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Original Article

Geological Heritage Site for the Rajmahal Flora at Mandro, Sahibganj, India: An Opportunity for an Integrated–Sustainable Tourism Circuit

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Abstract

Mandro in Sahibganj District of Jharkhand State, India is known for its abundance of petrified wood and floral impressions from the Rajmahal Traps of Albian–Aptian age. This locality is among the 34 Geological Heritage Sites identified by the Geological Survey of India. The scientific importance of the site is vested in the intricate preservation of petrified wood and floral impressions in a single locality. The plants were transported by pyroclastic volcanic activity, and the tuff and crystal-laden pumice helped preserve the fossils, including upright tree stumps with intact root systems. Such an association of floral fossils with ignimbrite is of high scientific relevance and is one of its kind in India. At present, the Geoheritage Site, Mandro is compromised by the lack of legislative provisions guiding conservation of the site. Our study highlights bottlenecks in the development of the Geoheritage Site and suggests the formulation of an integrated–sustainable tourism circuit combining natural, anthropological, cultural and historical touristic components. We advocate operating the circuit through community participation, ensuring trust and capacity building among the local People. The circuit is an exclusively local tourism engine that could address socioeconomic disparities while developing as a hub for research and innovation across different disciplines. Paramount to these efforts is attaining Sustainable Development Goals and global recognition for the Geoheritage Site and the Circuit.

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Introduction

Mandro is an administrative block in the Sahibganj District of Jharkhand State in India (Fig. 1). It is situated approximately 30 km from the Sahibganj District headquarters amidst the rolling topography of the Rajmahal Hills. The block has 55 villages with a dominant population of Scheduled Tribes. The population is mainly engaged in

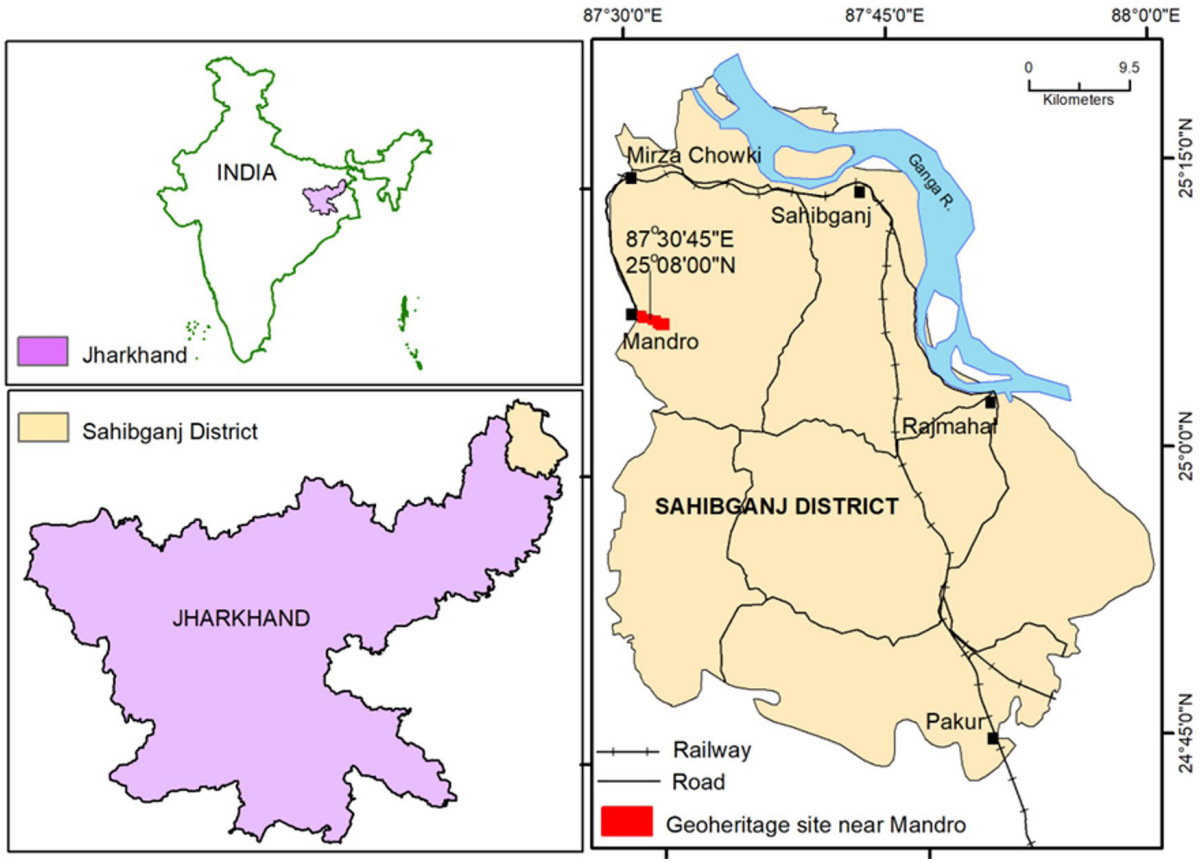

Figure 1. Location map of the Geoheritage Site, Mandro at Sahibganj District of Jharkhand State in India.

primary economic activity (agriculture) for livelihood. Amongst them, the Paharia tribe has inhabited the Rajmahal Hill region since prehistoric times. This tribe residing in the higher reaches and dense forests were labeled 'hostile' and areas inhabited by them as 'impenetrable' in early colonial literature (National Council for Educational Research and Training, 2023). However, now the tribe is listed among the Particularly Vulnerable Tribal Groups in India. Such groups require institutional support to overcome low indices of socio-economic growth and development. Various statistics like literacy rate, employment opportunities, etc. among individuals and access to basic amenities like kitchen and clean, smokeless cooking fuel, treated water for drinking, drainage facilities for waste-water outlets, etc., indicate Mandro is a demographically underdeveloped rural society (Census of India 2011).

Mandro, however, is known to the scientific community for the occurrence of rich petrified wood and impressions of the characteristic "Rajmahal flora" (Sastry *et al.* 1977). These fossils are associated with rocks of the Rajmahal Traps. Both, the flora and the Traps, derive their name from the Rajmahal Hills which define the geomorphology of the region. The flora is atypical as it represents

short-lived environmental conditions conducive to plant growth amidst the extensive continental volcanism occurring around ~118–115 Ma (Kent *et al.* 2002). The fossils are sporadically distributed throughout few hundred kilometers span of the Hills.

Floral impressions from the then inaccessible Rajmahal Hills were initially documented by Sir John Mc Clelland (Mc Clelland 1850; Sengupta 1988), a year before the formation of the Geological Survey of India (GSI). Later, Sir Thomas Oldham (Oldham, 1854), the first superintendent of GSI, and others systematically studied the Ptilophyllum flora from the Hills. Scientists from the GSI later discovered petrified plant material from Nipania, which is approximately 50 km northeast of Mandro. Subsequently, the region was studied by various researchers, leading to the discovery of numerous plant fossils. Presenting the most comprehensive geodiversity assessment of the Rajmahal Hills Sengupta (1988) described 36 geological type and reference sections, three biostratigraphic assemblage zones, and new species across the Rajmahal Traps and the underlying rocks (Table 1).

Table 1. Generalized litho-bio stratigraphic succession of the Rajmahal Hills: Modified after Raja Rao (1987); biozonation after Sengupta (1988); and 'Time slot classification' of Mukhopadhyay et al. (2010).

Formation	Lithology	Biostratigraphy & Age		Time slot classification
-	Alluvium Laterite	-	-	-
Rajmahal	Upper trap flows with or without intertrappean		Cretaceous	VII – Lower Cretaceous (Ma 105–118)
	Upper trap flows with fossiliferous intertrappean (Bed 8)	Taeniopteris spatulata-Brachyphyllum rhombicum - Assemblage Zone 3	Lower Cretaceous	
	Lower trap flows with fossiliferous intertrappean (Beds 4 to 7)	Cladophlebis indica – Dictyozamites indicus -Assemblage Zone 2	Middle Jurassic	
	Lower trap flows with unfossiliferous intertrappean beds (Beds (1 to 3			
	Unconformity (?) / Intrusive Contact			
Dubrajpur	Baked Sandstone, Siltstone	(Ptylophyllum flora (occasional	Lower Jurassic	VI – Lower to Middle Jurassic (Ma 160–184)
	Fossiliferous siltstone	Acutifolium, Glechienites – gleichenoides Assemblage Zone 1		
	Pebbly Sandstone		Triassic	
	Coarse sandstone, clay and shale beds			

The unusual richness in numbers and diversity of fossils at Mandro prompted the GSI to recognize the locality for its exceptional geological significance. Under its mandate by the Government of India to identify geoheritage sites for their protection, promotion, maintenance and enhancement of geotourism, the GSI declared Mandro a National Geological Monument or Geoheritage Site on 26th June 2014. The declaration placed Mandro on the geoheritage and geotourism map of India (www.gsi.gov.in) and projected it as a potential center of attraction in the region.

Declaring a site of geological significance as geoheritage and utilizing its uniqueness for geotourism are key aspects of changing human perception towards the Earth's geological resources (Newsome and Dowling 2018). Geoheritage is that part of the Earth which is valued, and geotourism is a form of tourism that is based on geological attraction. Geotourism is a link between the geoheritage and realization of socio-economic aspirations for overall sustainable development. It involves site visits, research, education, interpretation and economic activities.

With this background, we present an account of the geological significance of the Geoheritage Site, Mandro, while focusing on the present status of the site, and bottlenecks in its development under prevailing circumstances. Considering the two, we subsequently suggest the creation of an Integrated Sustainable Tourism Circuit revolving around the Geoheritage Site, Mandro, and incorporating natural, anthropological, cultural, and historical facets from nearby localities to popularize the Geoheritage Site, and to pave the way for its development for the benefit of the present and future generations.

The Geoheritage Site, Mandro

The Geoheritage Site, Mandro is the most significant site for the study of the fossils of the Rajmahal flora. Geomorphologically, it has an undulating topography with a large plateau at Gurmipahar and a few isolated mounds and hillocks. The lowland areas support water-intensive paddy cultivation. The site is situated in the lap of the Rajmahal Hills, which expose sedimentary rocks of the Triassic to Lower Jurassic overlain by volcanics of Cretaceous age (Table 1).

At several places in Mandro, petrified stumps are found upright and with root systems intact. The girth of other wood fossils is approx. 1.5 m in diameter. They are strewn over the rolling topography, particularly between Gurmipahar and Tara village (Fig. 2 A-E). The petrified wood intricately preserves anatomical details from bark to pith, including details of the anatomy at a cellular level (Fig. 2F).

Floral impressions found include Coniferophyta (conifers) in the form of Todites sp., Thinnfeldia chunakhalensis, Taeniopteris sarbadhikarii sp., Ptilophyllum acutifolium, Ptilophyllum cutchense, and Elatocladus tenerrima (Fig. 3 A-F).

The fossils are haphazardly distributed over a 1.62 Km2 area between Tara village and Gurmipahar (plateau). Most fossils in this part of the terrain are found in a churned and fragmented state. Within the broad area demarcated as extremely fossiliferous, the GSI identified 0.36 Km2 of a pristine area having a good concentration of in-situ fossils, at Basgobedo, Tara village and Gurmipahar, and recommended its immediate protection and conservation.

The Uniqueness of the Geoheritage Site, Mandro

The Rajmahal flora has been studied in detail (Sengupta 1988 and references therein). Other sites in India where fossilized/ petrified wood is found include the Akal Wood Fossil Park, Rajasthan. Here, the Lathi Formation, a sedimentary package of conglomerate, sandstone, and lignite

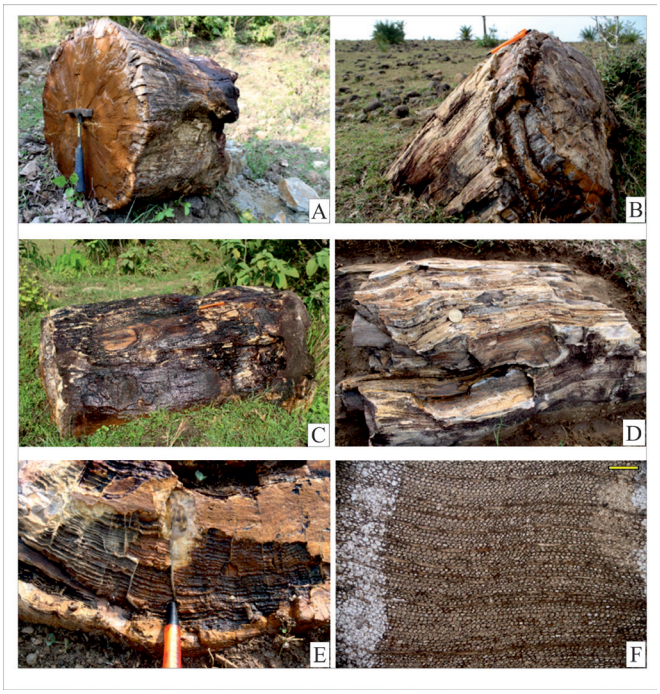

Figure 2. Plant fossils of the Rajmahal Flora. A-D) Different forms of petrified wood fossils (logs and trunks). E) Close-up view of preservation of annular rings and medullary rays. F) Preservation of cell structures within the petrified wood, from the Geoheritage Site, Mandro.

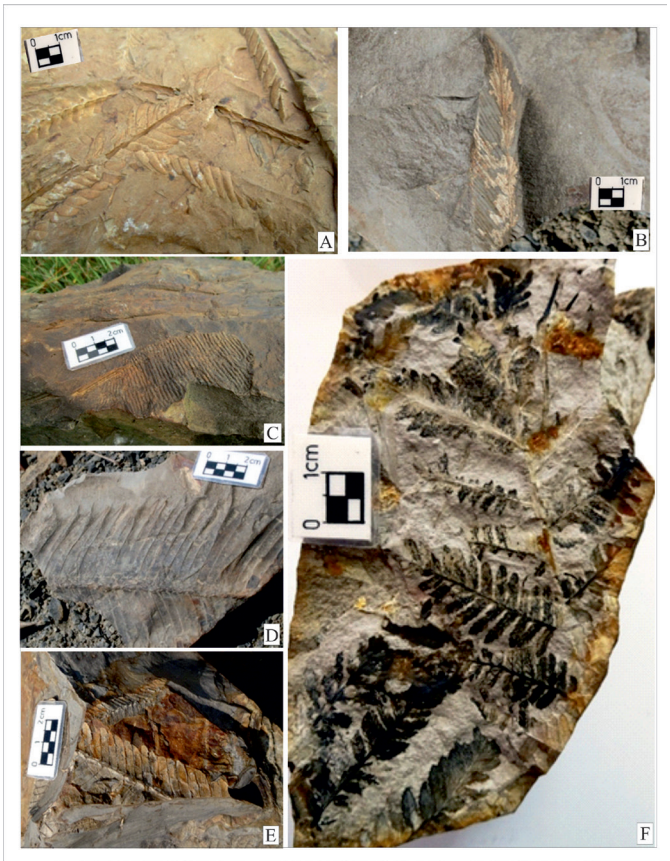

Figure 3. Floral impressions of the Rajmahal Flora from the Mandro geoheritage site. A) Todites sp. cf. williamsoni (Brongniart) Seward. B) Thinnfeldia chunakhalensis (Sah &Sukh Dev). C) Taeniopteris sarbadhikarii sp. D) Ptilophyllum acutifolium Morris. E) Ptilophyllum cutchenese. F) Elatocladus-Tenerrina (Feistmantle Sahni).

of Lower Jurassic age, hosts such fossils can be found (Geotourism / Geoheritage Sites Map of India 2023). The longest specimens here measure 13.4 m. It was declared a National Geological Monument in 1972 (as cited in Golani *et al.* 2016) and is presently maintained by the authorities of the Desert National Park under the Chief Wildlife Warden, Govt. of Rajasthan (Golani *et al.* 2016). Similarly, the Tiruvakkarai Fossil Wood Park in Tamil Nadu is another point of interest. It contains approx. 200 fossilized trunks of conifer and palm species of Mio-Pliocene age. The length of wood fossils varies from 3 to 15m and they measure up to 5 m in girth. The Site was recognized as a National Geological Monument in 1951 (Golani *et al.* 2016). The Sattanur National Fossil Wood Park was declared as a National Geological Monument also in 1951. Fossil Wood at Sattanur was first reported by Dr. M. S. Krishnan (Golani *et al.* 2016), who later became the first Indian to head the Geological Survey of India, in 1940. The initially reported 18 m long trunk is now only 14 m in length. It is within the Kulakkalnattam Formation, a marine sedimentary rock sequence under the Trichnopoly Group of Upper Cretaceous age (Golani *et al.* 2016; Geotourism / Geoheritage Sites Map of India, 2023).

The fossils at the Geoheritage Site, Mandro are unique. It was once thought that they were hosted in sedimentary inter-trappean beds, not so different from the other fossils just mentioned, and also preserved in exclusively sedimentary rocks. However, based on the recent study, we suggest that the fossils at Mandro are the first example of an ignimbrite-hosted fossilization from the Rajmahal Traps, built on the following observations:

- The fossils are fragmented and chaotically distributed both vertically and horizontally, indicating the action of catastrophic and turbulent forces. While some petrified tree stumps are found to be upright, other plant parts are randomly oriented and distributed.

- No sedimentary structures like bedding planes, cross beds, etc. were observed.

- The surrounding rock is dominated by tuff of various size fractions. Their proper segregation leads to the identification of changes in the energy conditions of the carrying media. It influences the fossil content found within each unit.

- Signatures of pyroclastic volcanic products include pumice which is widespread throughout the study area. It contains Pele's tears, fiammé, bombs, etc. Pumacious mudflow also constitutes an important unit here. The presence of such tuff-dominated pumacious volcanic products suggests that the pyroclastics were derived under violent eruptions leading to pumice flow deposits, i.e., an ignimbrite (Cas and Wright 1996; Branney and Kokelaar 2002).

- Differential welding of different lithounits complement lithounits of different tuff size fraction, providing direct evidence of compound cooling throughout the succession.

- Pumacious flows are rich in fragments of plant parts, giving the impression that the turbulent energy emerged on land and uprooted, fragmented, and transported the plant remains to their randomized deposition or in situ burial as in the case of the tree stumps.

- The entire package and products have been classified as surge, flow and fall deposits (Cas and Wright 1996; Branney and Kokelaar 2002)

In more detail of the Rajmahal ignimbrites, the basal surge is represented by the fine ash-dominated, highly welded and richly fossiliferous bottommost unit. It is intruded by and intermixed with the coarse ash, lithic, and crystal-dominated second surge. The initial surge must have originated from land and caused fragmentation of plants, including uprooting and transportation. The fine ash content

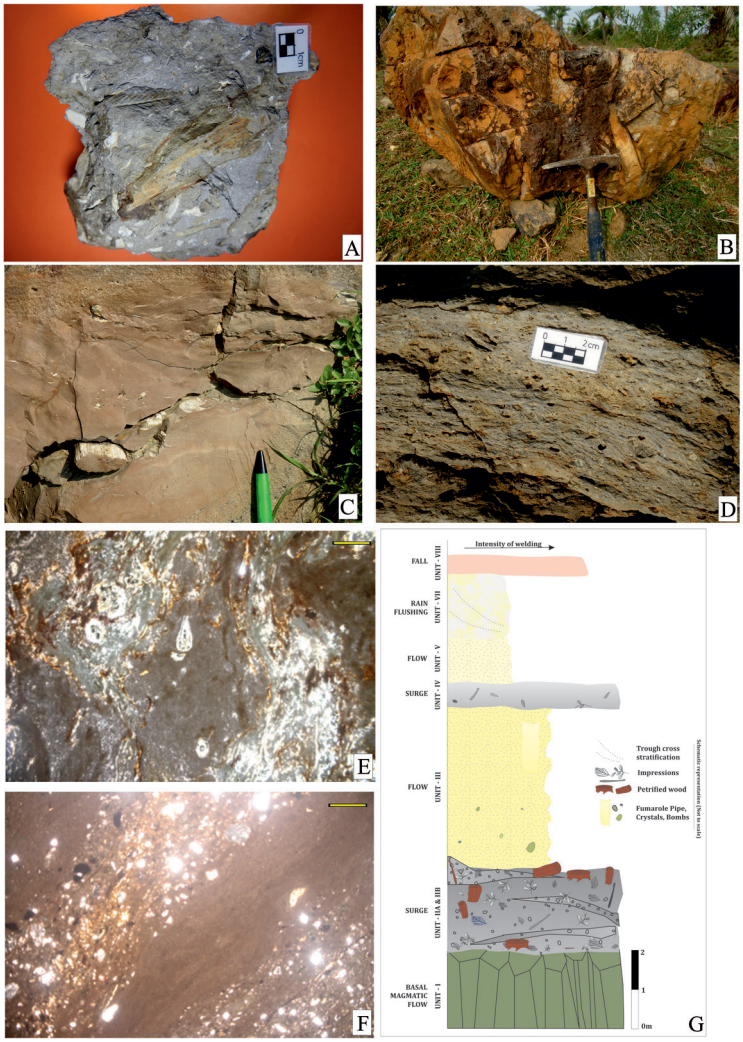

Figure 4. Evidence for volcanic phenomena in ignimbrites at Mandro. A-B) Haphazardly oriented fossils within the basal surge deposits. C) Wood fossil enclosed within the two, fine and coarse ash fraction of the basal surge unit. D) Crystal ladened pumacious mudflow. E) Pele's tears and F) fiammé in the pumice deposit. G) Composite litholog of the ignimbrite section at the Geoheritage Site, Mandro.

of the same facilitated the intricate preservation of the fossils. The impressions on the other hand are richly concentrated within the combined surge package (Fig. 4 A-C). They are haphazardly oriented and randomly stacked. Upright stumps with intact root networks confirm in situ preservation.

The pumice flow deposit is represented by well-sorted ash flow deposits. They are laden with crystals and are of uniform coarse ash size fraction (Fig. 4D). Such uniformity and sorting indicate steadiness of the carrying media. Fossil fumarole pipes, bombs, and lapilli are notable at exposure level while fiammé (Fig. 4E) and Pele's tears (Fig. 4F) are notable in this section. The deposit is considerably thick (approx. 3m), with an apparent topographic control on deposition. It is completely devoid of fossils.

A second surge or a prograding surge overlaps the flow deposits. The fine ash and distinct welding compared to the underlying ash flow deposit makes it easily distinguishable. It probably represents waxing and an increase in the flux of eruption. However, the second surge has fewer fragmented floral imprints, including those of twigs

and thin stems, which are randomly intermixed. Notable in it is the complete absence of fossilized wood.

The second pumice flow which overrides the second surge is made up of coarse ash fractions. Unlike the first flow, bombs and lapilli, etc. are absent and the floral content too, is completely missing.

The very faintly mega cross-bedded, coarse to very coarse-grained rain-flushing deposit contains angular gravel. It is very loosely packed and lacks matrix or cement. Such deposition is an expected event accompanying violent eruptions. Grains in these cases are derived from the underlying pyroclastic deposits.

The ash found atop and mantling the entire section represents the settling of the finest ash. It suggests that the succession of the surge and flow units was faster than the settling of fine ash from the overriding ash cloud or depositing ash clouds had plinian-like dimensions (Sigurdsson *et al.* 2000).

Geomorphic expressions directly equitable with the ignimbrite generating process, i.e., any violent volcanic eruption center(s), are difficult to locate in the vicinity of the Geoheritage Site. More so, locating one in an ancient erosional relict LIP like the Rajmahal Traps is even more challenging. However, our study realizes a complete ignimbrite succession beginning with the basal surges and ending with the ash fall deposit (Sigurdsson *et al.* 2000) (Fig 4G).

As far as fossilization is concerned, petrification leading to the intricate preservation of wood may have been caused by the circulation of hot water with abundant silica over ash-dominated units (Cas and Wright, 1996; Branney and Kokelaar, 2002). Despite the apparent randomness, the intricacy of preservation and distribution of fossils present a graphic testament to the strong lithological control and power of preservation in the tuff. On the other hand, the girth and uniformity of annual rings in fossilized tree trunks suggest quiescence intermittent with volcanic activity, allowing the development of soil and environmental factors conducive to plant growth.

Present Status of the Geoheritage Site

The variety and vividness of in situ fossils are best concentrated within a spatial distribution of 0.36 Km2 (Fig. 5A). Ownership of most of this land vests with the local (tribal) population. Gurmipahar (0.01 Km2), however, is an exception where the land is owned by the State Forest Department. The Department has developed it into a park with the name “Fossil Park, Mandro” (Fig. 5B). Infrastructure of this fenced and gated enclosure includes landscaping, an amphitheater and a museum, four shaded enclosures to preserve fossilized trunks concentrated along the northern slope of the plateau, foot track, etc.

The park is, however, not yet networked or associated with other parks and museums dedicated to similar phenomena. Thus, this limits its utility and scope for other benefits such as having exchange programs, wider dissemination of information on the subject, research opportunities to the benefit of the scientific cause, geotourism and allied socioeconomic activities affecting livelihood of the residents. The park mostly contains petrified trunks, many of which are dislodged and are contained in scree. Other sites located outside the fence boundary of the Park and with in situ petrified wood and floral impressions are left unguarded. The unattended fossils from these localities are often unscientifically excavated and damaged by people, including scientists, law keepers, visitors, local residents, etc (Fig. 5 C-E). Further, visitors to the Geoheritage Site and the Park are generally from neighboring localities. The situation therefore outlines a weakened scenario of protection and conservation at the Geoheritage Site, Mandro. It also highlights the underutilization of the Site’s potential to contribute towards the realization of the Sustainable Development Goals (SDGs).

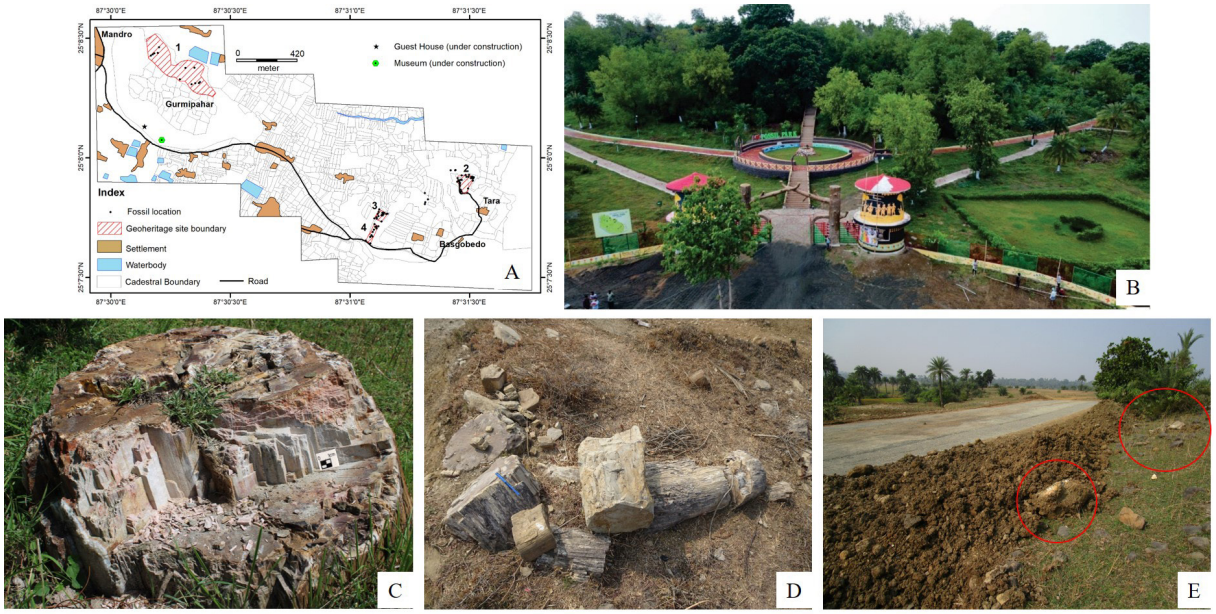

Figure 5. The Geoheritage Site Mandro. A) Location map showing distribution of fossils at Mandro, Sahibganj (mapped during January 2021). B) The Fossil Park, Mandro. C-E) Isolated petrified tree trunks in the Geopark.

Bottlenecks in Development of the Geoheritage Site

The extent of damage incurred at Mandro due to inappropriate behavior and scientific ethics connect with the bottlenecks in conserving what remains and what can be found in the future. There are three main hindrances to the transition of Mandro from "conditional geoheritage to geoheritage" (Gray 2018), and the potential of the Geoheritage Site to serve the larger interest, including environment and climate change. These are considered in turn.

Lack of Legislative Support: In India, the Wildlife Protection Act, of 1972 and a plethora of associated legislation lay down elaborate measures and provide legal cover to safeguard plants and animals in their natural habitats. Similarly, the Ancient Monument and Archaeological Sites and Remains Act, of 1958 ensures the preservation of historical and archaeological monuments, including sites and remains of national/international importance. However, the concept and policy governing the protection and conservation of geological sites and relics under the three-pronged approach of conservation, education, and geotourism is neither provided nor practiced in India.

In the case of Mandro, despite the absence of any nationwide legislation, the GSI pursued the State Government to notify the areas identified for the Geoheritage Site as a protected area. Issuance of such a notification, however, is long awaited.

The Local Community and their Socio-economic Condition: Geoconservation activities at Mandro face resistance from the inhabitants. The most obvious reason for such behavior is that the tribe has historically been fierce and extremely protective of their land. Secondly, a lack of employment opportunities other than small-scale agriculture and laboring results in their existential dependence on the land. However, another factor for the opposition appears to be their realization of the rarity and pricelessness of fossils. Learning from visitors over the years, the tribe is now at the forefront of protecting the fossils through their rudimentary, unscientific and culturally driven practices. However, the same attitude has made even placing a

foot and taking a small piece of fossil out of their land at Tara, Basgobedo and other similar villages dependent on their permission.

Disparity with Global Practices and Lack of Recognition: The scenario at Mandro is unlike other parts of the world, such as Spain (Carcavilla *et al.* 2009) or global initiatives like the UNESCO Global Geoparks (UGGp), UNESCO World Heritage Sites or IUGS Geoheritage Sites. Despite being a signatory member for launching the UGGp concept in 2015, no site from India has attained this prestigious recognition. On the other hand, seven sites in India are recognized as UNESCO World Heritage Sites for their natural values, and another site is listed under Mixed themes, yet none of these have been recognized for their significance in showcasing Earth's geological history. The current 34 geoheritage sites in India, including Mandro, do not feature on any significant international catalogue, including the First 100 IUGS Geological Heritage Sites (IUGS 2022).

The Way Forward

Geoconservation and geotourism practices in India are restricted to the study and identification of geologically significant sites by the GSI. However, recently the "Geoheritage Sites and Geo-relics (Preservation and Maintenance) Bill, 2022" was put up for public consultation. It aims to ensure site-specific research and development along with planning and managerial practices governing each site of geological significance throughout the country. The Bill should empower the Union Government of India, through the GSI, to notify Geoheritage Sites and Geo-relics. Enactment of the Bill would concentrate geoconservation and management-related matters concerning geoheritage and geo-relic sites under the uniform umbrella of the GSI (Fig. 6). The Bill is also expected to pave the way for creating a scientifically sound governing body, making research opportunities available and obtaining adequate financing to develop the capacity to self-finance in due course. However, until formal enactment of the Bill as an Act, or Notification by the State Government, the Geoheritage Site Mandro continues to face the threat of damage, destruction and underdeveloped potential. On the other hand, recognition of geologically significant sites, relics and geomorphosites (landscapes) on a national scale paves the way for global recognition like UNESCO World Heritage Site, Global Geopark, etc. Different criteria for selection of the UNESCO World Heritage Sites acknowledge that Earth processes/ geosciences have a defining role in shaping life on the planet. Validating the significance and uniqueness of geological heritage at the Nahanni National Park (Canada), the Galapagos Island (Ecuador) and Yellowstone National Park (United States of America), was the first UNESCO World Heritage Sites to be recognized, in 1978. Similarly, UGGp represents single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. UGGp advocates for a bottom-up approach of combining conservation with sustainable development involving local communities. As a member State of UNESCO, India is a party to both the UNESCO World Heritage Site and Global Geopark schemes. The country must adopt forward-looking measures and approaches for the protection, conservation, and sustainable development of its geological heritage, including the site at Mandro.

Development of even the most prominent fossil-bearing localities at Mandro requires an inclusive and symbiotic association with the inhabiting tribe. Education and capacity building among the local population are primary for achieving wider goals. Prospects for the Geoheritage Site include activities such as trekking, hiking and other forms of forest and nature-based adventure, leisure and wellness tourism, integrated with eco-friendly,

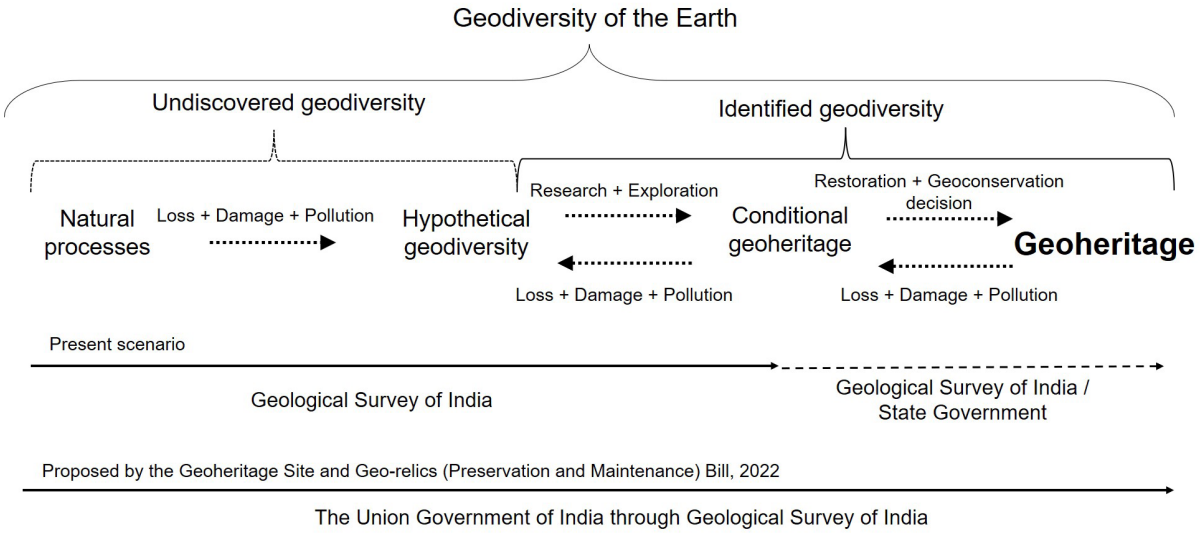

Figure 6. Status of geoconservation practices in India (Modified after Gray 2018).

natural homestay options developed in participation with the local community. Privately collected fossils of small sizes, too, can be prepared as souvenirs for authorized/ institutional sale. Crediting and incentivizing reporting of discoveries could help develop a sense of institutional belonging among individuals and discourage private collection and hoarding. Economic prosperity directly emerging from geoconservation and geotourism could lead to building trust. Building trust and confidence among the local population is essential to conserving a healthy environment for the people while achieving long-term SDGs.

The Integrated Sustainable Tourism Circuit

Solely considering the Geoheritage Site Mandro under present circumstances may be insufficient to steer large-scale geotoursim-driven socio-economic prosperity in the region. However, integrating various other natural, anthropological, cultural, archaeological and historical facets of nearby localities creates an unmatched opportunity for holistic and inclusive development of the region (Fig. 7A-G).

Therefore, we suggest the creation of an Integrated-Sustainable Tourism Circuit with the Geoheritage Site Mandro at its core and differentially themed interlinked satellite sites (Fig. 8). Our idea for the underdeveloped region relies not just on the core and satellite sites and ancillary nature-based activities, but equally on the emphasis of adoption of a community-based approach as a tool for the development of environmentally sensitive conservation strategies, co-management and partnership practices and propagation of equality and empowerment. At this juncture, we are aware that creating a single unified area, unlike a UGGp or UNESCO World Heritage Site, may be administratively challenging considering the unique land-revenue laws applicable for land with tribal ownership. However, these very laws and the unmatched anthropology of the region are among the important considerations for proposing the Integrated Sustainable Tourism Circuit instead of only concentrating on the geological heritage aspect of Mandro.

The first step in harnessing the multifaceted and sustainable tourism potential undoubtedly rests in building trust and confidence among the local inhabitants. Recently, the GSI brought on board the local inhabitants to assist in geoheritage assessment studies at Mandro. Subsequently, the GSI

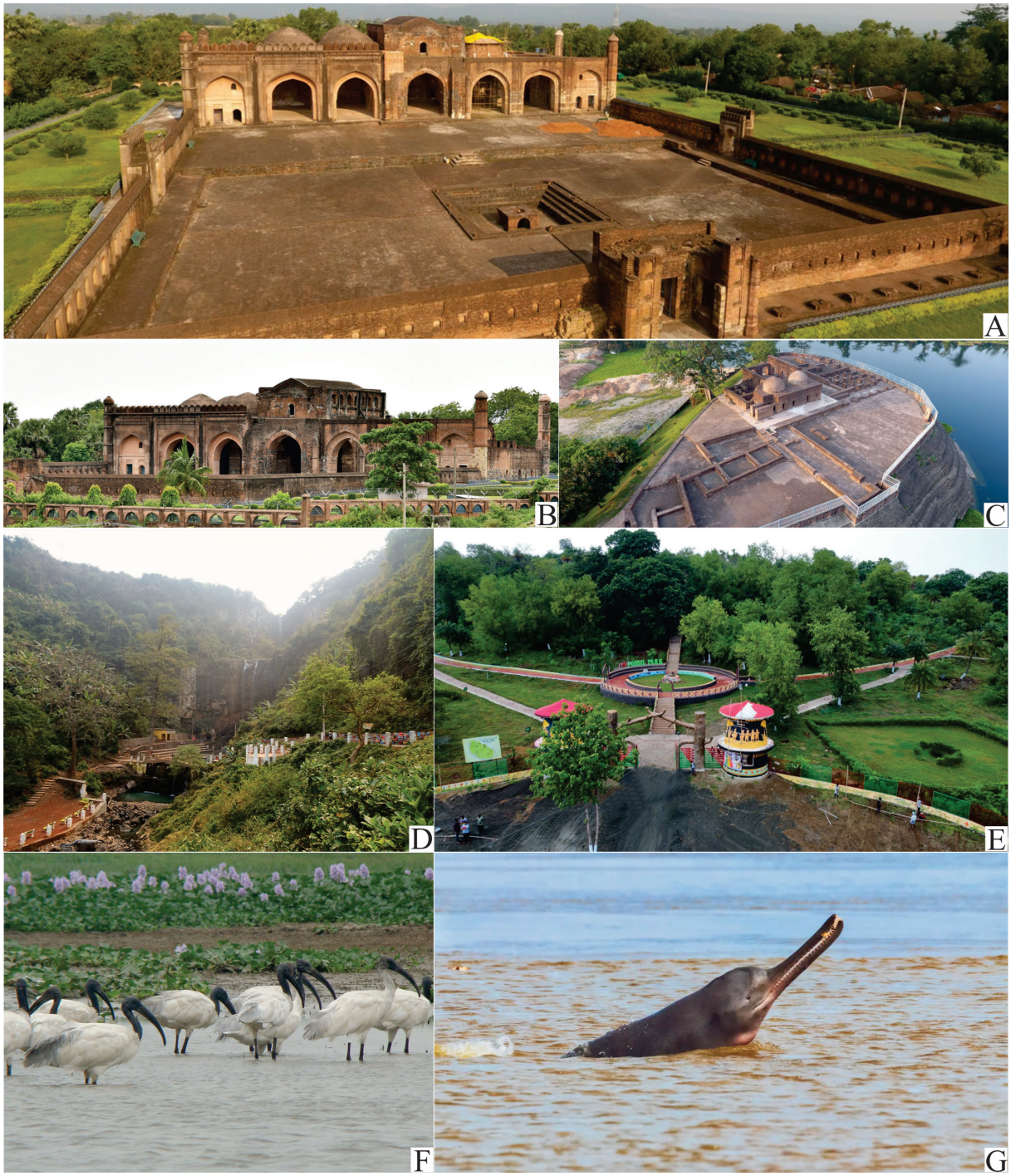

Figure 7. Tourism sites at Sahibganj. A-B) Jama Masjid (Source: Archaeological Survey of India). C) Baradari (Source: Archaeological Survey of India). D) Moti Jharna. E) Fossil Park Mandro (Source: Internet). F) Udhwa Bird Sanctuary, Rajmahal (Source: Internet). G) Gangaes Dolphin (Source: Internet).

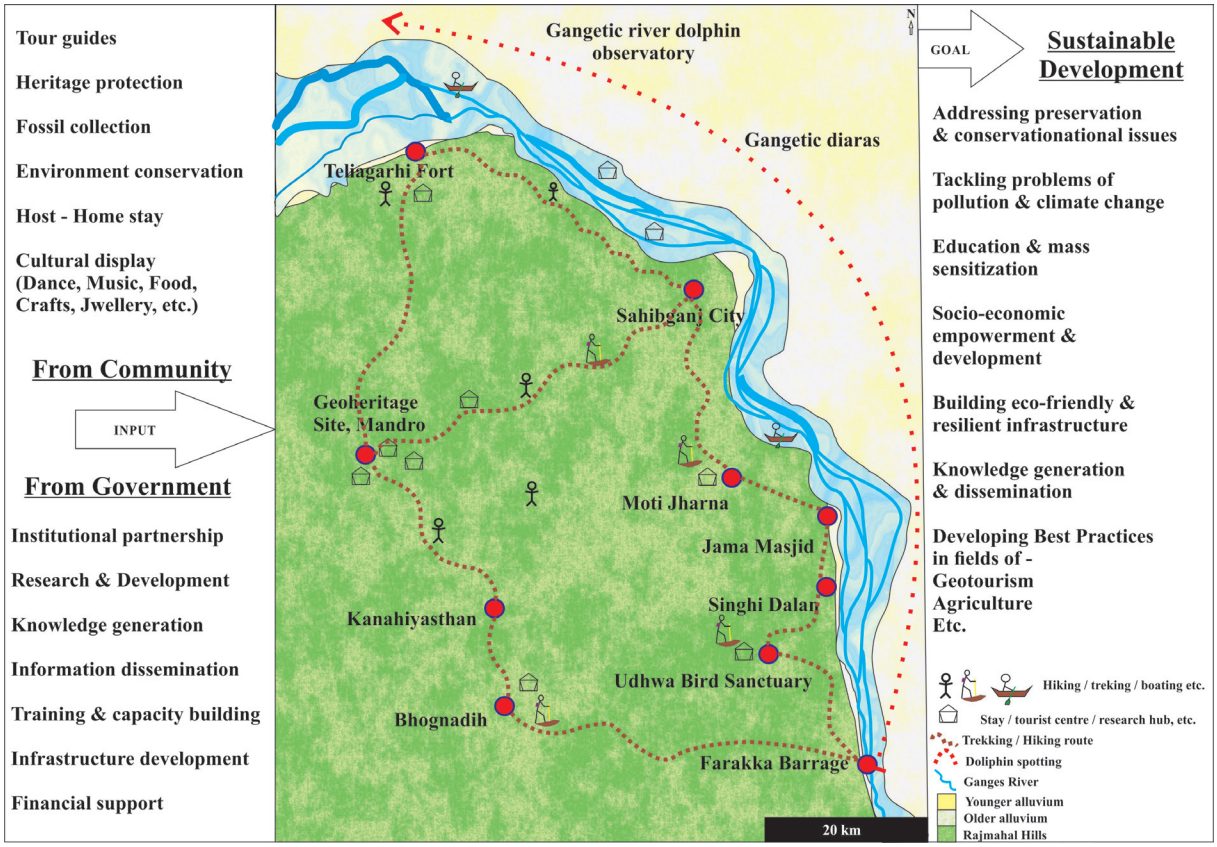

Figure 8. The Integrated Sustainable Tourism Circuit, Mandro.

also conducted sensitization programs at the Geoheritage Site in collaboration with the local university, schools and administration. It showcases that sustainable socio-economic development through community participation can be achieved with the required impetus. However, such efforts require institutional/ governmental support. Such support is also needed to address a wide spectrum of issues concerning knowledge, know-how, creativity, technology and financial resources for the proposed Circuit. Among the plethora of issues that the proposed Circuit has to address in the course of achieving the desired standard of quality of life and environment are a site specific multidisciplinary scientific evaluation; documentation and building of a geospatial database; wider dissemination of knowledge and information through physical and electronic means including museums, websites, applications, events; collaborations and exchanges with institutions of domain expertise; etc. Preserving the cultural heritage of the local peoples too is central to the realization of SDGs through the proposed Circuit. It requires the propagation of cultural practices within and between generations. Continuing practices in various forms of craftmanship like jewelry making, masonry, woodwork, painting, music, and dance, require incentivization which would result in socioeconomic empowerment and prosperity.

Concluding Remarks

Petrified stumps, logs and a wide variety of floral impressions are found throughout the Rajmahal Hills. They occur in unique concentration in the Tara, Basgobedo and Gurmipahar villages of Mandro, a designated Geoheritage Site in India. Geologically, the Lesvos Island UGGp, albeit younger, resonates best with the geological aspects of the Geoheritage Site Mandro. However, the present state of protection, conservation, and

development of the Geoheritage Site Mandro contrasts starkly with the Lesvos Island UGGp, as well as the other 176 UGGp sites in 46 countries including transnational ones, the UNESCO World Heritage Sites in India and across the globe, and other protected-conserved areas within the country or around the world.

Considering constraints in the development of the Geoheritage Site Mandro, this paper proposes a way forward for the underdeveloped site and the region by creating an Integrated-Sustainable Tourism Circuit. The Geoheritage Site Mandro is the core of the proposed Circuit, and it can be linked with satellite sites of natural, anthropological, cultural, archaeological and historical significance through hiking/ trekking trails. Along the trail and the satellite sites, natural or homestay options can be developed in cooperation with the local people. Such natural, eco-sensitive, and resilient infrastructure could provide an opportunity to showcase the cultural heritage of the region. We realize that appropriate legislative/ legal cover for the Geoheritage Site Mandro or the proposed Circuit is essential, but governmental support and community participation provide a start towards the attainment of various SDGs.

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Author contributions

Shreya Shrey: Conceptualization; field investigation; non-technical ideation and research; manuscript drafting, editing and finalization. Dr. Ravi Shankar Chaubey: Conceptualization, field investigation; manuscript editing. Dr. Pankaj Jaiswal: Field investigation; manuscript review.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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