only protects and conserves the biodiversity, but also protects the geodiversity of the area.

The present contribution is a commentary on interconnectedness of geodiversity and biodiversity aligned to cultural and natural heritage sites within these sacred groves and suggests potential areas for further exploration and research particularly in north Kerala's sacred groves in parts of Western Ghats that demonstrate how some of these sacred spaces host rare geosites of laterite including NGM at Malappuram and unique landscapes that also integrate socio-cultural entities and play vital role in sustainable protection and conservation of geodiversity together with the biodiversity.

★★★

Sustainable Geotourism in Meghalaya: A Participatory Approach to Geoheritage Conservation

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ABSTRACT

Meghalaya is known for its diverse geological, geomorphological, and biogeographical features, as well as its distinctive cultural landscapes. It holds some of India's most significant geoheritage assets; living root bridges, limestone caves, and canyons are prime examples. While these natural and cultural resources offer immense potential for geotourism, they face increasing threats from both natural and anthropogenic activities. This study explores how integrating indigenous communities, particularly the Khasi and Jaintia peoples, into geotourism planning and management can provide a sustainable pathway for conservation and development. Using a combination of field surveys, participatory interviews, geospatial mapping, and secondary data analysis, the research identifies key geoheritage sites and evaluates the challenges and opportunities of community involvement. Findings reveal that traditional ecological knowledge and locally rooted conservation practices can strengthen site stewardship, reduce environmental degradation, and enhance visitor experiences. The paper proposes a state-wide participatory model for geotourism that balances conservation priorities with livelihood generation. Policy recommendations highlight the need for capacity-building, legal recognition of geoheritage, and the integration of community-led initiatives into regional tourism frameworks. By positioning geotourism as both a conservation tool and a driver of inclusive development, Meghalaya can serve as a model for sustainable geoheritage management in India.

★★★

Sustainable Livelihoods through Geotourism: A Case Study of Lahaul–Spiti in the Trans-Himalayan Region

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ABSTRACT

The Trans-Himalayan landscapes of Lahaul–Spiti, located in Himachal Pradesh, India, represent one of the most distinctive geoheritage regions in South Asia, where unique geological formations, high-altitude ecosystems, and rich cultural traditions converge. The region has recently emerged as a focal point for geotourism, with its potential to foster sustainable livelihoods while safeguarding fragile mountain environments. This paper explores the geotourism potential of the proposed Lahaul–Spiti Global Geopark, assessing how local communities are integrating traditional livelihood practices with tourism-driven opportunities, particularly homestays, eco-guided treks, and cultural festivals. Drawing upon visitor statistics, household livelihood surveys, and conservation data from 2022–2024, this study examines the economic, social, and ecological dimensions of geotourism. The analysis demonstrates that community-based tourism initiatives, supported by sustainable infrastructure and conservation policies, have contributed to increased household incomes by an average of 18% between 2022 and 2024, while also fostering cultural resilience and environmental stewardship. However, challenges such as seasonal dependency, climate change impacts, and limited institutional capacity continue to hinder long-term sustainability. By situating Lahaul–Spiti within global geopark discourses, this paper emphasizes the importance of participatory governance, geoconservation education, and diversified livelihood strategies for building resilience in high-altitude rural economies. The findings underscore that geotourism, when aligned with the principles of UNESCO Global Geoparks, can serve as a model for balancing economic development, cultural preservation, and ecological sustainability in other Trans-Himalayan regions.

★★★

Analysing Cultural Sanctity of Pandavulaguatta, where Ancient Rock Formations Forged into Sacred Landscape

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ABSTRACT

Pandavulagutta is one of the most important geological and archaeological sites in India, predating the Himalayas. It islocated approximately 2 km away from Kothapalli village, Regonda Mandal of Jayashankar Bhupalpally district, in state of Telangana. It was officially recognised as a geo-heritage site in 2024 by the Geological Survey of India (GSI), and it is the only geoheritage site in Telangana state. The geological setting of the site reveals a complex evolutionary history and the sedimentary rock formations here influence the geomorphological features, such as the formation of rock shelters, natural stone arches, and naturally formed water bodies, formed due to differential weathering patterns, which acts as a significant force behind shaping the landscape. The evidence, such as petroglyphs, microliths, inscriptions and frescos at the site, indicates continuous human inhabitation from the mesolithic period to medieval times. Rock art here depicts various various figures such as giraffe, lizard, mongoose, porcupine etc., and a few anthropomorphic, geometric figures and other symbols that describe significant symbolic and ritualistic dimensions. Locals believe that the Pandavas took shelter here for some period. Frescoes in this site even depict dynamic action scenes. Locals associate these action scenes and few landform features with narratives of Mahabharata. Recently two inscriptions dated backto the 7th-9th century C.E. were found on the upper walls of caves in Pandavulagutta. This site embodies centuries of oral traditions, mythological narratives and cultural traditions of tribal communities that have inhabited the region over centuries. This paper aims to analyse the transformation of ancient geological formations into a sacred and cultural landscape through a series of human interactions and cultural evolutions from prehistoric to contemporary times.

★★★

Policy Frameworks for Geoheritage Conservation and Sustainable Land Use: An Empirical Study on Nalanda (A UNESCO World Heritage), Bihar

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ABSTRACT

This paper examines the policy landscape that affects geo-heritage conservation and sustainable land use in the vicinity of the Archaeological Site of Nalanda Mahavihara, a UNESCO World Heritage site in Bihar, India. Using Nalanda as a case study, the paper reviews international, national and local policy instruments that shape conservation outcomes; analyses gaps and overlaps between archaeological and geo-heritage management regimes; and proposes an integrated policy framework to align geoconservation, archaeological conservation, and sustainable land-use planning. This paper is based on primary and secondary data. The respondents of primary data are Indian Bureaucrats, Research Scholars, Policy makers, Native and Tourists who belong to or visited Nalanda. Various policy documents, Survey documents, and data from Bhuvan website have been taken. Secondary data has been collected from various Government Departments. Suggestions include institutional coordination mechanisms, statutory recognition of geo-heritage, buffer-zone land-use zoning, community engagement, and digital monitoring to secure both cultural and geological values while supporting sustainable local development.

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Spatial Landscape of Geoeducation for Sustainability Management

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ABSTRACT

The spatial landscape of geoeducation for sustainability management is critically examined through the lens of philosophical foundations, including epistemology, ontology, axiology, and critical realism. However, these lenses unpack the different dimensions of geoeducation. This paper uses discourse analysis, content analysis, and meta-synthesis as research methodologies. It critically examines the literature review. Furthermore, it discusses the pedagogical approaches, which include place-based education for sustainability. "Place is not just a thing in the world but a way of understanding the world" (Cresswell, 2005, p. 18). Furthermore, it provides the relevance of innovative pedagogical approaches of systems thinking, participatory, and inquiry-based learning in sustainability contexts. Watershed Management is a classic example of the participatory approach in sustainability management, which provides a practical epistemology of sustainability. Agricultural practices such as climate- smart agriculture, agroforestry, and conservation agriculture using systems thinking are an archetypal example of the systems thinking approach. Therefore, it discusses the interdisciplinary approach of Cultural, Human, Physical, and Social Geographies and different branches of Social Sciences leading to the production of innovative and unique blended geoeducation for sustainability management. However, digital space and geospatial tools, including GIS, Remote Sensing, and Artificial Intelligence, play a critical role in producing, constructing, conceptualizing, and managing large- scale data and knowledge. Hence, digital space plays a pivotal role in producing and consuming sustainable knowledge. For instance: Climate change impact in Uttarakhand by remote sensing and GIS application. Knowledge systems integration plays a pivotal role in shaping scientific literacy and environmental decision-making.

Furthermore, it emphasizes the integration of indigenous knowledge and local ecological knowledge. For instance: Himalayan Region – Community- Based Forest and Water Management leads to the intersection of indigenous knowledge and local ecological knowledge, which results in the sustainable capital landscape of social fencing, social capital, natural, and cultural capital. Therefore, this paper also discusses how curriculum and policy form the foundation stone for contemporary geographies. It critically examines the evolution, relevance, and importance of Sustainable Development Goals at the international and national levels. Hence, climate change education in school and higher education curricula is discussed. Furthermore, it critically explores the challenges and future directions in a sustainable way. This paper is a theoretical overarching discussion addressing different nodes of epistemology that produce geoeducation in sustainability.

★★★

Geoheritage, Geotourism, and the UNESCO Gap: Why India Needs its First Global Geopark

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ABSTRACT

India, with its extraordinary geological wealth and deep cultural interlinkages to landscapes, remains conspicuously absent from the global network of UNESCO Global Geoparks (UGGs). Despite hosting sites of immense geodiversity, such as the Deccan Traps, Aravalli Craton, Mawmluh Cave, and the Bagh Fossil Beds, the country has yet to secure recognition for any formal geopark under the UNESCO framework. This study critically examines the potential of India's geoheritage to align with the criteria of UGGs and explores the policy, administrative, and sociocultural barriers that have hindered progress in this domain. It emphasizes the strategic integration of geotourism as a sustainable development tool that not only enhances local economies but also fosters public education, scientific awareness, and cultural preservation .

Through a multidisciplinary perspective, this study highlights successful international case studies while presenting an evaluative framework suited to the Indian context. It also underscores the importance of inclusive participation, especially of local communities and women, in developing community-led geopark models. The lack of a geopark policy in India is identified a critical vacuum, demanding institutional collaboration among geoscientists, policymakers, tourism stakeholders, and environmental planners. The paper concludes by proposing a roadmap for establishing India's first UNESCO Global Geopark, rooted in innovation, inclusivity, and geoheritage-based sustainability.

★★★

Forging a Sustainable Geoheritage Legacy: Policy-Driven Community Mobilization for Establishing UNESCO Global Geoparks in India

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ABSTRACT

UNESCO Global Geoparks (UGGp's) are internationally recognized sites that integrate geological heritage with sustainable development, education, and community engagement. India, despite its vast geoheritage, from the Deccan Traps to Himalayan formations, yet to establish a UGGp as of 2025. This study proposes a novel framework for creating UGGp's in India by harnessing community-driven awareness and strategic policy formulation to promote geoconservation and sustainable tourism.

The envisioned roadmap pivots on empowering local communities through targeted awareness initiatives, underpinned by robust policy mechanisms that prioritize inclusivity, transparency, and adaptive governance. By engaging diverse stakeholders, local governments, non-governmental organizations, academic institutions, and private enterprises, this approach addresses critical challenges such as urban sprawl, unregulated tourism, and resource exploitation that threaten India's geological assets. Policies are crafted to ensure inter-ministerial coordination, establish clear regulatory frameworks, and incentivize sustainable practices, aligning seamlessly with UNESCO's stringent criteria for geopark designation. This framework draws inspiration from global UGGp models, which emphasize local involvement as a cornerstone of sustainable geotourism, adapting these principles to India's unique socio-cultural and geological context.

Methodologically, the study adopts a mixed-methods approach, integrating participatory action research with stakeholder consultations, community workshops, and in-depth case studies of prospective geopark sites, the study also illuminates how localized policy interventions can cultivate community ownership, foster pride in geoheritage, and stimulate eco-tourism economies. Collaborative efforts with organizations like the Geological Survey of India (GSI) and UNESCO facilitate capacity-building programs, public awareness campaigns, and technical training, ensuring alignment with international standards while grounding initiatives in local realities.

Preliminary findings indicate that a policy-driven, community-centric model could catalyze the establishment of multiple geoparks across India, each serving as a nexus of conservation, education, and economic opportunity. By leveraging community engagement, the framework not only safeguards geological treasures but also empowers local populations through job creation and sustainable tourism ventures. For instance, sensitizing communities around sites like the Lonar Crater can transform them into custodians of their heritage, while well-crafted policies ensure long-term protection against environmental degradation. Projections suggest that with sustained policy advocacy and training, India could propose over a dozen geopark candidates, significantly enhancing its global geoconservation profile.

★★★

Exploring Cultural Sustainability through Tourism: A Case Study of the Tagin Tribe in Upper Subansiri, Arunachal Pradesh

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ABSTRACT

This study explores the potential and challenges of sustainable tourism development in Upper Subansiri district, Arunachal Pradesh, with a particular focus on the Indigenous Tagin tribe. Nestled in the Eastern Himalayas, the district is endowed with pristine forests, rivers, waterfalls, and snow-clad mountains, offering immense opportunities for adventure tourism, birdwatching, trekking, and cultural exploration. Despite these natural and cultural assets, tourism remains largely untapped in the region. This research is grounded in a qualitative methodology comprising in-depth interviews, open-ended questionnaires, the Participatory Rural Appraisal (PRA) method, and participant observation. The highlight several several constraints, including geographical remoteness, poor infrastructure, lack of travel services and homestays, economic limitations, and diminishing Indigenous knowledge due to globalization. The Tagin tribe, historically connected to Tibetan trade networks, preserves rich traditions such as wet-terraced paddy cultivation, water harvesting, unique handicrafts like the traditional "Tagin hat," rich indigenous food culture, medicinal knowledge and colourful folklores and costumes. The Tagin tribe is an animist and a nature worshipper of the Sun and Moon, called "Donyi-Polo," and is a preacher of a vibrant festival called "Si-Donyi." However, the community faces challenges in leveraging this heritage for sustainable livelihoods. The study concludes that conscious, inclusive, and culturally sensitive tourism policies-backed by community participation and government support are essential for harmonizing environmental conservation with socio-economic development in Upper Subansiri. The research aims to contribute to policy frameworks that promote sustainable tourism while preserving Indigenous identity and biodiversity.

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Geoheritage-sites Preservation in Chhattisgarh, Central India: Initiatives and Management Strategies

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ABSTRACT

Chhattisgarh, located in central India, is home to various geoheritage sites of national and scientific importance. The state hosts rich geological diversity and ancient rock formations from Archean to recent. From Asia's largest marine fossil park in Manendragarh to the ancient limestone caves of Kanger Valley National Park, Chhattisgarh offers valuable insights for scientific research, education, and sustainable geotourism. The Geological Survey of India (GSI) has played a pivotal role in the identification, documentation, and conservation of these valuable geoheritage sites. Many of these sites are vulnerable to industrial pressures, unregulated tourism, and environmental changes. To address this, the GSI, in collaboration with state authorities, has proposed protective measures and infrastructure development. A multidisciplinary approach involving heritage management, public awareness, promotion of geotourism, and strong conservation laws is recommended to protect and sustain Chhattisgarh's geoheritage legacy. As a result, the state government has taken key steps to preserve these geoheritage sites, including infrastructure development, the inclusion of Kanger Valley National Park in UNESCO's tentative list of natural heritage sites, and collaborations with government agencies and academic institutions. This will not only protect these non-renewable geological archives but also support tribal empowerment, education, and economic development in Chhattisgarh. Despite the absence of a comprehensive geoheritage protection law in India, GSI's continuous efforts have laid the foundation for a sustainable geoheritage management framework in the region. This study highlights the efforts of GSI including successes, challenges, and future directions of geoheritage preservation in Chhattisgarh, emphasizing the need for public participation, stronger legal frameworks, and inter-agency collaboration to safeguard India's geological legacy.

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Socio-Economic Impact of Religious Tourism: Kumbh Mela, Prayagraj 2025

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ABSTRACT

The Kumbh Mela is enshrined in ancient scriptures, mythology and Hindu scriptures as a sacred pilgrimage site. Millions of Indian and foreign devotees gather at one place to take bath. In India, the Kumbh Mela is mainly held at four places- Haridwar on the banks of the Ganges, Prayag at the confluence of the Ganges and the Yamuna, Ujjain on the banks of the river Chhapra and Nashik (Trimbak) on the banks of the Godavari. Prayag Kumbh is one of the major religious gatherings in the world. UNESCO has recognised it as an intangible cultural heritage of India. The Kumbh Mela Prayagraj 2025was conducted at the confluence of the holy rivers Ganga and Yamuna, which has been a centre of attraction not only for India but for the entire world. About 660 million pilgrims participated in Mahakumbh 2025. An estimated Rs 2 lakh crore was generated in direct activities out of the revenue generated from this in the field of economy. This Mahakumbh was a centre of attraction not only because of its spiritual significance but also because of its cultural, socio-economic factors. As a result, it makes a unique contribution and unparalleled significance in strengthening faith in the ancient tradition of culture. This paper examines the socio-economic impact of the Kumbh Mela along with a discussion of the changing nature of the Kumbh Mela, which has led to the emergence of the Kumbh Mela as a form of religious tourism in the present times.

This article discusses the impact of Mahakumbh Mela on India's spiritual tourism scenario on the world stage, mainly covering the impact of pilgrim footfall, tourism growth, socio-economic impact, infrastructure, spiritual and religious significance. The present study is exclusively based on secondary data collected from Kumbh Mela Authority, district website, government departments as well as various research papers, journals and others relevant literature.

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Geoheritageand Geodiversity in India: Integrated Strategies for Conservation, Policy, and Sustainable Geotourism

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ABSTRACT

India's remarkable geological diversity forms a living chronicle of the Earth's evolution, embodied in landscapes, rock formations, fossils, and mineral deposits that span billions of years. From the ancient cratonic shields of the Aravalli and Dharwar regions to the fossil-rich Siwalik Hills, this geodiversity is a repository of immense scientific, educational, and cultural value. It underpins an understanding of tectonic, sedimentary, and volcanic processes while offering tangible connections to deep time. Yet, despite this richness, India remains without a single UNESCO Global Geopark, a gap that highlights the absence of an integrated approach to recognising and managing these irreplaceable natural assets. The country's geoheritage spans a breathtaking array of sites. The Lonar Crater in Maharashtra, a rare meteorite impact structure, is revered both as a geological phenomenon and a sacred landscape. The columnar basalt formations of St. Mary's Islands in Karnataka reveal the dramatic story of Deccan volcanism, while Paleoproterozoic stromatolite-bearing sequences in Madhya Pradesh preserve some of the earliest evidence of life. The fossil parks at Ghughua and Mandla hold petrified forests dating back over 65 million years, and the ancient lead–zinc–copper mining belts of Zawar and Khetri in Rajasthan stand as testimony to advanced metallurgical knowledge nearly two and a half millennia ago. Caves such as Borra in Andhra Pradesh and Siju in Meghalaya intertwine geological wonder with spiritual narratives, while thermal springs from Himachal Pradesh to Sikkim merge geothermal processes with pilgrimage traditions. Hills like Parasnath in Jharkhand and Nandi Hills in Karnataka combine geological antiquity with enduring cultural significance. Despite the grandeur of these landscapes, many are under mounting threat from unregulated urbanisation, unsustainable extraction, and climate-induced degradation. The lack of a coherent policy framework for geoheritage conservation has left protection efforts fragmented and reactive, dependent on isolated initiatives by government agencies or local actors. Public awareness remains limited, and tourism models often prioritise short-term gains over long-term stewardship. To address these challenges, the study proposes a comprehensive, multidisciplinary framework that unites conservation imperatives, sustainable tourism, and cultural engagement. At its core lies the need for statutory recognition of key geosites, embedding geoheritage firmly within environmental and land-use legislation so that it is safeguarded alongside biodiversity and cultural heritage. Conservation in this vision is complemented by the careful development of sustainable geotourism designing interpretive infrastructure, heritage trails, and educational resources that reveal the scientific and aesthetic

value of these sites while preserving their integrity. Interpretation is conceived not as static signage, but as an immersive, participatory experience that deepens public understanding and fosters a culture of guardianship. Just as crucial is the acknowledgement of the spiritual, historical, and livelihood connections that communities maintain with these landscapes. Geoheritage in India is inseparable from its cultural contexts, and any strategy that seeks to preserve it must work in dialogue with local knowledge systems, rituals, and identities. By weaving together the insights of geoscience with the lived realities of cultural landscapes, this chapter presents geoheritage as a vital pillar of sustainable development, a wellspring for education, and a unifying source of shared identity. It advances a vision in which India's geodiversity is not only protected and celebrated nationally, but also recognised globally as part of humanity's common natural legacy.

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Moving towards Sustainability from Geo-local Knowledge: A Geographical Study of Prashar Lake

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ABSTRACT

Geo-local knowledge has been found to be effective in the preservation of the indigenous cultures, climate, and ecology. In regions such as Himachal Pradesh, where local communities coexist closely with nature and maintain a complex, delicately balanced ecosystem, it is possible to have sustainable development by increasing equitable resource usage and strengthening the ecological conservation capabilities of those communities. This knowledge has been transmitted orally by indigenous people from one generation to the next, which continues in a limited manner but is of as much significance as earlier. This approach not only safeguards habitats but also redefines human ecological relationships and fosters environmental stability alongside societal well-being, thereby contributing to the Sustainable Development Goals. The integration of both traditional ecological knowledge and geo-local wisdom is essential for the protection and management of natural resources, as well as understanding the balance between anthropogenic activities and the environment. The area surrounding Prashar Lake is rich in rare medicinal plants that thrive naturally within its ecosystem. In addition to its religious significance, the lake's role as a reservoir for numerous sustainable practices highlights the need to maintain ecological balance while pursuing development in the region. This study seeks to explore the geo-local knowledge embedded in the oral traditions of the Prashar Lake area and the rituals that support the lake's sustainability. Furthermore, it aims to document the myths and stories that emphasise traditional practices of environmental protection and conservation.

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Naga Hills Ophiolite: An Integrated Framework for Geoconservation, Socio-Cultural Heritage and Sustainable Development

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ABSTRACT

The Naga Hills Ophiolite (NHO) in the Noklak district of Nagaland, India, represents a site of immense g cfiitneicsoevalue as a national geological monument. Its ecnacfiingisis indistinguishably linked to the cultural significance of the rich, living heritage of the local Khiamniungan community, whose traditional practices provide a unique geo-cultural context. This paper proposes a conservation framework for the NHO that must exceed traditional, geology-focused models and adopt an integrated, community-based approach that takes cultural and socio-economic factors into account. The relationship of geology, culture, and sustainable development is becoming a central precept of modern conservation strategies. Geologically, the NHO is a fragmented sequence of Neo-Tethyan Ophiolite, preserving a complex tectonic history with petrological and geochemical signatures from both Mid-Ocean Ridge Basalt (MORB) and Supra-Subduction Zone (SSZ) environments. This landscape forms the foundation of the Khiamniungan people's way of life, shaping their agriculture and crafts. It includes historical iron smelting in Wui using magnetite and pottery making from local clays and serpentinite. The region's biodiversity, with forests of oak, bamboo, and pine, is utilised for illumination, which is essential to geoheritage. The paper emphasises the importance of community involvement, demonstrating how local insights and cooperation are vital for effective field work, conservation and sustainable resource use. An integrated approach should leverage geotourism and geoeducation to link geological conservation with community empowerment and cultural preservation. This approach can transform geoscientific research into a means of promoting sustainable development across India's diverse landscapes. The landscape, biodiversity,and the community's way of life demand a conservation approach that transcends geology-focused frameworks. The NHO can serve as a national model for geoheritage conservation that is both scientifically and socially equitable.

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Echoes of Deep Time: Mapping India's Geoheritage as a Blueprint for Sustainability, Climate Resilience, and Global Goals

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ABSTRACT

Geoheritage, encompassing landforms, stratigraphic sequences, fossil archives, and geomorphic imprints, represents Earth's deep-time narrative while shaping present-day cultural, ecological, and economic landscapes. India, with its exceptional geological diversity—from the fossil-rich strata of the Spiti Valley and tectonically active Himalayan belts to the Deccan basalts, glacial landforms of the Trans-Himalayas, and dynamic coastal margins—holds one of the world's richest but underutilized geoheritage portfolios. Despite inventories by the Geological Survey of India and academic initiatives, efforts remain fragmented, lacking a unified framework that integrates ecological, cultural, and developmental dimensions with the United Nations Sustainable Development Goals (SDGs).

This study addresses the gap through a comprehensive geospatial inventory and thematic classification of 168 geoheritage sites across four major geoprovinces: the Himalayan Belt, Deccan Volcanic Province, Coastal Margins, and Peninsular Shield. Sites are categorized into six thematic types—Paleontological & Evolutionary Records, Volcanic & Tectonic Landforms, FlowForm Terrains, Impact Structures, Cultural & Archaeological Geoheritage, and Multi-value/Integrated Sites. A structured, weighted evaluation model was developed, integrating scientific, conservation, educational, tourism, community, accessibility, and interpretive dimensions. Using GIS-enabled multi-criteria overlays, the analysis linked geoheritage attributes to SDG-relevant indicators, including biodiversity corridors, climate risk zones, infrastructure resilience, and tourism density.

Findings reveal that geoheritage sites are multidimensional platforms for education, conservation, and inclusive development. Over 84% of sites strongly support SDG 4 (Quality Education) through scientific value, educational potential, and interpretive materials. SDG 13 (Climate Action) and SDG 15 (Life on Land) are advanced by 64% and 56% of sites, respectively, emphasizing their role in biodiversity stewardship and climate resilience. Additionally, 31% of sites contribute to SDG 8 (Decent Work and Economic Growth) and 27% to SDG 11 (Sustainable Cities and Communities) through sustainable tourism and community engagement. Regional patterns underscore the climate sensitivity of Himalayan sites, the volcanic and impact structures of the Deccan, the marine and deltaic assets of the Coastal Margin, and the fossil-rich and cultural-geological hybrids of the Peninsular Shield.
Beyond regional insights, the study proposes both site-specific and national-level strategies, including climate-resilient zoning in the Himalayas, digital documentation and hazard mapping in the Deccan, community-led conservation and speleological

protection in the Peninsular Shield, and blue geoheritage corridors in coastal regions. At the policy interface, recommendations include the creation of a National Geoheritage Register, integrating geoheritage into SDG planning, and using technology-driven tools such as GIS dashboards, drone monitoring, and augmented reality-based interpretive platforms.

By systematically mapping and aligning India's geoheritage with global sustainability frameworks, this work advances a blueprint for harnessing geodiversity as a strategic asset for climate resilience, inclusive growth, and cultural continuity. It demonstrates that when contextualized within modern development agendas, India's ancient geological narratives can inform transformative pathways toward achieving the Sustainable Development Goals while strengthening science–policy–society linkages.

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Geoheritage Significance of Fossils Wood from Ladakh (Basgo & Rumbak), NW Himalaya

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ABSTRACT

The discovery of fossilized wood in the Basgo Formation, near the World Heritage Fort at Basgo, marks the tsrfirecorded gnidnfiof plant fossils in this region. This gnidnfiholds tnacfiingispaleontological and paleoclimatic importance and provides insights into late Miocene paleoclimate and tectonics of the Trans-Himalayan region. The Basgo Formation is situated between the Indus Group and the Ladakh Batholith and about 40 km from Leh. Lithologically, the formation is characterized by grey sandstone with pebbles and alternating red mudstone. Preserving and protecting this fossil wood can significantly enhance enhance the educational and scientific experience for both visitors and researchers. Since it is essential to protect our fossil sites for future generations, ensuring that they continue to serve as valuable resources for education, research, and cultural heritage. However, the fragile sandstone matrix makes the fossils extremely vulnerable to erosion, weathering and human interference. It is proposed to protect and preserve this site for further research and declare it a geoheritage site to boost Geotourism.

The Rumbak is an additional wood fossil site situated about 25 km from Leh, across the Indus River. The area can be accessed via a route that follows a stream originating from the villages of Rumbak and Yurutse, which eventually joins the Indus River near Phey. Geologically, the region belongs to the Indus Group and is primarily composed of sedimentary rocks such as sandstone, shale, and conglomerates containing clasts of granite, shale, and quartzite.

In Ladakh, the well-preserved plant or wood fossils are exposed just above Rumbak village, along with a marine one-foot-thick nummulitic limestone horizon and indicating a once vegetated terrestrial environment. Nummulitic limestone horizon which contains abundant nummulites characteristic of shallow marine conditions and suggest a Palaeoenvironmental condition. These fossiliferous exposures are scientifically significant and require proper documentation and preservation. The geological and fossil records of Rumbak provide valuable insights into the paleoenvironmental and depositional history of the Indus Basin. The presence of both wood fossils and marine Nummulitic limestone within close proximity indicates major environmental shifts from terrestrial to marine conditions in the geological past. Such findings are crucial for reconstructing paleoclimatic conditions, understanding basin evolution, and contributing to the broader knowledge of Himalayan geology. Additionally, proper conservation of these fossils is essential, as they hold educational, scientific, and heritage value.

★★★

Innovative Technologies in Geosite and Geodiversity Site Monitoring: A Legal Perspective on Governance, Accountability, and Sustainable Development

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ABSTRACT

The integration of innovative technologies-such as remote sensing, GIS mapping, UAVs (drones), AI-based data analysis, and digital twin models—has significantly transformed the assessment and monitoring of geosites and geodiversity sites. However, these technological advances raise critical questions around legal governance, data sovereignty, environmental justice, and sustainable development.

This paper explores the intersection of technology and law from a legal scholar's viewpoint, assessing how existing environmental, property, and heritage protection laws accommodate or fail to accommodate the dynamic nature of tech-based geosite monitoring. Drawing on international case studies, this research analyses regulatory frameworks, intellectual property implications of geospatial data, and the rights of indigenous and local communities. The study advocates for a multidimensional legal approach that integrates scientific innovation with environmental ethics and participatory governance. By framing geodiversity not just as a scientific concern but as a legal and socio-political issue, the paper proposes recommendations for updating legal standards and policies to ensure that the use of emerging technologies in geoconservation is ethical, inclusive, and sustainable.

★★★

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GSSP of the Meghalayan Stage in The Mawmluh Cave. India

HAS BEEN DESIGNATED AND INCLUDED IN THE LIST OF
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In Zumaia, Basque Coast UNESCO Global Geopark **28 / October / 2022**

Stanley Finney
Secretary General International Union of Geological Sciences (IUGS)

Asier Hilario
Chair IUGS-International Commissions on Geoheritage

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Secretary General International Union of Geological Sciences (IUGS)

Asier Hilario
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Geoheritage & Geopark workshops

Chitrakoot Geopark Workshop

Flexible Sandstone Field Workshop

Kachchh Geopark Workshop

Bagh Geopark Workshop

Udaipur Field Workshop

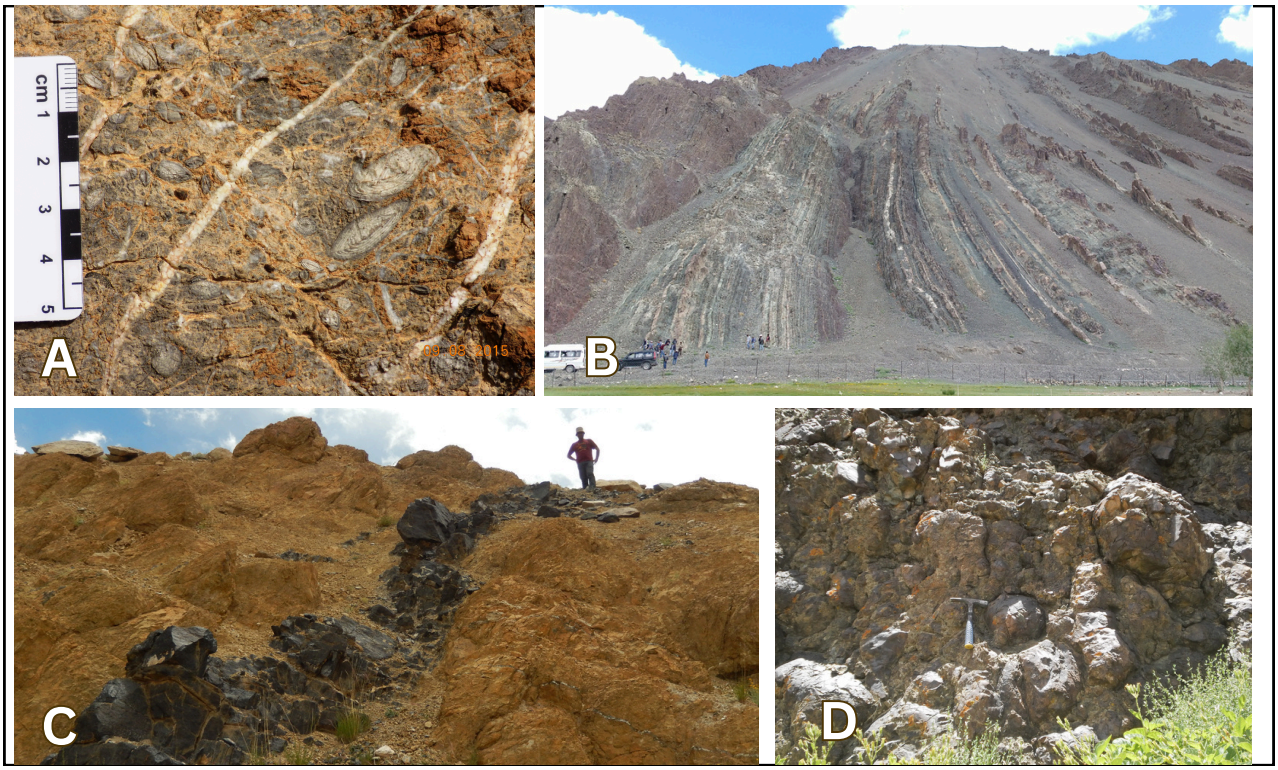
Zawar Potential Geopark, Udaipur, Rajasthan: A. Ancient (about 2000 years old) mining; B. Remnants of furnace used for zinc smelting by ancestors; C. Heaps of ancient retarts used for zinc smelting; D. Close up view of retarts. E. 11th century Zawar Mata Temple. *Photos: K. L. Verma, Udaipur*

Gandikota Potential Geopark, Kadapa District, Andhra Pradesh: A. Grand canyon along Penna river; B. Exotic camping sites; C. Madhavaraya Temple of 16th century ; D. Juma Masjid build in the year 1650. *Photos: Satish Tripathi, Lucknow & Govt. website*

Andaman Potential Geopark: A. Baratang Island contains the only known examples of mud volcanoes in India; B. Limestone cave at Baratang Island; C. Natural coral bridge in Neil Island; D. Historic Cellular Jail. *Photos: Alok Kumar, Varanasi & Govt. website*

Kotumsar limestone cave, Jagdalpur, Chhattisgarh. Caves of Kanger Valley National Park are magic of nature. *Photos: Anzar Nabi & Amitanshu Jha, Jagdalpur*

Proposal submitted to the Government of India for declaration of National Mineral & Fossils: A. *Glossopteris* indica Gondwana fossil leaf as National Plant Fossil; B. Diamond as National Mineral of India; C. *Kotasaurus* (Jurassic Indian dinosaur) as National Animal Fossil.



Nidar Ophiolite Potential Geopark, Ladakh: A. Nummulitic (larger foraminifera) limestone deposited in Tethys Ocean; B. Turbidite sedimentary sequence C. Chromite (chromium ore) in ultramafic rocks; D. Pillow lava developed due to interaction with ocean water*: Satish Tripathi, Lucknow*