Indian Institute of Technology, Kanpur

ES306
Field Geology II

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ACKNOWLEDGMENT

I truly appreciate the invaluable opportunity to participate in the field trip to Jabalpur, Madhya Pradesh. This experience has been truly enriching, allowing me to apply geological concepts in a real-world setting and deepening my understanding of the subject through hands-on exploration. The knowledge and insights gained during this trip have been instrumental in strengthening my passion for geology.

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Lastly, I am profoundly grateful to my family and friends for their unwavering encouragement and motivation. Their constant support has been instrumental in keeping me focused and inspired throughout this journey.

This field trip has not only reinforced my academic knowledge, but has also nurtured a deeper curiosity and appreciation for the Earth's geological wonders. I hope to apply the skills and insights gained from this experience to future studies and professional endeavors.

Field Investigations in Jabalpur, Madhya Pradesh

November 28, 2024 to December 2, 2024

- 27 November (Day 0) - Kanpur to Jabalpur (travelled by train)
- 28 November (Day 1) - Trishul Bhed, Balancing Rock, and Rani Durgawati Fort
- 29 November (Day 2) - Trishul Bhed (studied eight outcrops)
- 30 November (Day 3) - Chui Hills and Paat Baba Ridge
- 1 December (Day 4) - Lamheta Ghat (studied eight outcrops)
- 2 December (Day 5) - Lamheta Ghat and Bhedaghat

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1 Introduction

Jabalpur, located in central India along the Narmada River valley, is surrounded by a diverse range of rock formations spanning from the Precambrian to the Cretaceous periods. The field trip in this region was designed to examine key outcrops that illustrate Jabalpur's geologic history and structural features. During the course of the trip, several geologically interesting locations were visited in and around Jabalpur, each chosen for its unique significance. Trishul Bhed, Balancing Rock (near Rani Durgawati's Madan Mahal Fort), Chui Hills, Paat Baba Ridge, Lamheta Ghat, and Bhedaghat. These sites collectively showcase the stratigraphy of the area from ancient metamorphic rocks of the Mahakoshal Group to younger sedimentary units like the Jabalpur Formation and Lameta Formation, and the volcanic Deccan Traps as well as notable geomorphological and structural features.

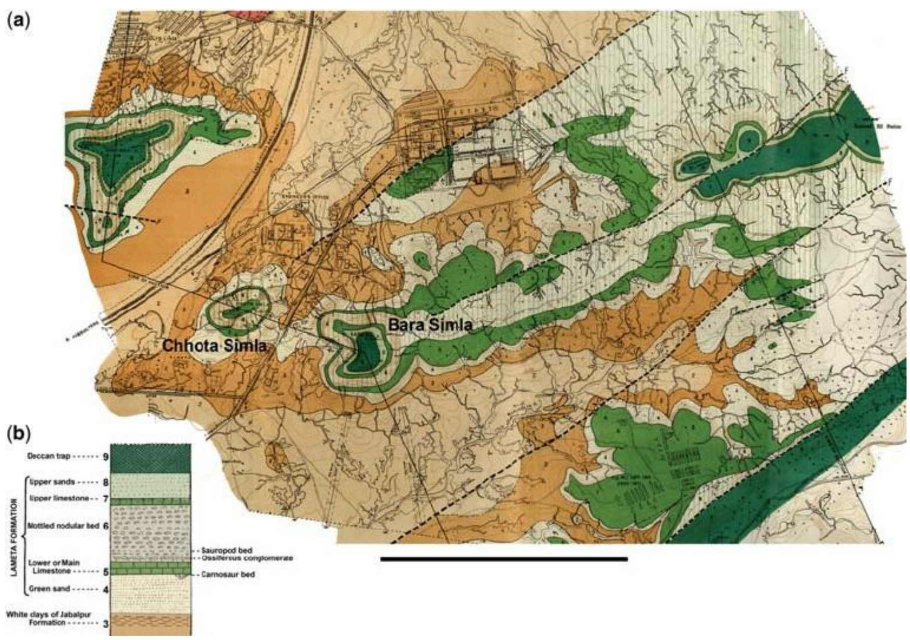

Figure 1: (a) Geological map of the Jabalpur region, showing Lameta Formation outcrops at Chui Hill, Chhota Simla, and Bara Simla; scale bar, 1 km (modified from Matley 1921 a). (b) Geological profile of the Lameta Formation at Jabalpur (modified from Huene & Matley 1933 by the addition of colours corresponding to strata in the main map).

- **Geological Features of Each**

Site Trishul Bhed:

Trishul Bhed is located on the Narmada River bank, roughly 25 km from Jabalpur, where the river's flow is intriguingly split into three channels. Geologically, this site lies close to the exposures of the Lameta Formation at Lamheta Ghat, but also near outcrops of the older basement rock. The river here runs over hard Precambrian bedrock. These rock obstacles in the channel force the Narmada to braid into multiple streams the "trident" of water that inspired the name Trishul (trident) Bhed. The bedrock at Trishul Bhed is massive and resistant, which is why it has not been completely eroded away by the river.

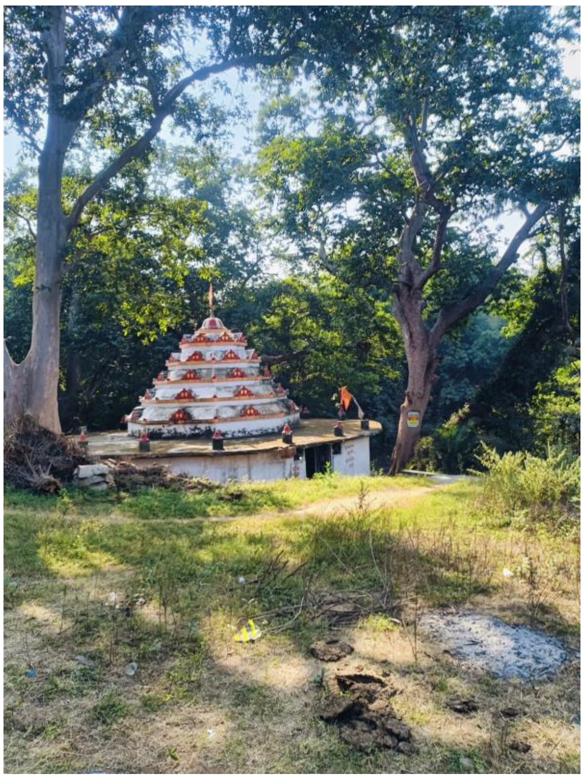

Figure 2: The Trishul Bhed of Jabalpur

By extension, Trishul Bhed's rocky island is probably a continuation of these metamorphic outcrops. The geological significance of Trishul Bhed lies in observing the interaction of geology and river dynamics: the exposure of hard crystalline rocks in the river forms rapids and splits in flow, and it offers a serene view of how ancient rocks shape modern landscapes. In summary, Trishul Bhed served as a natural laboratory for examining fluvial erosion on crystalline rocks and for introducing the group to Jabalpur's oldest rock units in the field.

Balancing Rock (Madan Mahal area):

Balancing Rock is an illustration of weathering and erosion in the Madan Mahal hills. Geologically, the rocks here are part of the Madan Mahal Granite. The granite is coarse-grained and felsic, composed predominantly of quartz and feldspar with biotite mica. In outcrop around the Madan Mahal Fort, this granite typically forms rounded boulders due to spheroidal weathering and exfoliation.

Figure 3: The Balancing Rock of Jabalpur.

The Balancing Rock itself consists of two pieces of this granite: a large base rock and an upper boulder. Over geological time, exfoliation along joints likely produced the rounded boulder, and differential weathering removed softer portions of the rock, leaving the boulder perched on a small contact point. Essentially, it is an erosional remnant or "mushroom rock" where the lower part was undercut very slightly slower than the rest, creating the optical illusion of a gravity-defying rock. Despite its fragile appearance, the Balancing Rock is actually stable; its center of gravity lies well within the base, and the hard granite is able to support the load.A testament to its stability is that it reportedly survived the 1997 magnitude approximately 6 earthquake in Jabalpur without dislodging.

At the Balancing Rock site, we noted multiple sets of cooling joints in the granite, including near vertical fractures. These joints are what facilitated the blocky breakup of the granite into boulders. We also observed minor veins of quartz coursing through the granite, a byproduct of late-stage fluids during the cooling of the intrusion. No major faults are exposed at this small site, but its proximity to the Narmada-Son lineament zone was contemplated when discussing why an isolated hill of granite stands here (the granite may have been exhumed by uplift along ancient faults). In summary, the Balancing Rock highlights the rock type (granite) and its weathering behavior: it is a monolith formed by long-term exfoliation of jointed granite, demonstrating the durability of this rock under tropical weathering and seismic forces alike.

Rani Durgawati Fort (Madan Mahal Fort):

The Madan Mahal Fort, associated with Rani Durgawati's Gond dynasty, sits atop the same rugged hill that hosts the Balancing Rock. Geologically, this hill is one of the conical granite inselbergs of Jabalpur. The fort's foundation is the massive Madan Mahal Granite outcrop, which provided both a strategic high ground and a sturdy building base. In and around the fort, the granite exhibits classic features of an intrusive igneous body. We observed large feldspar crystals (some microcline phenocrysts), giving parts of the rock a porphyritic texture.

Dark mafic inclusions were also seen, these are xenoliths of the country rock (metamorphic schist) engulfed by the granite. Such xenoliths, visible on the fort hill, are typically fine-grained black or grey patches within the pinkish-grey granite. The presence of xenoliths confirms that the granite is intrusive and younger than the surrounding metamorphics. The fort location offered an excellent view to discuss regional structure: to the north, the Narmada valley can be seen, aligning ENE-WSW, this marks the trace of the Narmada–Son fault system which has downthrown the basin where younger sediments accumulated.

Figure 4: The Rani Durgawati Fort of Jabalpur.

To the south, rolling hills of granite and metamorphic rocks are visible, representing the uplifted block of the Central Indian Shield. On the fort hill itself, we mapped several joint sets in the granite. There are sub horizontal sheet joints (leading to the slab-like exfoliation) as well as vertical joints trending N-S and E-W. In essence, the Rani Durgawati Fort site demonstrated the internal features of the granite pluton (like mineralogy and xenoliths) and how regional tectonics have fractured it.

Chui Hills:

Chui Hill is an important geologic section on the western fringe of Jabalpur, where both the Upper Gondwana (Jabalpur) and Lameta Formations are exposed in superposition. At the base of the hill, outcrops of the Jabalpur Formation appear as thick-bedded, coarse sandstones and interbedded clays. These sandstones are typically light brown to white, medium- to coarse-grained, and show trough cross-bedding in places, suggesting deposition by rivers. In fact, the Jabalpur Formation here is interpreted as fluvial in origin – braided stream deposits laid down in the Early Cretaceous when the region was part of a rift valley environment.

The Jabalpur sandstones are generally soft and friable; however, at the very top of the formation we observed a thin pebbly conglomerate layer directly beneath the overlying Lameta beds. This conglomeratic horizon, often marks the unconformity with the older rocks at Chui Hill, it marks the discontinuity between the fluvial Gondwana sands below and the overlying Lameta sediments above. The Lameta Formation at Chui Hill commences with what early workers called the “Green Sand” unit. This bed is exposed prominently as a greenish-gray to rusty red sandstone layer capping the white Gondwana sandstone.

The Green Sand is about 2–3 m thick at Chui Hill and consists of fine- to coarse-grained sandstone rich in ferruginous material. It is highly cross-bedded. Above the Green Sand, the Lower Limestone of the Lameta Formation is present, though not continuously exposed at Chui Hill. The upper part of the Lameta at Chui is composed of the Mottled Nodular Beds (MNB), a unit we observed in a small abandoned quarry on the hill. These beds are a mixture of variegated clays and marls – colored purple, pink, green, and brown – with abundant calcareous nodules. The MNB at Chui Hill is quite thick (approximately 30 m). These beds have thin laminae and some horizontal bedding, possibly representing overbank floodplain deposits with soil formation in between episodes of sedimentation.

Paat Baba Ridge (Bara Simla Hill):

Figure 5: The Paat Baba Ridge of Jabalpur.

Paat Baba Ridge is essentially the continuation of the Lameta outcrop from Chui Hill, extending further north and east. It corresponds to the locality historically called

Bara Simla Hill, which, along with nearby Chhota Simla Hill. On this ridge, the sequence of Lameta Formation is fully developed and capped by Deccan Trap basalt. At the lower slopes near the Paat Baba temple, outcrops of the Lower Limestone of the Lameta Formation are well exposed. Jabalpur is noted for Late Cretaceous paleontology – the Lameta beds here represent an ancient terrestrial ecosystem.

An Upper Limestone was identified in one small cliff face – a harder, yellowish sandy limestone about 1–2 m thick. It had low-angle cross-bedding and contained small pebbles at its base. It graded upward into the Upper Sandy Zone. The Upper Sandy Zone on Paat Baba Ridge is not very well exposed due to erosion and the cover of trap rock debris. According to literature, this is a thin bed of sandstone or grit that represents the last phase of Lamheta sedimentation before volcanism, and it's often patchy or erode.

Lamheta Ghat:

Lamheta Ghat is a classic locality on the Narmada River, historically significant as the place where the Lamheta Formation was first studied and named. The geological highlight of this site is the unconformity between the Precambrian basement rocks and the overlying Lamheta Group. We observed quartz veins cut across the schist at high angles. Lying unconformably atop the schist at Lamheta Ghat are the basal beds of the Lamheta Formation. The contact is an angular unconformity – the schist foliation dips 60° to the south, whereas the Lamheta beds above are nearly horizontal. Above the conglomerate at Lamheta Ghat, a sequence of sandy and calcareous beds belonging to the Lamheta Formation is exposed in the river cliff. We noted a greenish sandstone layer and overlying buff-colored calcareous shale and limestone layers. The section here is somewhat condensed compared to Chui Hill, perhaps because we are closer to the paleo-shoreline of the Lamheta basin.

The limestone is fossiliferous; although no large bones were spotted in situ, we did find small black carbonized bits in a shale layer which might be plant remains or invertebrate traces. According to literature and local experts, dinosaur eggs have been found in the Lamheta Ghat area as well. Another important feature at Lamheta Ghat is the evidence of paleo-flow and paleogeography recorded by the Lameta sediments. Cross-beds in the basal sandstone indicated current directions to the south-west. Moreover, the presence of calcrete and mudcracks in some of the shales suggested periodic subaerial exposure. The environment of deposition here has been interpreted as a low-lying coastal plain with ephemeral lakes and streams – possibly seasonal wet and dry periods. The Lamheta Ghat section, albeit truncated, gave us a glimpse into these environmental indicators.

Figure 6: The Lamheta Ghat of Jabalpur.

Bhedaghat:

Bhedaghat offers a unique geological exposure of Jabalpur's Precambrian metamorphic basement, particularly the carbonate-rich Mahakoshal Group. The Marble Rocks gorge is carved into thick, white-to-gray metamorphosed limestone (marble), which displays a coarse crystalline texture due to contact metamorphism. The presence of anthophyllite and other calc-silicate minerals indicates thermal alteration, likely caused by the intrusion of the 1.8 Ga Madan Mahal Granite pluton. The marble exhibits intense jointing and near-vertical folding, with prominent fracture sets that guide river incision, forming the steep-walled gorge. Weathering patterns, such as "elephant skin" textures, further highlight chemical dissolution processes acting on the carbonate rock.

A major structural feature of Bhedaghat is the Swarg Dwari Dolerite Dyke, a dark igneous intrusion cutting through the marble. Approximately 23 meters wide, the dyke trends NNE–SSW and forms a distinct narrowing of the river channel. It exhibits an ophitic texture with plagioclase and pyroxene, and displays well-developed columnar jointing, creating large polygonal blocks and spheroidal boulders along the riverbank. This dyke likely exploited deep-seated fractures and may be linked to Late Cretaceous Deccan magmatism, indicating tectonic activity associated with Gondwana's breakup.

The Dhuandhar Falls at the northern end of the gorge exemplify differential erosion, where the Narmada River transitions from softer upstream rocks to the resistant marble and dolerite ridge, creating a steep drop. Though Lameta Formation outcrops were limited, sediment deposits and tufa-like formations suggest a shift from an alluvial to a bedrock-controlled channel. The overall geology of Bhedaghat reveals a complex history of metamorphism, magmatism, and structural deformation, shaping its present-day landscape.

- **Rock Types and Geological Formations in Jabalpur**

The Jabalpur region's geology can be understood in terms of a stratigraphic sequence that spans from the Precambrian basement to the Cretaceous volcanic cap. The major formations studied during the field trip include the Mahakoshal Group (basement metamorphics), the Madan Mahal Granite (intrusive into the basement), the Jabalpur Formation (Upper Gondwana sedimentary rocks), the Lameta Formation (Infratrappean Cretaceous sedimentary rocks), and the Deccan Traps (Cretaceous-Paleogene flood basalts). Each of these has distinct lithology, age, and depositional or emplacement environment:

- Jabalpur Formation (Upper Gondwana Group): The Jabalpur Formation represents the sedimentary rocks of the Gondwana Supergroup exposed in the

Jabalpur area. Stratigraphically, it belongs to the Upper Gondwana sequence and is of Early Cretaceous age. This formation lies with an unconformity over various older rocks. The Jabalpur Formation is composed predominantly of continental clastic sediments. Its lithology, as observed and recorded, includes: thick sandstones (yellow, brown, or white) that are cross-bedded and coarse-grained, interbedded with variegated clays and shales, implying localized swampy conditions. The Jabalpur Formation is underlain by older Gondwana formations elsewhere, but locally it directly sits on basement. It is overlain unconformably by the Lameta Formation. Age-wise, it's important as it indicates that after the long gap since the Precambrian, sedimentation resumed in this area in the Early Cretaceous, possibly connected to global sea level rise or regional sag in the rift.

- Lameta Formation (Upper Cretaceous) – The Lameta Formation (often called Lameta Beds) is a Late Cretaceous sedimentary formation , representing the last phase of significant sediment deposition before the Deccan Trap volcanism in this region. Stratigraphically, Lameta rests unconformably on the Jabalpur Formation or directly on older rocks where Gondwana sediments are absent. It is overlain by the Deccan Trap basalts, except in eroded exposures where traps are gone. The lithology of the Lameta Formation is varied, reflecting a mix of fluvial, lacustrine, and pedogenic facies. In general, it consists of clays, siltstones, sandstones, and limestones arranged in distinct layers. Key subdivisions (from base to top) identified in the Jabalpur area include: Green Sandstone, Lower Limestone, Mottled Nodular Bed (MNB),Upper Limestone and Upper Sandy Zone. In composite, the Lameta Formation thickness in the Jabalpur area ranges from about 18 m to as much as 45 m. Economically, parts of the Lameta (particularly the limestones) have been quarried for cement manufacture and lime.

- Deccan Traps: The Deccan Traps represent one of the largest volcanic events on Earth, covering large parts of western and central India in flood basalts around the Cretaceous–Paleogene boundary. In the Jabalpur region, the Deccan Traps occur as the uppermost formation, overlying the Lameta Formation. Much of the Deccan Trap exposure is actually in the form of dolerite dykes and sills, because the main bulk of flows lies a bit further west and south. The age of the Deccan Traps is latest Maastrichtian to early Paleocene. Within the traps, there are also thin intertrappean beds in some areas, though we did not specifically study one in this trip. Those have fossils of freshwater organisms indicating brief return of lakes or soils between eruptions.

- **Objectives**

The primary objectives of this geological field trip were:

1. To identify and describe the various rock types present at each site, understanding their mineralogical composition and depositional environments.
2. To analyze geological structures such as folds, faults, joints, and dykes, and to interpret the tectonic history that led to their formation.
3. To examine fossil content, particularly within the sedimentary formations at Lamheta Ghat, to reconstruct past environments and biological communities.
4. To assess mineral deposits, including marble at Bhedaghat, and understand their distribution and potential economic value.
5. To develop practical skills in geological mapping, sample collection, and the use of field instruments such as geological compasses and hand lenses.

- **Map**

The following map illustrates the study area covered during our field excursion, emphasizing major geological sites including Trishul Bhed, Lamheta Ghat, Bhedaghat, Rani Durgawati Fort, Balancing Rock, Paat Baba Ridge, and Chui Hills. These locations were selected for their diverse lithological characteristics, distinctive structural formations, and geomorphological significance.

Figure 7: Study area for the field trip

- **Instruments and Materials used**

The following instruments and materials were utilized during the field study:

1. Brunton Compass: For measuring strike, dip, and dip direction of rock layers.
2. Rock Hammer: For breaking rock samples to observe fresh surfaces.
3. Hand Lens: For magnified examination of mineral structures and rock textures.
4. Stereonet and Tracing Paper: For plotting structural data and analyzing geological orientations.
5. Field Notebook, Rulers, Protractors, and Pencils: For recording observations and making field sketches. Sample Bags – For collecting and preserving rock specimens.

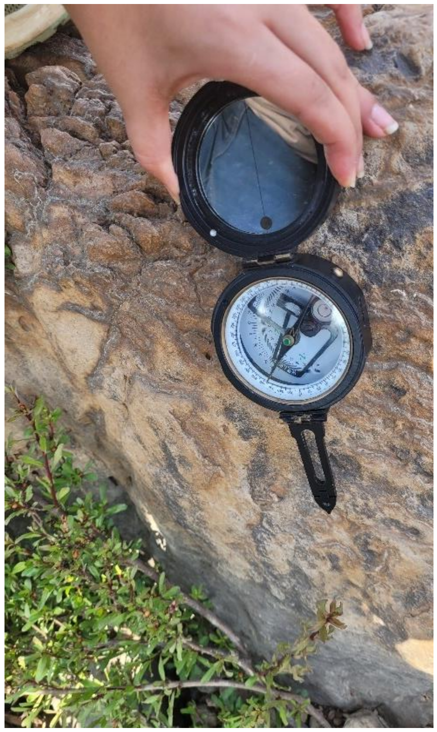
Figure 8: Bruton Compass

- **Field Methodology and Techniques**

The fieldwork in Jabalpur was conducted using a structured and hands-on approach to ensure a comprehensive understanding of the region's geological features. Our methodology revolved around identifying rock types, analyzing structural formations, and mapping geological patterns through direct observations and instrumental measurements. We received three instruments provided by the Department of Earth Sciences, IIT Kanpur to proceed with our methodology. We used the geological compass to measure strike, dip and dip direction data for structural analysis.

Lithological Analysis

Rock types were identified based on field characteristics such as color, grain size, mineral composition, texture, and reaction to acid (for carbonates). Sedimentary structures like cross-bedding, ripple marks, and mud cracks were noted in stratified units, while igneous and metamorphic textures were recorded for granites, basalts, and schists.

Structural Analysis

To understand the regional geological framework, structural measurements were systematically taken at each site:

- Strike Measurement: The edge of the Brunton Compass was placed flat against bedding planes or foliation surfaces, and the reading was taken when the bull's eye bubble was centered.
- Dip and Dip Direction Measurement: The compass was rotated 90° from the strike, placed against the dipping surface, and the clinometer reading recorded.
- Joint and Fault Analysis: Fracture orientations were measured, and fault kinematics were inferred from slickensides and offset strata.

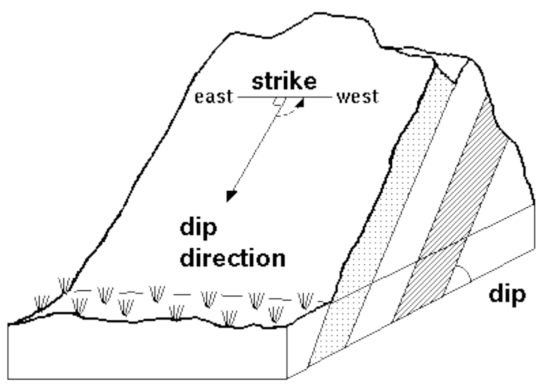

Figure 9: Strike and Dip direction

Stratigraphic Correlation and Mapping

At locations such as Chui Hills and Lamheta Ghat, we logged stratigraphic sections by recording lithological variations, fossil content, and key marker horizons. Structural and lithological data were later plotted on a stereonet to analyze regional trends and deformation patterns.

2 Day 1: Trishul Bhed, Balancing Rock, and Rani Durgawati Fort

On the first day (28 Nov 2024), our group explored three sites around Jabalpur: Trishul Bhed (near Lamheta Ghat), the Balancing Rock, and Rani Durgawati Fort. The focus was to observe different rock types and geological features, especially sedimentary formations of the Lamheta Formation and underlying basement rocks. Below are the key observations from each site:

Trishul Bhed (23°06’28"N, 79°50’42"E):

This site lies along the Narmada River and exposes sedimentary rocks of the Lamheta Formation. We noted predominantly limestone (sedimentary) and some basalt (igneous) outcrops. Several limestone surfaces had circular holes formed by water dissolution – rainwater (slightly acidic from carbon dioxide) has gradually dissolved the limestone, creating pits and cavities over time. We measured the attitude of bedding planes here; for example, one limestone bed showed a dip direction of approximately 150°/330° with a dip of approximately 37.5°, indicating the layers tilt moderately towards the southeast/northwest. The Narmada’s erosion has carved the banks, exposing a cross-section of rock strata that provides insight into the area’s geological history.

Figure 10: Study area of Trishul Bhed

Notable geological features included distinctive circular cavities and pits in limestone outcrops, resulting from prolonged chemical weathering known as karstification. These cavities form due to mildly acidic groundwater (carbonic acid) reacting with calcium carbonate in limestone, gradually dissolving the rock.

We also identified conglomerate deposits comprising rounded calcareous clasts, indicating historical high-energy water transportation and deposition. Unlike breccias, which contain angular fragments due to limited transportation, the rounded nature of these conglomerates supports the interpretation of significant fluvial or marine transport processes during sediment deposition in the Cretaceous period.

Furthermore, planar quartz veins were observed within rock fractures, signifying past tectonic stress and fluid infiltration events. The platy and laminated structure of the sedimentary rocks suggested deposition in low-energy aquatic environments, such as shallow marine or lacustrine settings. Additionally, extensive weathering and erosion by the Narmada River have significantly exposed these geological features.

Igneous basaltic layers observed atop sedimentary sequences indicated younger volcanic activity linked to the Deccan Trap volcanism. The basalt's fine-grained texture confirmed rapid cooling at the surface. Contact zones between basalt and limestone featured charred margins, reflecting thermal alteration and mixing during volcanic events.

Structural observations included prominent shear zones parallel to bedding planes, indicative of low-grade metamorphism and tectonic shearing, leading to local marble formation from original limestone beds. Additionally, slickensides and a half-graben structure were identified, clearly demonstrating regional extensional tectonics associated with normal faulting, notably dipping north-south locally and east-west regionally.

Figure 11: Half Graben in the field

Balancing Rock (Coordinates: 23°08’55"N, 79°54’17"E):

This famous geological marvel is a large granite boulder balanced precariously atop another rock. It appears to defy gravity, with only a very small contact area between the two rocks. Geologically, the Balancing Rock is part of the ancient Bundelkhand Granite outcrops. Its peculiar shape is a result of prolonged exfoliation weather- ing – repeated temperature changes caused outer layers of the granite to peel off over millennia, sculpting the boulder into a rounded shape. Despite its delicate ap- pearance, the Balancing Rock is extremely stable. It has even withstood signifi- cant earthquakes, such as the 6.2 magnitude Jabalpur earthquake in 1997, without toppling. This stability is due to the rock’s weight distribution and the hardness of granite, as well as the region’s stable cratonic foundation. The site, located at the base of the Madan Mahal hill, is a popular stop for understanding weathering pro- cesses and for appreciating the balance between erosion and gravity.

Rani Durgawati Fort (Coordinates: 23°08’57"N, 79°54’13"E):

The fort sits on a hill (approximately 500 m above sea level) overlooking Jabalpur, near the balancing rock. The hill itself is a massive granite outcrop, part of the Bundelkhand craton, which provided a sturdy foundation for the medieval fort. We observed that the granite here shows surface exfoliation similar to the balancing rock thin outer sheets of rock are flaking off due to thermal stress over time. Geologically, the granite has remained largely intact for millions of years, surviving weathering and even nearby tectonic disturbances (the area is near the Narmada Rift zone). In fact, the fort's rock withstood the 1997 earthquake with minimal damage, underscoring the strength of the granitic terrain. Historically, this site (also known as Madan Mahal Fort) was built in the 11th century by the Gond rulers and later occupied by Rani Durgawati. Our literature mentions how in 1564, Rani Durgawati bravely defended this fort against Mughal forces at one point even cutting off access to nearby water sources to disadvantage the enemy. Ultimately, though she was outnumbered, her legacy lives on as a symbol of valor. This blend of historical significance and geological resilience makes the fort a fascinating stop: one can observe how the sturdy granite geology contributed to its strategic importance and long-term preservation.

3 Day 2: Detailed Measurements at Trishul Bhed (Lamheta Formation)

On the second day (29 Nov 2024), we returned to the Trishul Bhed area to perform detailed geological mapping and data collection. The team investigated eight different sites along the exposures, collecting measurements of rock layer orientations and examining lithology in detail. We focused on the sedimentary-igneous rock interfaces and structural features within the Lameta Formation. Key findings and observations include:

- Structural Data Collection: We used a Brunton compass to measure the strike and dip of bedding planes and any fracture/fault planes at each site. By the end of the day, we had a comprehensive set of orientation data for multiple layers across the outcrop. This data would later be plotted on stereonets (the analysis was done on Day 4) to infer the general dip direction of formations. Most beds in this area showed a gentle to moderate dip towards the south, which aligns with our Day 1 observation that younger layers appear in the southerly direction, implying the strata tilt southward.

- Columnar Joint in Basalt: While traversing the path to one of the sites, we came across a striking example of columnar jointing in a basalt flow. Columnar joints are polygonal (often hexagonal) columns in volcanic rocks that form as hot lava cools and contracts, cracking into pillar-like structures. The basalt columns we observed were nearly vertical and had a hexagonal cross-section, characteristic of slow, uniform cooling of a thick lava flow. This finding is significant because it confirms that the basalt here is part of the Deccan Traps (the vast sequence of flood basalts in central India). The presence of columnar joints is a classic feature of the Deccan Trap volcanism in this region, indicating that after these lava flows erupted in the Late Cretaceous, they cooled in place to form the columns. These structures also imply that the area experienced no major disturbance since their formation, as severe tectonic deformation would have shattered or tilted the columns.

Figure 12: Columnar joints and Non-Conformity

- Nonconformity and Sequence of Layers: One of the most illuminating observations was identifying a nonconformity in the stratigraphic sequence. We noted an exposure where sedimentary conglomerate layers lie directly on top of basalt, with limestone beds underlying the basalt. In simpler terms, the sequence from bottom to top was: limestone → basalt → conglomerate. This is geologically significant because it indicates an unconformity in time:

   i) The limestone at the base is part of the Lameta Formation (Late Cretaceous sedimentary deposits).

   ii) The basalt above it intruded or flowed later (during the Deccan Trap eruptions), cutting across the older sedimentary layers. The contact between limestone and basalt is an igneous-sedimentary interface, evidencing that molten lava once flowed over the sediment or injected into it.

iii) Over the basalt, a conglomerate layer (rounded pebbles cemented together) sits, which suggests that after the basalt cooled and solidified, there was a period of erosion and sediment deposition that laid down river sediments (conglomerates) on top. This nonconformity (sedimentary rock over much younger igneous rock) confirms that the area underwent a major volcanic event after initial sedimentation, followed by renewed deposition.

- Lithology and Alteration: The rock types encountered on Day 2 were chiefly limestone (often fossil-bearing) and basalt. The limestone is typically grey and massive, whereas the basalt is dark and fine-grained. At some contact zones, we observed that the intense heat of the basalt had thermally altered the adjacent limestone, a phenomenon known as contact metamorphism. For instance, at one site the limestone immediately next to the basalt had a hard, siliceous texture (possibly forming chert-like bands) where the magma's heat recrystallized the carbonate rock. We also noticed thin veinlets in the basalt filled with quartz and calcite, indicating hydrothermal activity post-solidification. These observations suggest that the meeting of lava and wet sediment led to localized alteration – a small-scale version of what happens when igneous intrusions bake the surrounding rock.

- **Outcrop Site 1 (Coordinates: 23°06'11"N, 79°49'48"E, Elevation - 1200 ft)**

- Measurements:

Dip Direction	160°- 340°	170°- 350°	160°- 340°	165°- 335°	167°- 333°
Dip Amount	30°	20°	25°	27°	29°

Table 1: Calculated dip direction and dip amount in outcrop site 1

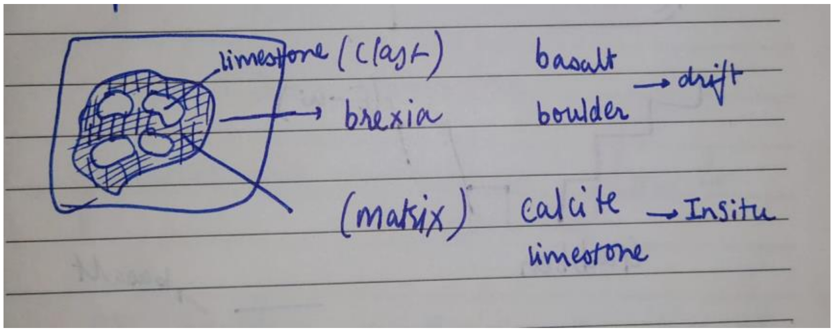

Figure 13: Composition of the sample

At this outcrop, we observed limestone with significant calcareous composition. Additionally, smaller igneous fragments forming conglomerates were identified at the base, indicating past transportation and deposition. Basaltic intrusions into the limestone layers were evident, reflecting volcanic activities that impacted the sedimentary formations. Furthermore, ferrogenous veins were noted within the breccia, signifying episodes of mineral-rich fluid infiltration and subsequent mineralization.

- **Outcrop Site 2 (Coordinates: 23°06’11"N, 79°49’46"E, Elevation - 1218 ft)**
  - Measurements:

Dip Direction	30°- 210°	40°- 220°
Dip Amount	11°	10°

Table 2: Calculated dip direction and dip amount in outcrop site 2

The lithological sequence observed at this site begins with limestone, indicating its early formation in a deep marine environment. Subsequent volcanic activity occurred as the region moved, causing intermittent basalt eruptions directly onto the limestone. Eventually, intense volcanic events associated with the mantle plume resulted in thick basalt layers covering the earlier limestone deposits. Overlying these volcanic layers, sediments composed primarily of pebbles were deposited through erosional processes in fluvial environments. The pebble sizes generally decrease in diameter away from the fluvial source, illustrating a clear fining upward sequence. Thus, the overall lithological succession consists of basal limestone transitioning upward to igneous rocks, with visible basalt intrusions intersecting the underlying limestone.

- **Outcrop Site 3 (Coordinates: 23°06’10"N, 79°49’45"E, Elevation - 1190 ft)**

• Measurements:

Dip Direction	30°- 210°	35°- 225°
Dip Amount	7°	10°

Table 3: Calculated dip direction and dip amount in outcrop site 3

The lithological arrangement at this site comprises sedimentary rocks, primarily limestone, at the base, overlain by igneous rocks, notably the Deccan basalts. Intrusions of basalt are visible penetrating into the underlying limestone layers, indicating volcanic activity following sediment deposition. Additionally, fossil evidence was noted, with both in-situ and transported fossils suggesting a historical river flow that interacted with these geological formations.

- **Outcrop Site 4 (Coordinates: 23°06’11"N, 79°49’43"E, Elevation - 1187 ft)**

• Measurements:

Dip Direction	150°- 330°	155°- 335°
Dip Amount	50°	55°

Table 4: Calculated dip direction and dip amount in outcrop site 4

Here, the primary lithology consisted of platy metamorphic schists, showing a distinct younging direction towards the south. Additionally, transported boulders of limestone and basalt were identified, suggesting their deposition through ancient river channels. A fault plane was observed, indicating past tectonic activity in the area.

3.5 Outcrop Site 5 (Coordinates: 23°06’12"N, 79°49’43"E, Elevation - 1209 ft)

• Measurements of bed planes:

Dip Direction	155°- 335°	160°- 340°
Dip Amount	55°	49°

Table 5: Calculated dip direction and dip amount in outcrop site 5

• Measurements of fault planes:

Dip Direction	22°- 202°	5°- 185°
Dip Amount	55°	45°

Table 6: Calculated dip direction and dip amount in outcrop site 5

The lithology at this site predominantly consisted of limestone. We observed numerous veins within the limestone, which had formed due to mineralization along fracture lines. Additionally, we noted evidence of younger fault planes superimposed upon older ones, resulting in distinct sheared zones indicative of complex tectonic activity.

Figure 14: Planar quartz veins

3.6 Outcrop Site 6 (Coordinates: 23°06'12"N, 79°49'43"E, Elevation - 1194 ft)

• Measurements of bed planes:

Dip Direction	165°- 345°	160°- 340°
Dip Amount	80°	85°

Table 7: Calculated dip direction and dip amount in outcrop site 6

- Measurements of fault veins:

Dip Direction	165°- 345°	160°- 340°
Dip Amount	83°	83°

Table 8: Calculated dip direction and dip amount in outcrop site 6

At this location, the lithology predominantly comprised schist and well-defined schistose beds. Additionally, we observed shale layers containing veins, which had likely formed through mineral deposition associated with hydrothermal processes.

3.7 Outcrop Site 7 (Coordinates: 23°06’12"N, 79°49’43"E, Elevation - 1189 ft)

- Measurements:

Dip Direction	60°- 240°	55°- 235°
Dip Amount	25°	30°

Table 9: Calculated dip direction and dip amount in outcrop site 7

We see two primary rock types: limestone, representing the older sedimentary formation, and basalt, which is relatively younger and indicative of subsequent volcanic activity.

3.8 Outcrop Site 8 (Coordinates: 23°06’12"N, 79°49’43"E, Elevation - 1200 ft)

- Measurements of bed planes:

Dip Direction	165°- 345°	160°- 340°
Dip Amount	85°	88°

Table 10: Calculated dip direction and dip amount in outcrop site 8

- Measurements of fracture planes:

Dip Direction	85°- 265°	70°- 250°	85°- 265°
Dip Amount	45°	45°	52°

Table 11: Calculated dip direction and dip amount in outcrop site 8

Throughout the entire area, a normal fault system was identified, accompanied by four distinct sets of fracture planes. Additionally, slicken sides, indicating fault movement, and a notable half-graben structure were observed. The dominant lithology at this site was mica schist, emphasizing the region's metamorphic character.

4. Day 3: Chui Hills Stratigraphy and Paat Baba Ridge Fossils

Day 3 (30 Nov 2024) took us to two new locations: Chui Hills in the morning and Paat Baba Ridge in the afternoon. These sites offered a broader regional perspective, highlighting the transition from sedimentary environments to volcanic events and revealing evidence of prehistoric life in the area. The goals for the day were to understand the stratigraphic sequence at Chui Hills and to examine fossil-bearing horizons at Paat Baba.

Figure 15: Area near Chui Hills

4.1 Chui Hills (Coordinates: 23°10’9” N, 79°58’21” E, Elevation: 1526 ft)

Stratigraphy at Chui Hills: At Chui Hills, we were able to observe an excellent exposed sequence of rock layers from bottom to top, capturing the transition between different geologic formations. The base of the hill consists of older sedimentary rocks (sandstones and shales) which likely belong to the Jabalpur Formation (Early Cretaceous). Above these, we encountered layers of the Lameta Formation (Upper Cretaceous) and, capping the sequence, the flat-lying Deccan Trap basalt flows. This progression provides a window into the region's geologic evolution:

(a) The sedimentary layers (below) with fossils of plants or minor invertebrates indicate a period when the area was a low-lying fluvial or lacustrine environment (rivers and lakes).

(b) One prominent layer was a greenish sandstone unit. This "Green Sandstone" marks a transitional phase – it has a green hue (possibly from minerals like glauconite) and represents a short-lived marine influence in the environment. Its presence suggests that before the Lameta Formation was fully established, there might have been shallow sea incursions that deposited these sands. In our field inspection, this layer was fine- to medium-grained and laterally continuous, indicating a widespread depositional event.

Figure 16: Green Sandstone

(c) Above the green sandstone, the Lameta Formation proper includes limestones and marls. We saw nodular limestone beds and mottled clays typical of soil formation or caliche, which implies periods of exposure and soil development in between sediment deposition. (d) Finally, the Deccan basalt overlying the sediments is a remnant of the massive volcanic eruptions ~66 million years ago. At Chui Hills, the contact between the uppermost Lameta sediment and the first basalt flow was clearly visible. We noted a thin reddish layer at this contact, possibly an intertrappean bed (soil or sediment that existed briefly between lava flows). This stratigraphy confirms that Chui Hills was at the edge of the Deccan volcanic province – earlier a landscape of rivers and floodplains, later buried by lava.

Figure 17: Stratigraphy of Chui Hills as observed in the field

- **Deccan Traps (Coordinates: 23°10’31” N, 79°57’50” E, Elevation- 1519 ft)**

    - Measurements:

Dip Direction	150°- 330°	15°- 195°
Dip Amount	10°	11°

Table 12: Calculated dip direction and dip amount at deccan traps

The lithology of the Deccan Traps primarily consists of extensive basaltic lava flows, forming the uppermost unit of the sequence. These flows are typically dark-colored, mafic, and fine-grained. Intervening thin layers of sedimentary rock, such as clay, limestone, or fossil-bearing beds, known as Intertrappean Beds, were deposited between successive lava flows. Beneath these beds, older Deccan lava flows reappear, marking the initial phase of volcanic activity that blanketed the region in basaltic lava. This widespread volcanism also covered and preserved pre-existing sedimentary formations, including the Lameta Formation.

- **Calcified Sandstone (Coordinates: 23°10’30” N, 79°57’51” E, Elevation- 1449 ft)**

  - Measurements:

Dip Direction	100°- 280°	110°- 290°
Dip Amount	12°	9°

Table 13: Calculated dip direction and dip amount at calcified sandstone

The lithology of calcified sandstone consists of medium- to coarse-grained sandstone, cemented by calcium carbonate ($CaCO_3$). It is typically hard and resistant, often forming ridges or compact layers in the field. This rock type develops through the precipitation of calcium carbonate within the pore spaces of pre-existing sandstone, leading to its distinctive durability and structural integrity.

- **Mottled Nodules (Coordinates: 23°10’ 22” N, 79°57’ 52” E, Elevation- 1445 ft.)**

Measurements:

Dip Direction	120°- 300°	110°- 290°	130°- 310°
Dip Amount	12°	9°	10°

Table 14: Calculated dip direction and dip amount at mottled nodules

The lithology of mottled nodules consists of a layer of nodular claystone and calcareous concretions. It is characterized by reddish to yellowish mottling, which signifies pedogenic (soil-forming) processes. This formation develops due to prolonged weathering and soil formation under arid to semi-arid climatic conditions.

- **Lower Limestone (Coordinates: 23°10’30” N, 79°57’51” E, Elevation- 1440 ft)**

Measurements:

Dip Direction	125°- 305°	130°- 310°
Dip Amount	4°	9°

Table 15: Calculated dip direction and dip amount at lower limestone

The lithology of the Lower Limestone consists of a fossiliferous limestone unit rich in calcium carbonate. It represents deposition in a shallow lacustrine or swampy floodplain environment, where carbonate accumulation occurred. The presence of this unit indicates seasonal wet-dry conditions that prevailed before the volcanic eruptions of the Deccan Traps.

- **Green Sandstone (Coordinates: 23°10’29” N, 79°57’52” E, Elevation- 1427 ft.)**

Measurements:

Dip Direction	25°- 210°	85°- 265°
Dip Amount	22°	25°

- Table 16: Calculated dip direction and dip amount at green sandstone

The lithology of Green Sandstone consists of a fine- to medium-grained, greenish-colored sandstone, formed in slow-depositing, marine-influenced environments. It represents a transitional phase between the Jabalpur Formation at the base and the overlying Lameta Formation (Lower Sandstone). The presence of this unit indicates intermittent marine incursions, suggesting periods of shallow marine conditions before the resumption of full terrestrial deposition.

4.2 Paat Baba Ridge (Coordinates: 23°10’14” N, 79° 58’32” E)

In the afternoon, we shifted to Paat Baba Ridge, a site world-renowned for its dinosaur fossils. This ridge is part of the Lameta Formation outcrop and is known as one of India’s richest Late Cretaceous dinosaur nesting grounds. Our field visit did not disappoint:

(a) We observed numerous mottled nodules in a particular layer of silty limestone. These round concretions were spread throughout the rock and often have a variegated coloring. They could be pedogenic calcretes or iron-rich nodules formed in ancient soils. These nodules gave the layer a “mottled” appearance (hence the term Mottled Nodular Bed, often used for part of the Lameta Formation).

(b) Excitingly, the team found several spherical objects embedded in the rock that strongly resembled dinosaur eggs. These fossils were about 15–20 cm in diameter, with a hardened shell-like surface. In fact, recent studies in the Narmada Valley have documented entire egg clutches; our guide pointed out the outlines of what could be a small nest of eggs on the ridge surface. The presence of these egg fossils, suggests this area was a dinosaur breeding ground during the Late Cretaceous. Many such nests have been found around Jabalpur.

Figure 18: Dinosaur egg fossil observed at the site

(d) We also found fossilized mollusk shells in the sedimentary layers. One limestone bed contained numerous impressions of bivalves (clams) and gastropods, indicating a shallow aquatic habitat at the time those sediments were laid down. This aligns with the idea that parts of the Lameta Formation were deposited in lakes or slow-moving rivers. The combination of aquatic fossils and dinosaur nesting sites is fascinating – it paints a picture of a landscape with rivers or ponds frequented by dinosaurs who nested on the higher, drier grounds nearby.

Figure 19: Mollusk fossils observed at the site

By the end of Day 3, we had deepened our understanding of the regional geology. Chui Hills gave us a clear stratigraphic record of the pre-volcanic environment transitioning into volcanic activity. Paat Baba Ridge provided tangible evidence of the life forms that existed just before the dinosaurs went extinct – the eggs and fossils in the Lameta Formation here date to right before the end-Cretaceous mass extinction. The coexistence of sedimentary evidence (fossils, paleosols) and igneous evidence (basalt flows) in this area makes Jabalpur's geology exceptionally rich.

5. Day 4: Lamheta Ghat Outcrops and Structural Analysis

On the fourth day (1 Dec 2024), we focused on a single locality, Lamheta Ghat (Coordinates: 23°6'16" N, 79°49'52" E, Elevation: 1240 ft), but in much greater detail. Lamheta Ghat is a classic geological site along the Narmada River, known from the earliest days of Indian geology (the term "Lameta beds" originates here). Our aim was to study multiple rock outcrops along the river bank, collect structural measurements, and then analyze this data to interpret the geological structure of the area. We visited 8 outcrops spread across a ~1 km stretch. After field measurements, we spent time using stereonets and other tools to analyze the data.

Figure 20: The Lamheta Ghat (day 4)

- **Outcrop Site 1**

  - Measurements of bed planes:

Dip Direction	176°- 356°	160°- 340°	170°- 350°	174°- 354°	165°- 345°
Dip Amount	75°	70°	55°	80°	60°

Table 17: Calculated dip direction and dip amount in outcrop site 1

  - Measurements of fracture planes:

Dip Direction	130°- 310°	70°- 250°
Dip Amount	70°	75°

Table 18: Calculated dip direction and dip amount in outcrop site 1

At this outcrop, we observed sediments composed primarily of cobbles and pebbles, indicative of deposition through river processes. Additionally, slate was identified, suggesting metamorphic transformations driven by substantial tectonic pressure. Furthermore, conjugate fractures were evident at this location, highlighting past episodes of structural deformation within the rock formations.

- **Outcrop Site 2**

  - Measurements of bed planes:

Dip Direction	175°- 355°	165°- 345°	170°- 350°	167°- 347°	172°- 352°
Dip Amount	63°	72°	70°	65°	68°

Table 19: Calculated dip direction and dip amount in outcrop site 2

  - Measurements of fracture planes:

Dip Direction	175°- 355°	115°- 295°	110°- 290°
Dip Amount	42°	51°	78°

Table 20: Calculated dip direction and dip amount in outcrop site 2

At this outcrop, we noticed that rock layers transitioned into increasingly coarse and thickly bedded structures moving southward, towards the river. Additionally, prominent jointing was observed extensively, suggesting past tectonic stress and subsequent fracturing of the rock formations.

- **Outcrop Site 3**
  - Measurements of bed planes:

Dip Direction	172°- 352°	170°- 350°	170°- 350°	160°- 340°	165°- 345°
Dip Amount	58°	65°	63°	52°	60°

Table 21: Calculated dip direction and dip amount in outcrop site 3

  - Measurements of fracture planes:

Dip Direction	170°- 350°	70°- 250°
Dip Amount	25°	80°

Table 22: Calculated dip direction and dip amount in outcrop site 3

At this outcrop, we primarily observed prominent jointing patterns, indicating structural fracturing. The dominant rock types were schist and shiny mica, characteristic of the local geology. Additionally, evidence of low-grade metamorphism was clearly visible, reflecting mild tectonic pressures and heat that have influenced the rock formation.

- **Outcrop Site 4**
  - Measurements of bed planes:

Dip Direction	177°- 357°	175°- 355°	170°- 350°	160°- 340°	165°- 345°
Dip Amount	64°	61°	63°	58°	60°

Table 23: Calculated dip direction and dip amount in outcrop site 4

  - Measurements of sub vertical fracture planes:

Dip Direction	85°- 265°	80°- 260°
Dip Amount	85°	80°

Table 24: Calculated dip direction and dip amount in outcrop site 4

At this outcrop, numerous rounded-shaped rocks were observed, clearly indicating prolonged erosion and weathering processes. Additionally, slate formations were identified, reflecting significant metamorphic activity caused by substantial tectonic pressures. Furthermore, a conjugate fracture system featuring both sub-horizontal and sub-vertical fracture planes was documented, highlighting past episodes of structural deformation and stress within the rock layers.

- **Outcrop Site 5**

  - Measurements of bed planes:

Dip Direction	172°- 352°	170°- 350°	160°- 340°
Dip Amount	44°	45°	63°

Table 25: Calculated dip direction and dip amount in outcrop site 5

  - Measurements of sub vertical fracture planes:

Dip Direction	105°- 285°	100°- 280°
Dip Amount	85°	80°

Table 26: Calculated dip direction and dip amount in outcrop site 5

At this outcrop, bedding planes were observed dipping towards the southeast, indicating a regional structural orientation. The rocks here exhibited characteristics of low-grade metamorphism, suggesting mild tectonic stress and moderate heat conditions during their formation. Additionally, prominent joint patterns were evident, reflecting extensive fracturing and past geological stress events.

- **Outcrop Site 6**

  - Measurements of bed planes:

Dip Direction	160°- 340°	170°- 350°	170°- 350°	160°- 340°	165°- 345°
Dip Amount	43°	34°	45°	33°	40°

Table 27: Calculated dip direction and dip amount in outcrop site 6

  - Measurements of sub vertical fracture planes:

Dip Direction	110°- 290°	95°- 275°
Dip Amount	85°	80°

Table 28: Calculated dip direction and dip amount in outcrop site 6

At this outcrop, the predominant rock type was phyllite, characterized by its distinctive foliated texture and reflective sheen, indicating low-grade metamorphic processes. Additionally, prominent jointing patterns were observed, suggesting significant historical tectonic stresses that resulted in structural fractures throughout the formation.

- **Outcrop Site 7**

  - Measurements of bed planes:

Dip Direction	172°- 352°	170°- 350°	175°- 355°	174°- 354°	165°- 345°
Dip Amount	32°	38°	45°	41°	39°

Table 29: Calculated dip direction and dip amount in outcrop site 7

  - Measurements of sub vertical fracture planes:

Dip Direction	55°- 235°	60°- 240°
Dip Amount	80°	79°

Table 30: Calculated dip direction and dip amount in outcrop site 7

At this outcrop, numerous phyllite sheets were observed, exhibiting textures similar to sandy limestone, indicating their sedimentary origin prior to undergoing metamorphic transformation. A variety of structural features were prominently noted, reflecting complex tectonic histories. Additionally, extensive erosion of limestone was evident, especially towards the northern side of the site, suggesting significant weathering due to their considerable geological age.

- **Outcrop Site 8**

  - Measurements of bed planes:

Dip Direction	172°- 352°	168°- 348°	170°- 350°	160°- 340°	165°- 345°
Dip Amount	69°	50°	49°	50°	70°

Table 31: Calculated dip direction and dip amount in outcrop site 8

  - Measurements of fracture planes:

Dip Direction	90°- 270°	95°- 275°
Dip Amount	75°	70°

Table 32: Calculated dip direction and dip amount in outcrop site 8

At this outcrop, the dominant rock type observed was phyllite, characterized by its foliated texture resulting from low-grade metamorphism. Sediment accumulation appeared more pronounced closer to the riverside, indicating active fluvial deposition processes. Additionally, structural features such as joints and conjugate fractures were prominently observed, suggesting significant tectonic stresses and deformation events in the area's geological past.

6. Day 5: Lamheta Ghat and Bhedaghat

On December 2, 2024, we concluded our field study with a revisit to Lamheta Ghat in the morning, ensuring that all remaining geological observations were documented. Later in the day, we traveled to Bhedaghat, where we explored its striking marble cliffs and waterfalls. Though partly recreational, the visit to Bhedaghat provided crucial geological insights, particularly regarding the interactions between sedimentary and igneous processes.

6.1 Lamheta Ghat (Coordinates: 23°6’18” N, 79°50’18” E)

During our final examination of the site, we encountered several intriguing geological structures that shed light on the deformation history of the region:

- Soft-Sediment Folding: One of the most notable findings was a fold in the sedimentary layers that appeared to have developed while the material was still semi-consolidated. Unlike typical lithified folds, this structure had gently curved limbs that suggested it formed shortly after deposition. Possible causes include gravitational slumping on a slope or seismic activity during the Late Cretaceous period.

- Tight Isoclinal Folding: In a more competent rock layer nearby, we identified a tight fold with nearly parallel limbs, classifying it as an isoclinal or tight fold. This type of deformation typically occurs under higher pressure and over extended durations. The presence of such a fold in an otherwise brittle-deformation-dominated environment suggests that localized stress—possibly due to movements along the Narmada Rift—allowed some layers to deform plastically.

- Possible Algal Fossil Impressions: Another unusual feature we encountered was a set of wavy, ripple-like markings on a rock surface. Unlike typical ripple marks, these indentations lacked symmetrical patterns and instead had a more irregular, lumpy distribution. After detailed discussion, we hypothesized that these could be algal fossil impressions, possibly remnants of ancient stromatolitic structures that formed in a swampy environment within the Lameta Formation.

- Fault-Bend Fold and Right-Lateral Faulting: Perhaps the most structurally significant observation was a minor fault accompanied by a bending of adjacent layers. This "fault-bend fold" illustrated how stress was initially accommodated through bending before breaking and lateral displacement occurred. A few meters away, we observed a small right-lateral (dextral) offset in the same layer, confirming fault movement. Measurements of the structure revealed steeply dipping fault planes with slickenlines indicative of lateral slip. The presence of this small-scale fault system provides valuable insight into the region's stress history and deformation mechanisms.

6.2 Bhedaghat (Coordinates: 23° 6' 18" N, 79° 50' 18" E)

After completing our study at Lamheta Ghat, we traveled to Bhedaghat, located about 25 km from Jabalpur. The site is famous for its Marble Rocks, towering white cliffs of metamorphosed limestone along the Narmada River, and the Dhuandhar Falls, a steep cascade known for its misty appearance. Bhedaghat provided a unique geological contrast to Lamheta Ghat, offering insights into metamorphism, igneous intrusions, and river erosion. Some geological features are:

- Marble Rocks
  Composed of metamorphosed limestone from the Vindhyan Supergroup. Formed in a shallow marine environment and later underwent metamorphism, crystallizing into white marble. The Narmada River has carved a narrow gorge through the marble, with Dhuandhar Falls eroding the landscape further.
- Basaltic Dykes
  Dark, nearly vertical igneous intrusions cutting through the white marble. Formed when magma forced its way through fractures during the Deccan Trap volcanic episode. More resistant to erosion than marble, creating rib-like structures in the landscape. Aligned mostly northwest-southeast, indicating tectonic stresses related to rifting.
- Tectonic Influence
  Bhedaghat lies along the Narmada Rift Valley (Narmada–Son Lineament), a major fault zone. Uplift or displacement along these faults exposed the marble and juxtaposed it with Deccan volcanics. The region sits on the stable Bundelkhand cratonic block, which has helped preserve features like the Marble Rocks and Balancing Rock. Even the 1997 earthquake (6.2 magnitude) caused minimal

damage, showcasing the craton’s stability.

The Dhuandhar Falls is actively eroding the gorge, as seen in fresh rock falls and scour marks. The river transports fine marble sand, gradually shaping downstream rock surfaces. Over time, the waterfall is retreating upstream, lengthening the gorge.

Figure 21: The Dhuandhar Falls

Conclusion

The detailed geological exploration around Jabalpur, Madhya Pradesh, significantly enhanced our understanding of the region's complex geological history and structural evolution. Our observations spanned a diverse array of lithologies, from sedimentary limestone deposits indicative of ancient marine and fluvial environments to basalt layers reflecting significant volcanic activities related to the Deccan Trap eruptions.

Key geological processes such as karstification in limestone, hydrothermal vein formation, and low-grade metamorphism in schist, slate, and phyllite were documented extensively across multiple outcrops. Structural analyses revealed the presence of conjugate fractures, joints, shear zones, and normal faults with associated slickensides and half-graben formations, underscoring the area's dynamic tectonic history marked by extensional forces and mild metamorphic alterations. Notable geological landmarks, such as Balancing Rock and Rani Durgawati Fort, provided insights into long-term geological stability and weathering processes shaping the region. Furthermore, sedimentological features including conglomerates and transported fossil evidence highlighted historical riverine activity and depositional environments. The data collected through systematic measurements of bedding orientations, fracture systems, and lithological assessments contributed significantly to a comprehensive geological model of the study area.

Overall, this fieldwork has provided valuable practical exposure, enhanced our geological interpretation skills, and deepened our appreciation for the intricate geological history preserved within the Jabalpur region.