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Integrated Structural and Geomorphological Analysis of Gupteswar Cave Surroundings, Bastar, Chhattisgarh, India

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Abstract
The area around Gupteswar Cave, which is situated along the Eastern Ghats, has a variety of structural and geomorphological characteristics that provide insight into the formation of karst and the evolution of the landscape. The systematic analysis of surface geological features, such as joints, faults, bedding planes, sedimentary dykes, potholes, stromatolitic structures, and characteristic weathering patterns like crocodile-skin textures, is the main emphasis of this study. The results emphasize the Gupteswar region's importance as a Geoheritage site with potential for more geological and geomorphological research and advance knowledge of the link between structural geology and geomorphology.
Keyword: *Geomorphology, Joints, Faults, Stromatolites, Potholes, Paleoenvironment*

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I. Introduction

The Gupteshwar cave is at the bank of the Kolab River. Here, certain structural indicators were noted, including well-jointed rock formations and strongly inclined dolomite rocks. There is stromatolitic dolomite in the Gupteswar-Tiriya-Machkote region. Few caves have formed in this dolostone. Dolomite is exposed to the surface in this region. The terrain of this region was formed by highly jointed, weathered, and faulted dolostone. N18°54.260' E082°10.685' is the GPS location of a noticeable fault that is trending NE.-SW. in Tiriya village. A few striated shale bed outcrops can be observed. Very well-jointed Jagdalpur shale can be seen along the riverbank in the Tiriya region, close to Gupteswar Cave. The intense and tightly jointed nature of this shale makes it extremely vulnerable to weathering and erosion. Furthermore, sedimentary dykes have been found in the Tiriya-Machkote-Gupteswar region. (Gautam, 2015)

II. Study Area

Gupteswar Cave is situated in the Koraput District, some 55 miles from Jaypore, and 15 kilometers from the Kanger Valley region. It is a dolomite cave, and its main attraction is the gigantic Shiva. Gupteshwar Cave's coordinates are N18°54'15.6", E82°10'41.1," and it is situated 698.96 meters above mean sea level. Near the Gupteshwar-Mchkote-Tiriya region, the River Kolab forms the border between the states of Chhattisgarh and Orissa. The geological composition consists primarily of Indravati group rocks, includes, limestone, shales, and dolostone and covers the toposheet no. 65J/1. (Dutt, 1963, Das et al., 2021).

III. Methodology

This study's technique included methodical fieldwork in the Indravati basin area around Gupteswar Cave. In addition to geomorphological and sedimentary phenomena including potholes, stromatolites, sedimentary dykes, and weathering patterns like crocodile-skin textures, detailed traverses were carried out to detect and record structural elements like joints, faults, and bedding planes. A Brunton compass and GPS were used to record structural data, such as strike and dip, and location and observations were recorded. For appropriate representation, the gathered data was plotted by rose diagram and accompanied by field sketches and photos. To comprehend the impact of lithology and structural discontinuities on landform formation, the spatial distribution and connections of geological features were examined. In order to deduce potential karst development in the region and to create links between structural controls and geomorphological processes, such as surface weathering and river activity, the data were further analyzed. (Gupta et al., 2021).

IV. Geomorphological features Near the Gupteshwar Cave

Geomorphologically, the Gupteshwar-Mchkote-Tiriya region is very peculiar. The weathering and erosion of the Kolab River has created a number of unique landscapes along the Chhattisgarh side. (Khalaf,2022, Das & Halder (2024). Some landscapes were formed on limestone and stromatolitic dolostone. Here, the Shabri River has sculpted a number of unique landforms, including tortoise-shaped weathering, mushroom-shaped weathering, and cobra-hood-shaped weathering. In this area, crocodilian skin weathering of stromatolitic dolomites is clearly visible. (Kale, 2002). The existence of large potholes is another interesting feature in this area. Some shattered large potholes formed on stromatolitic dolomite show both vertical and horizontal sections of stromatolitic colonies. These algal colonies have a horizontal segment that is around 8 cm in size and a vertical extension that is roughly 22 to 40 cm long. Additionally, limestone and stromatolitic dolostone are in contact. Here, another fascinating process of the formation of thin sandstone lithounits is shown. According to James Hutton, "the present is key to the past." Here, sedimentary dykes composed of shale are also being noticed here. (Hooke, 2020, Arora et al., 2020).

In addition to the geomorphological characteristics mentioned above, a section of the Kolab River near Tiriya Village exhibits structural control. The river Shabari is oriented in the same direction as the 40°–220° trend of the Tiriya fault.

Buff and purple-colored Jagdalpur shales are being exposed to the surface in the Bank of Kolab's Tiriya Village, creating stunning, picture-perfect landforms. The Jagdalpur shale in this region is highly strongly jointed, folded, and inclined in a variety of ways. Because of the extremely closely joints, extremely sharp pieces of shale are formed

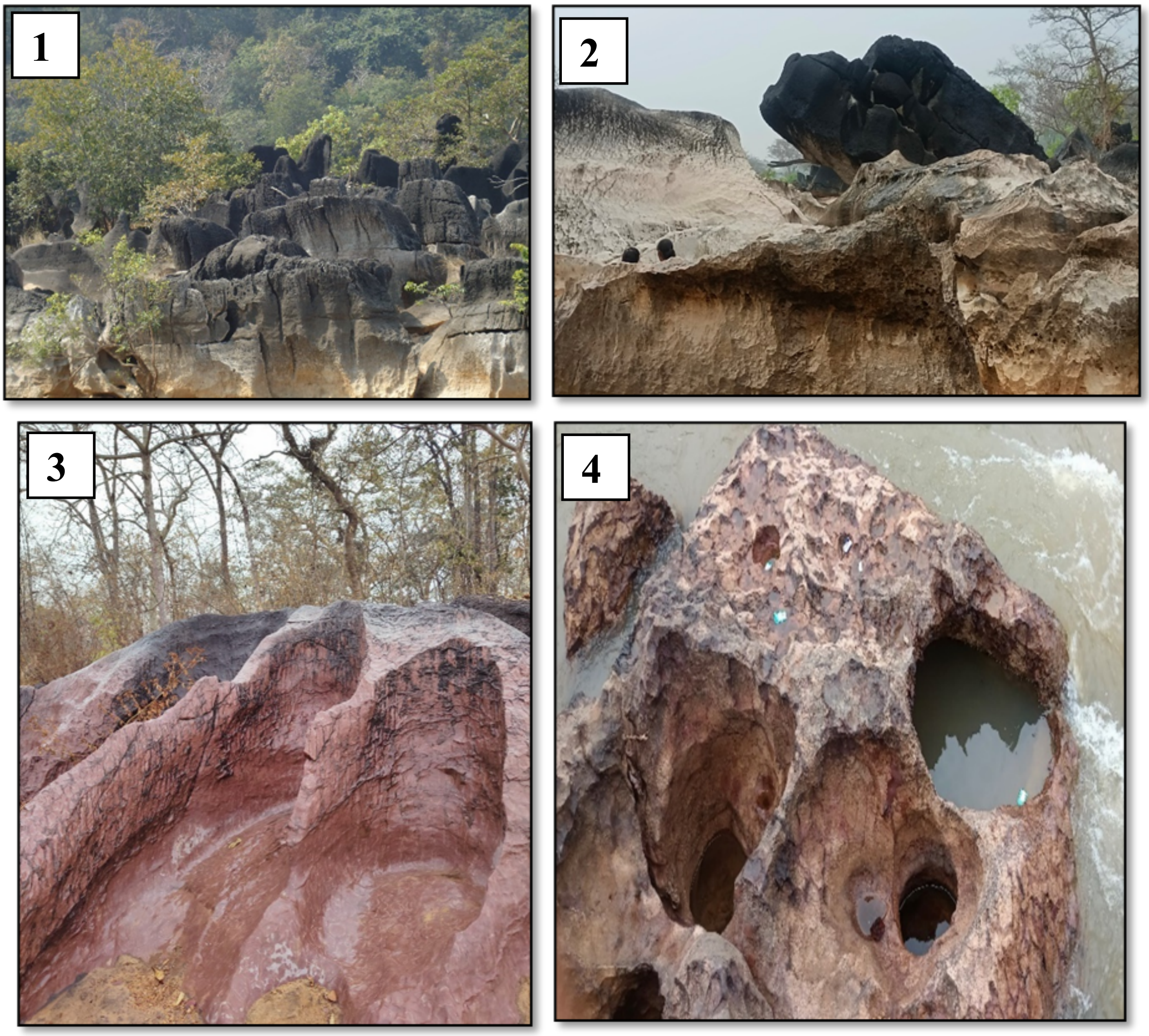

Plate No. 1 – Landforms Near Gupteswar Cave, 1) Exotic Landscape, 2) Tortoise Shaped Weathering, 3) Broken Big Pothole, 4) Pot Holes

V. Stromatolite in the Gupteshwar-Tiriya- Machkote Area

The reserve forests of Machkote in Chhattisgarh and Gupteshwar in Orissa are rich in natural beauty. The dolomites and stromatolitic limestones create an extremely unique landscape. During the Neo-Proterozoic era, 1100–700 million years ago, when shallow water filled the Indravati Basin, stromatolites—organo-sedimentary structures were formed. Massive stromatolitic features were formed in this area due to the intertidal palaeo-environmental conditions that encouraged the luxuriant growth of blue-green algae. This deposit is among the biggest in India to date. (Walter, 1976, Acharya, 1973).

Gymnosolen, conophyton, Colonella, Tongussida (Baicalia, Anabaria), and Kussiellida are the species of stromatilytes that GSI has identified in this area. An Upper Riphean assemblage (1100–700 Ma) is most likely represented by these stromatolytes. (Schnitzer, 1977). The Upper Chattisgarh Group of rocks and the Jagdalpur Formation of the Indravati Group of rocks are frequently correlated by the Geological Survey of India. According to the K-Ar technique, glauconitic sandstones near the base of the Chhattisgarh Basin have a radioactive age of 700–750 Ma. When one visits this region, the stromatolytic limestones and dolomites have weathered into fascinating landscapes that resemble crocodilian skin. (Guhey et al., 2011, Jha et al., 2015).

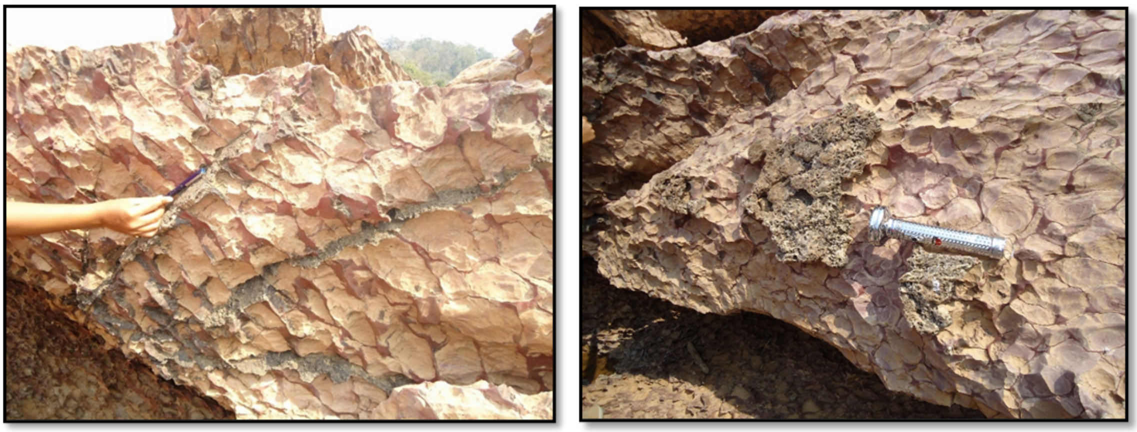

Plate No. 2 -Stromatolitic Dolomite at Gupteswar Area

VI. Lithology of the Area

The research region contains dolomite and Jagdalpur Shale from the Indravati basin. Purple and buff shales make up the Jagdalpur Formation's predominant rock type. Pyrite oxidation may be the cause of the 2 cm diameter circular ferruginous patterns found in the shales, which are frequently fissile. The monotony of the Shaly land is broken up by magnificent pillars of purple and grey stromatolitic dolomite that rise 15 to 20 meters above the ground in the Machkot area. (Krupanidhi,1970). The stromatolitic dolomite-related shales of Khotpadar include flat shale pebbles throughout and good intraformational aggregates. These dolomite-associated shales also exhibit greyish limestone intercalations. In the Tiriya village next to the riverbed Kolab, there is extremely well-jointed Jagdalpur shale. The shale is quickly eroded by weathering and erosion because it is so densely and intensely jointed. In addition to many coloured shales, this area is well-known for its thin, pointed shale pieces. Additionally, sedimentary dykes have been observed in the Gupteswar, Machkote, and Tiriya regions. (Ramakrishnan,1987).

Apart from field observation and megascopic study of all rocks in the study area also collected samples of Jagdalpur Shale and prepared thin section for the detail study of lithological character of the study area. Microscopic Characters includes very fine grain most of the grains are of equal size, very well sorted, sub-rounded, mineral composition- quartz, feldspar, clay minerals. Deposited continental shelf area. (Gupta, 2024).

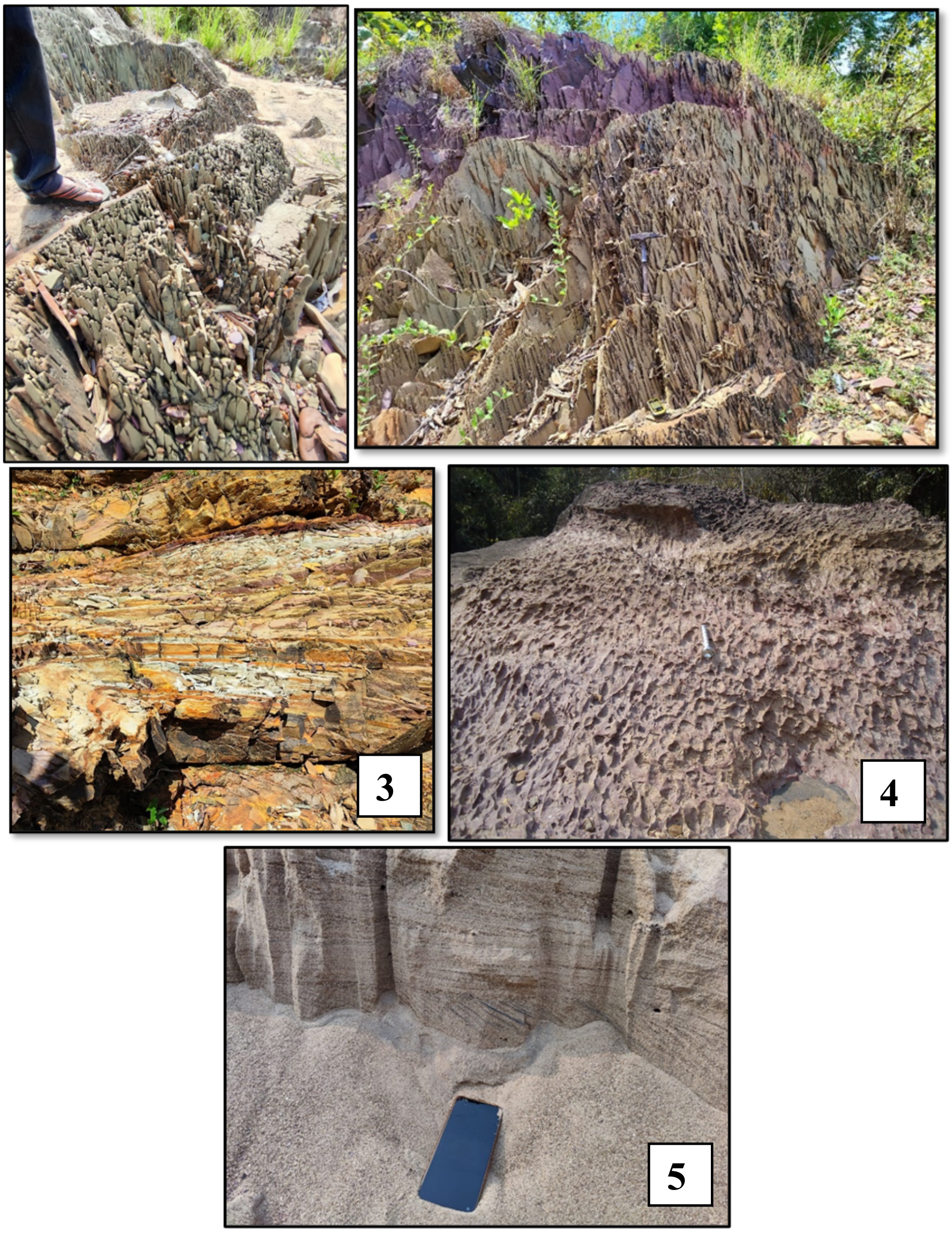

Plate No. 3. Various Geological Features Near Gupteshwar cave - 1) & 2) Well Jointed Jagdalpur Shale, 3) Variable Colour of Jagdalpur Shale, 4) crocodile skin weathering, 5) formation of cross bedding structure at Tiriya region.

VII. Structural Information

The rocks of Tiriya area (which is near to Gupteswar cave) are very intensely jointed, folded, and faulted. The Tiriya fault has a different trend when this fault is compared with other prominent faults of Indravati Basin. This fault has alignment in the NNE-SSW direction. Whereas the Sirisguda, Tirathgarh, Keam, Karka faults are in ESE-WSW directions. (Gupta et al., 2021) Several joints have been reported from the Tiriya region. Joints in the Tiriya area have no preferred orientation; joints have been observed in all the directions. Here the Jagdalpur shale formation is highly jointed and due to intense jointing very sharp rhombic shale fragments are observed. Rock beds are preferably aligned in N-S direction. Dip amount varies from 15° -60°. Rock formations are dipping due East to NE direction. In the Gupteswar area highly inclined stromatolitic Dolostone are seen. Dip amount varies from 40°-85°. The strike direction of beds is in NE-SW quadrant and dips are in the SE quadrant. Joints are mainly in NE-SW directions. One fault is observed in the NNE-SSW direction. Very intense diastrophic movement might be responsible for these highly inclined, jointed and faulted rock formation. (Gupta, 2024)

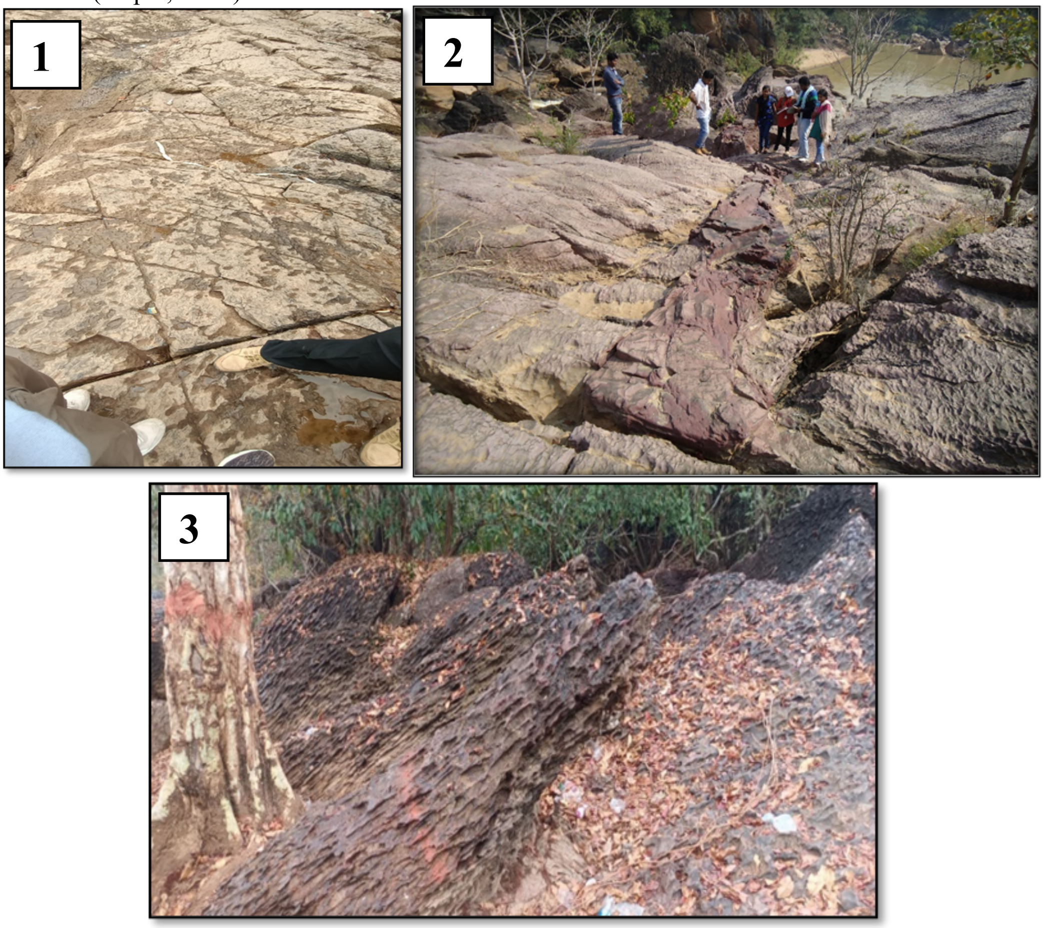

Plate no. 4– Structural features Near Gupteshwar cave - 1) Joints, 2. Sedimentary Dyke Near Gupteswar Cave and 3) Inclined Rock Formation

Table No. 1 Structural data of Study Area (after Gupta, 2024)

AREA	SPOTS	FEATURES	STRUCTURES	STRIKE DIRECTION	DIP DIRECTION	DIP AMOUNT
GUPTESWAR AREA	**SPOT 1** GPS location N 18°49.533' E 082°09.729' Altitude - 455 m	Rocks opposite to Gupteswar cave and on the bank of river Kolab	Inclined beds of Jagdalpur dolomite	80°-260°	170°	71°
	SPOT 2 GPS location N 18°49.503' E082°09.730' Altitude - 455 m	Rocks opposite to Gupteswar cave and river Kolab	Inclined bed of Jagdalpur dolomite	50°-230°	140°	40°
	SPOT 3 GPS location N 18°49.516' E 082°09.780' Altitude- 551 m	Rocks on the middle portion of river Kolab (near Gupteswar cave)	Joints - Secondary filling of quartz in dolomitic rocks	Trends of joints - 1) 40°-220° 2) 95°-275°		
	SPOT 4 GPS location N 18°49.529' E 082°09.787' And -449 m	Rocks on the middle portion of river Kolab (near Gupteswar cave)	Clusters/several parallel secondary silica depositions along the inclined joints of dolomitic rocks	70°-250°	340°	28°
			Presence of fault in dolomitic rock.	Fault plane trends - 20°-200°	110°	70°
	SPOT 5 GPS location N 18°49.514' E 082°09.868' Altitude- 448 m	Rocks on the middle portion of river Kolab (near Gupteswar cave)	Several parallel joints	Trends of joints- 1) 15°-195° 2) 70°-250°		
			Several parallel major joints	70°-250°		
	SPOT 6 N 18°49.571' E 82°10.880' Altitude - 449m	Rocks Near the Gupteswar Cave (Contact of shale and dolomite beds)	Inclined shale beds	70°-250°	160°	85°

AREA	SPOTS	FEATURES	STRUCTURES	STRIKE DIRECTION	DIP DIRECTION	DIP AMOUNT
TIRIYA AREA	**SPOT 1** GPS Location- N 18°54.239' E 082°10.635' Altitude - 476 m	Several parallel joints associated with Jagdalpur shales and inclined beds	1.Inclined Joint	110°-290°	200°	85°
			2.Vertical joint	95°-275°		
			3.vertical joint	160°-340°		
			4.Vertical joint	30°-210°		
			5.Inclined bed (Jagdalpur shale)	120°-300°	30°	15°
			6.Inclinde bed (Jagdalpur shale)	150°--330°	60°	41°
			7. Inclined bed (Jagdalpur shale)	0°-180°	90°	43°
	SPOT 2 GPS location N 18°54.260' E 08210.685' Altitude - 478 m	Striated inclined bed of Jagdalpur shale	1.Striated inclined bed of Jagdalpur shale	40°-220°	130°	60°
	SPOT 3 GPS location N 18°54.263' E 082°10.719' Altitude - 478 m	Stromatolitic Dolomite (purple colour)	1.Inclined Joints and silica filling vein in this joint associated with dolomite	310°-130°	220°	45°
			Inclined joint	95°-275°	185°	50°
	SPOT 4 GPS location N 18°54.279' E 082°10.741' Altitude - 474 m	Joint sets associated with purple colour shale	Inclined joint	80°-260°	170°	70°

	SPOTS	FEATURES	STRUCTURES	STRIKE DIRECTION	DIP DIRECTION	DIP AMOUNT
TIRIYA AREA	**SPOT 5** GPS location N 18°54.274' E 082°10.734' Altitude - 480 m	Several parallel closely spaced joints associated with Jagdalpur shales and inclined beds	Joint set 1	70°-250°	340°	80°
			Joint set 2	175°-355°	265°	80°
			Joint set 3	5°-185°	275°	80°
			Joint set 4	160°-340°	250°	80°
			Joint set 5	130°-310°	40°	80°
	SPOT 6 GPS location N 18°54.274' E 082°10.734' Altitude - 480 m	Joint sets associated with Jagdalpur shale	Joint set	60°-240°	330°	34°
	SPOT 7 GPS location N 18°54.274' E 082°10.734' Altitude - 480 m	Variation in colour of shale (red and gray colour)	Joint set	155°-335°	65°	45°
	SPOT 8 GPS location N18°54.308' E082°10.783' Altitude - 481 m	Several parallel Joint sets associated with Jagdalpur shale (alternate colours)	Joint set 1	50°-230°	320°	5°
			Joint set 2	140°-320°	50°	80°
			Joints set 3	65°-245°	335°	45°
	SPOT 9 GPS location N18°54.308' E082°10.783' Altitude - 482 m	Folded bed of Jagdalpur shale and axial joints also present	Plunging fold	44°-222°	Plunge direction - 44°	Plunge 15°

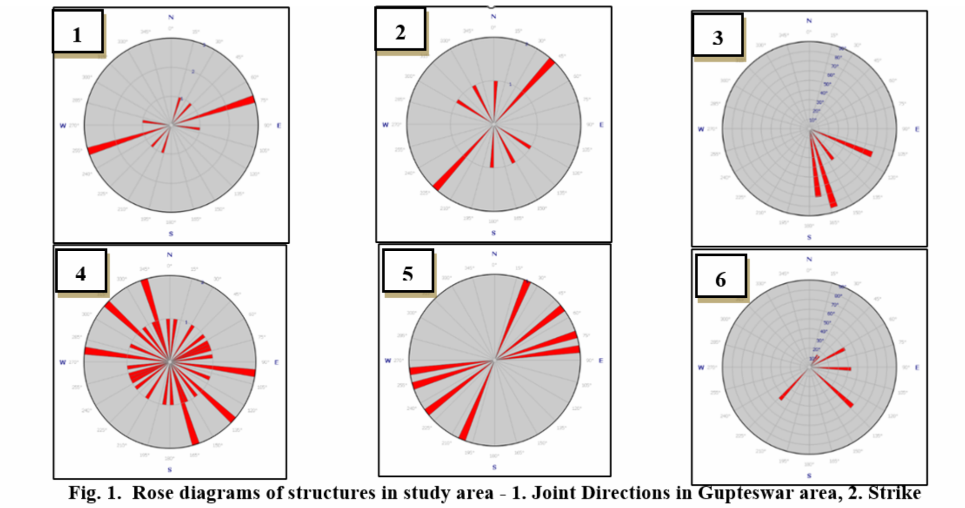

Fig. 1. Rose diagrams of structures in study area - 1. Joint Directions in Gupteswar area, 2. Strike Directions of Beds (Gupteswar area), 3. Dip Direction of Beds (Gupteswar area), 4. Joint Directions in Tiriya Area, 5. Strike Directions of Beds (Tiriya Area), and 6. Dip Direction of Beds Tiriya Area

VIII. Conclusion

Based on the examination of satellite imagery, earlier geological maps of this region, detailed fieldwork, and the gathering of structural, lithological, and geomorphological data, we determined that the Tiriya–Gupteswar region exhibits complex structural characteristics marked by intense jointing, folding, and faulting. The Tiriya fault shows a distinct NNE–SSW trend, differing from other regional faults, indicating varied tectonic influences within the Indravati Basin. The absence of a preferred joint orientation and the presence of highly jointed shale suggest strong deformational forces. Rock beds display significant variation in dip and alignment, with stromatolitic dolostones in the Gupteswar area showing particularly steep inclinations. Overall, the structural features of the area reflect intense diastrophic activity, which has played a crucial role in shaping the present geological framework. Field studies show that structural discontinuities, especially joints and faults, are important in regulating drainage patterns, micro-geomorphic feature development, and rock disintegration. Potholes are a sign of active fluvial processes, whereas bedding planes and sedimentary structures affect the orientation and distribution of erosional landforms. Stromatolites provide evidence of paleoenvironmental conditions in the area and point to a shallow marine depositional environment in the geological past. Distinctive weathering patterns—such as crocodile-skin textures reflect the combined impacts of chemical and mechanical weathering. Although the study is limited to surface observations the results demonstrate that structural and geomorphological features offer important insights into ongoing surface processes and potential subsurface karst development. Overall, the study highlights the Gupteswar region's significance as a geologically significant place with possibilities for more in-depth research and improves our understanding of how structure and geomorphology interact there.

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