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Characterization and Valorization of the Jurassic Geoheritage in the Eastern Middle Atlas: A Standardized Inventory Approach for Geosite Promotion

By Souhail Mounir[*] & Naoufal Saoud[±]

The Middle Atlas, a 500 km-long mountainous massif dominated by Jurassic carbonate formations, possesses remarkable yet vulnerable geodiversity. Despite this wealth, the absence of a systematic inventory and rigorous characterization of geological objects limits the potential for effective protection and valorization. The primary challenge of this study is to identify and qualify these entities to halt heritage degradation caused by uncoordinated territorial development and a lack of formal geoconservation strategies. The core interest of this research lies in the identification, classification, and documentation of geosites with high heritage value. The methodology is based on the approach developed in our doctoral research (2020), integrating Geographic Information Systems (GIS) and 3D modeling for precise spatial analysis. Each potential geosite underwent a multi-criteria diagnostic assessment—evaluating scientific value, educational potential, and vulnerability—to establish a robust database of detailed inventory sheets. The study successfully characterized a series of representative geosites, including karst systems, tectonic structures, and paleontological and archaeological sites. These geosites serve as the fundamental units of the regional geotourism offer and have been organized into thematic geological tours. The use of 3D modeling and descriptive sheets provides a deep understanding of the genesis and functioning of each site, ensuring a faithful representation of both tangible and intangible geoscientific heritage. The valorization of these geosites through scientific mediatization and geotourism acts as an immediate lever for socio-economic development. Ultimately, grouping these high-interest sites within a coherent perimeter justifies and supports the establishment of a UNESCO Global Geopark, ensuring sustainable management and international recognition of this exceptional heritage.

Keywords: *Geodiversity, Geo-heritage, Geotourism, Geosite, Geopark, Middle Atlas, Morocco*

Introduction

The geographical environment integrating geology, geomorphology, climatology, and socio-economics, constitutes a distinct geotouristic product. The strategic valorization of this geological heritage, through scientific dissemination, is a key driver for developing new tourist flows and fostering regional growth (Williams 2008).

The Eastern Middle Atlas, situated south of the historic city of Taza, offers a vast array of natural and cultural potentialities (Zine El Abidine 2024). Its diverse landscapes form an undeniable natural heritage that grants the region a remarkable

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identity. The study area proposed for this Geopark project exhibits significant geodiversity, providing a foundation to define, identify, and classify remarkable geological objects, grouped as "Geosites."

The exceptional characteristics of the dolomitic and limestone formations, combined with specific tectonic, geomorphological, and hydrological features, have led to the development of extensive karst networks. These include complex underground cavities such as avens, caves, and underground rivers as well as highly developed surface networks like sinkholes, dolines, and poljes (Mounir, 2020). Among these, the Tazekka dome-shaped massif stands out as the most prominent geological structure in the eastern Middle Atlas. Its unique biodiversity and geological diversity, characterized by exceptional tectonic and geochemical features, hold immense scientific and educational value.

To effectively manage and promote this complex heritage, a rigorous inventory and characterization approach was implemented, as detailed in the following methodology.

The promotion of geoheritage as a driver for territorial development is experiencing significant momentum in Morocco, supported by a growing body of academic research. While foundational studies (El Hadi et al. 2011, Errami et al. 2015) established the initial basis for national geoconservation, more recent research has shifted focus toward the specific characterization of Atlasic massifs. In the Middle Atlas, the work of Mounir 2020, Baadi et al. 2021, El Hamdi et al. 2024 and the hydro-karst analyses (Mounir et al. 2019) emphasize the complexity and exceptional value of the geological archives within the Taza region.

The concept of "Geoheritage", at the heart of this study, defines geological objects possessing remarkable scientific, educational, or aesthetic value (Brilha 2016, Mounir et al. 2021). It is no longer merely about preserving isolated sites but about integrating these "Earth archives" into a vision of sustainable development. In Morocco, this ambition is bolstered by the success of the M'Goun UNESCO Global Geopark, which serves as a model for the emergence of new geotourism hubs. Our approach aligns with this trend, utilizing modern digital tools to transform scientific knowledge into a socio-economic asset for the local populations of the Middle Atlas.

By prioritizing the identification of geosites as fundamental units, this research contributes to the national effort of documenting Morocco's "memory of the Earth." It aims to bridge the gap between pure geoscientific research and practical territorial management, ensuring that geological diversity becomes a pillar of regional identity and economic resilience.

Location and Geological Setting

The study area is located in the northern part of the Middle Atlas. It belongs to the major watersheds of Sebou and Moulouya. The region includes two national parks, Tazekka and Rass El Ma, the Bou Iblane mountain range, about 60 km from the historic city of Taza (Figure 1).

The formations of the Middle Atlas domain are composed essentially of limestone layers, tabulate in the northwest (Middle Atlas plateau) and wavy in the

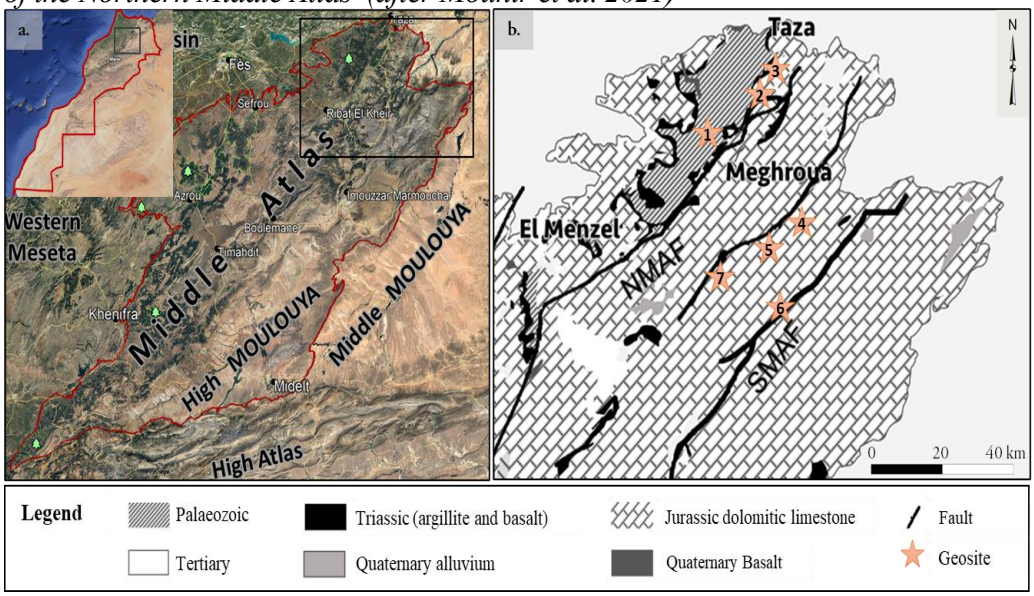
southeast (folded Middle Atlas), while they sometimes exceed 3000 meters in the eastern ridges of the folded domain.

The geomorphology of the eastern Middle Atlas illustrates a vast landscape characterized by the alternation of domes and basins following a general NE-SW orientation, thus revealing the traces of the Atlasic structuring (Mounir et al. 2019). The structural analysis of the Jurassic Atlasic demonstrates a simultaneity between synsedimentary deformations in compression and others in extension, during which the fracturing that affects the region has led to the establishment of several aquifers within the Jurassic carbonate formations (Fedan 1989, Mounir 2020). The genesis of these formations consists of the development of strong hydrothermal activity along fracture surfaces, which triggers the process of dissolution of the carbonates embedded in the Jurassic series (dolomite and limestone with flint or fossils).

In the eastern Middle Atlas, the Tazekka dome-shaped massif (1986 m above sea level), separates a border of plateaus and a folded chain with a NE-SW orientation (Charrière 1990, Charroud 1990, Frizon de Lamotte et al. 2008, Sabaoui 1998). The buttonhole is composed of metamorphic Paleozoic rocks (schist, shales, quartz sandstone).

The study area presents an important geological interest, notably due to the presence of Jurassic carbonate formations that have led to the establishment of several aquifers. The Tazekka massif constitutes a remarkable geomorphological element that deserves to be studied in detail.

Figure 1. *a. Map of Morocco and Location Map of the Study Area. b. Geological Map of the Northern Middle Atlas (after Mounir et al. 2021)*



Methodology

This work aims to valorize the identified geological heritage of the Middle Atlas. The objective is to promote this territory within a national strategic framework of geoconservation, education, and sustainable development (UNESCO 2012; Newsome &Dowling 2018). This approach aligns directly with the priorities of the Moroccan Tourism Roadmap 2023-2026 regarding the development of innovative tourism products and the responsible management of natural sites, while offering new socio-cultural perspectives for the region (OCDE 2024).

The establishment of geosites and geoparks ensures a faithful representation of a region's tangible and intangible wealth from a geoscientific perspective. These initiatives will foster the emergence of new forms of alternative tourism, a modern trend that actively contributes to the socio-economic development of territories.

Through rigorous field investigations and extensive data collection conducted across the Middle Atlas, a set of potential geosites featuring diverse geological characteristics has been identified. These sites are complemented by other attractions of biotic, archaeological, and cultural interest, thereby strengthening the multidisciplinary dimension of the regional heritage.

To structure these results, the site selection and qualification process was based on the methodological approach developed within the framework of our doctoral research (Mounir 2020). This method relies on a precise characterization of scientific and educational values, as well as a vulnerability analysis of the inventoried geological features. Each potential geosite is documented by a detailed inventory sheet, enhanced by 3D plans and models generated via Geographic Information Systems (GIS). These supports consolidate all descriptive, spatial, and justificatory data required to support the relevance and future management of this heritage within the Geopark project.

Tazekka Geosite

The geosite of Tazekka is a dome-shaped inlier that separates a border of karsts and a folded chain with NE-SW orientation. It is located near the Bab Louta dam (Figure 2.a), which offers the public a panoramic view of the vegetation cover of the Tazekka National Park (Mounir et al. 2019).

The geosite also provides a pedagogical opportunity to observe a stratigraphic log that extends from Miocene molasses, Jurassic carbonates, Triassic clays and basalts to the metamorphic Paleozoic formations of the inlier.

The Tazekka massif (1986 m above sea level) is composed mainly of Ordovician schists traversed by quartzite strata and siliceous veins (Martin 1977, Tennevin 1978, Mounir 2020). The Paleozoic basement outcrops to the west and northwest of the village of Bab Boudir (Figure 2.c), which belongs to the Tazekka inlier. This basement is associated with Sb and Pb mineralizations related to the emplacement of Hercynian granitoids and the uplift of the anticlinal massif. The paleontological character of the geosite is represented by fields of ammonites of Domerian age (Gardet & Gérard 1946), located near the mouflon reserve (Figure 2.b.d).

Figure 2. *The Geosite of Tazekka. a. Panoramic View on the Reliefs of the Eastern Middle Atlas and the dam of Bab Louta. b. The Station of the Deer Valley. c. The Black Shales in Crenulation. d. The Ammonite Field*

Ifriouatou Geosite

The Ifriouatou sinkhole, with a depth of 271 meters (Figure 3.a), is considered to be the deepest sinkhole in the region. The resurgences of surface waters in the eastern Middle Atlas are closely linked to fracture networks characteristic of the upper structural style (Mounir et al. 2019).

This is an impressive example of the geomorphosites of North Africa, with a wide diversity of karst forms (avens, caves, sinkholes, dolines, poljes, ponors, underground rivers, or paleokarstic depressions) represented by a subterranean linear feature of 3,500 meters or more in length, since the cave is the outlet of an underground river (Figure 3.b-c).

Figure 3. *a. The Entrance to the Ifriouatou Chasm. b. The Underground Karst Forms of Ifrouatou. c. The Vast Cavities formed in the Cave Circuit*

Chiker Geosite

The Chiker sinkhole (-146 meters) with a length of 3,856 meters, presents the most attractive karst for experienced speleologists (Figure 4.a-b-c). It collects the waters of the Daya Chiker, especially during flood periods, which continue to shape several networks of well-developed underground and surface cavities (avens, caves, sinkholes, dolines, poljes, and underground rivers) (Figure 4.d-e).

The geodiversity and richness of the Jurassic limestone formations make it an important water reservoir in the eastern Middle Atlas (Ek & Mathieu 1964). The karstification process is active in areas of rock weakness, particularly at the intersection of synthetic and antithetic faults (nodes), where the dissolution of carbonates by water is oriented, using the geometrical arrangement of the pre-existing fractures.

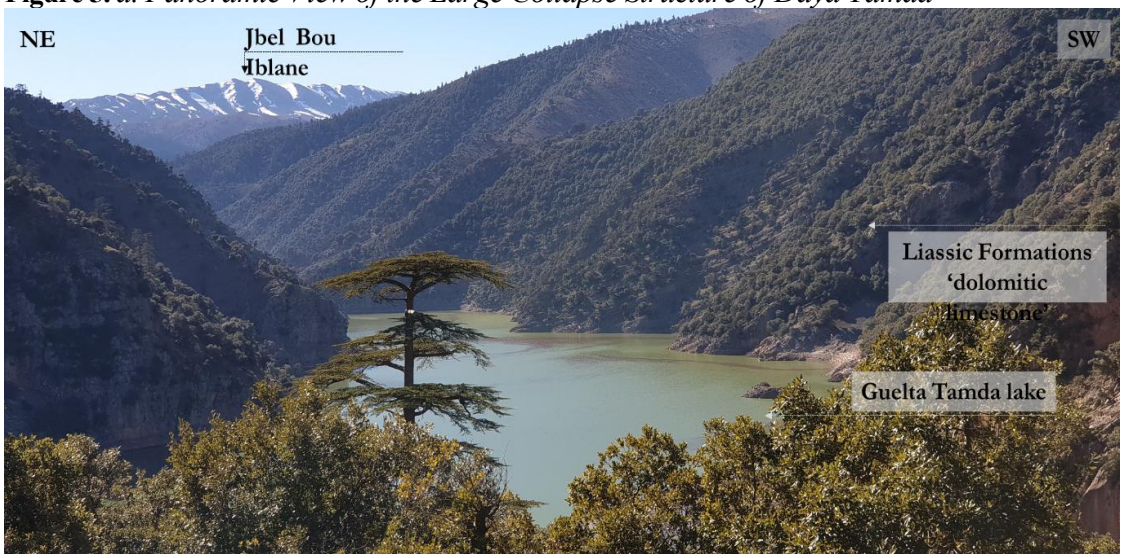
Guelta Tamda Geosite

The Guelta Tamda geosite is located in the Liassic formations, which are composed mainly of dolomite limestone that rests on Triassic clays in the eastern part of the folded Middle Atlas (Figure 5). It is an immense tectonic-karst collapse of more than

2,000 hectares (more than 100 hectares of floodable area), surrounded by accentuated reliefs (2,000 meters above sea level) covered with forests of green oak and cedar (El Fellah 1994). The natural dam of Guelta Tamda is listed as a site of biological and ecological interest, as it is home to a very abundant diversity of fauna and flora.

Figure 4. *The Chiker Basin during Floods, feeding the Karst. b. The Entrance to Chiker Sinkhole using Stairs. c. The Speleologists Team in search of other Entrances to Caves and training for Amateurs. d-e. The Karstic Structures of the Dayet Chiker Chasms*

Figure 5. *a. Panoramic View of the Large Collapse Structure of Daya Tamda*



Oued El Bared Geosite

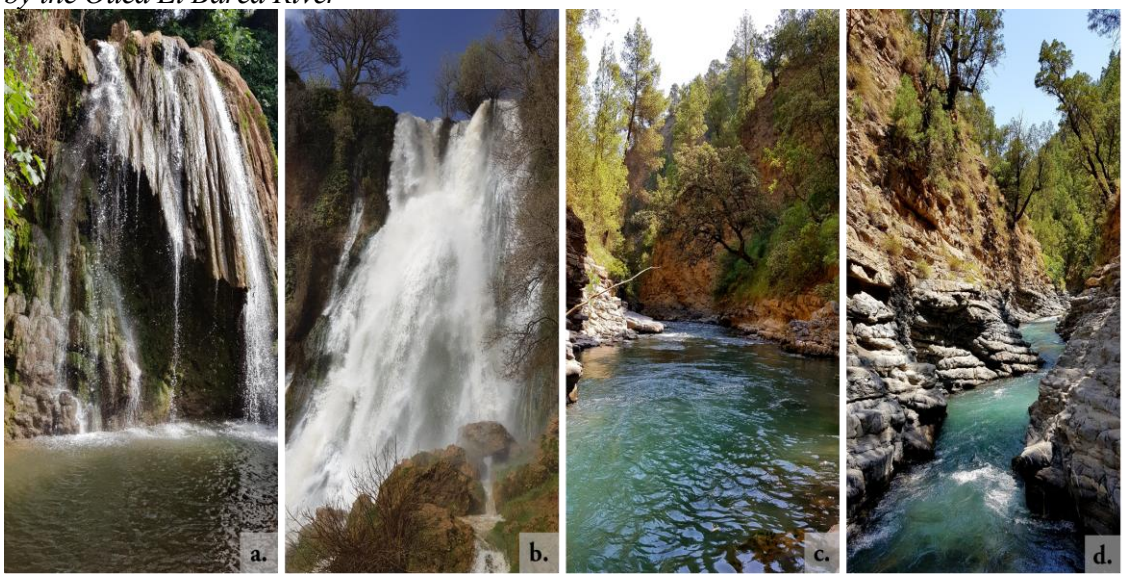
The eastern part of the Middle Atlas has numerous intermittent and perennial watercourses, due to the high rainfall that exceeds 1200mm at Bab Bou Idir and 350mm at Meghraoua, generating rapid runoff and significant hydrological activity (Figure 6-a.b.c.d).

The Oued El Bared linear feature (more than 5 m3/s) represents a striking example of the river hiking trails network, emerging from a cave, several waterfalls, and sparkling gorges (Taous et al. 2009, Mounir et al. 2016, Mounir et al. 2019).

This geosite is of great interest for its geomorphological and ecological features. The river has carved a deep and narrow gorge through the limestone bedrock, creating a spectacular landscape. The gorges are home to a variety of plants and animals, including several species of birds, mammals, and reptiles. The site is also a popular destination for hiking and camping.

The Oued El Bared geosite is a valuable asset for the region. It provides a unique opportunity to learn about the natural history of the Middle Atlas and to enjoy the beauty of the Moroccan countryside.

Figure 6. *The Karstic and Landscape Forms (springs, waterfalls and gorges) shaped by the Oued El Bared River*



Bou Iblane Geosite

The anticlinal structure is affected by two major faults with steep dips (70°) and directions oriented from N50 to N70, belonging to the South Middle Atlas Fault (SMAF), with a small overlap of the fold towards the NW (Sabaoui 1998, Charroud 2002). The NW compartments of the chain are represented by blackish dolomitic slabs and reefal marno-limestones of the Lower Lias, and are represented to the SE by Liassic limestones with Toarcian marls.

The Jbel Bou Iblane is a popular destination for hikers and cavers. It is the second highest peak in the Middle Atlas, with an elevation of over 2,980 meters at Jbel Tanout and 2,920 meters at Jbel Bou Iblane (Figure 7).

Taffert Géosite

The turbulent waters of the Oued Zloul gorges are undoubtedly among the best rafting routes in the Atlas Mountains. The valley receives rainwater and snowmelt, which it then drains into the main waterways. This drainage has shaped a perfect geomorphological expression of the ultimate stage of karst evolution (Figure 8).

The gorges are also home to exceptional geological characteristics, including rock and reef formations of scientific value. These characteristics include tectonic, geomorphological, and hydrological features.

Figure 7. *a. The Dolomitic and Marlstone Structures of the Lower Lias 'Bou Iblane Massif'*

Figure 8. *The Tectonic-sedimentary Structures of the Taffert Geosite. a. Waterfalls and Gorges of Iouchache. b.The Tamjghyoult Gorges. c. El Jider Canyons*

Forms for inventoried Geosites

<table>
<tr><th colspan="2">Identification</th></tr>
<tr><th colspan="2">Geosite: Tazekka</th></tr>
<tr><td>Serial number: GEO 01</td><td>Typology: Geologic (Natural surface site)</td></tr>
<tr><th>Location</th><th>Itinerary</th></tr>
<tr><td>Administrative province: Taza</td><td rowspan="9"> 
</td></tr>
<tr><td>Location: 30 km SW of the city of Taza (Eastern Middle Atlas)</td></tr>
<tr><td>Cartographic references: Topographic map of Taza (1/50.000)</td></tr>
<tr><td>coordinates: 34° 03’ 42" N / -04° 07’ 22"W</td></tr>
<tr><th>Terms and conditions of access</th></tr>
<tr><td>Legal protection: Protected area, such as a natural site within Tazekka National Park.</td></tr>
<tr><td>Accessibilité: the geosite is less than 100 m from the P5420 provincial road.</td></tr>
<tr><td>Observation conditions: Visible from a distance</td></tr>
<tr><th colspan="2">Site description</th></tr>
<tr><td colspan="2">Geological description: The Tazekka massif is part of the eastern inliers of the Middle Atlas, separating the edges of the folded and eastern tabular domains. The Paleozoic terrains of the eastern Middle Atlas form an inlier composed of several series ranging from the Cambrian to the Carboniferous. This dome, rising above 1980 m in altitude, is characterized across most of its area by metamorphosed Paleozoic series of green to purplish and wine-red schists, mudstones, and Ordovician quartzitic sandstones. The geosite offers several observation points for Sb and Pb mineralizations related to the emplacement of Hercynian granitoids and the uplift of the Tazekka massif.</td></tr>
<tr><th colspan="2">Additional interest</th></tr>
<tr><td colspan="2">Variety of geological features: Internal geodynamics, Metamorphism, Plutonism, Structural geology, Geomorphology (karst), Sedimentology and landscape</td></tr>
<tr><td colspan="2">Rarity: National</td></tr>
<tr><td colspan="2">Utility: Geosite of scientific, educational and geotourism interest</td></tr>
<tr><td colspan="2">Fragility and vulnerability: No anthropic or natural threats detected</td></tr>
<tr><th colspan="2">3D model description</th></tr>
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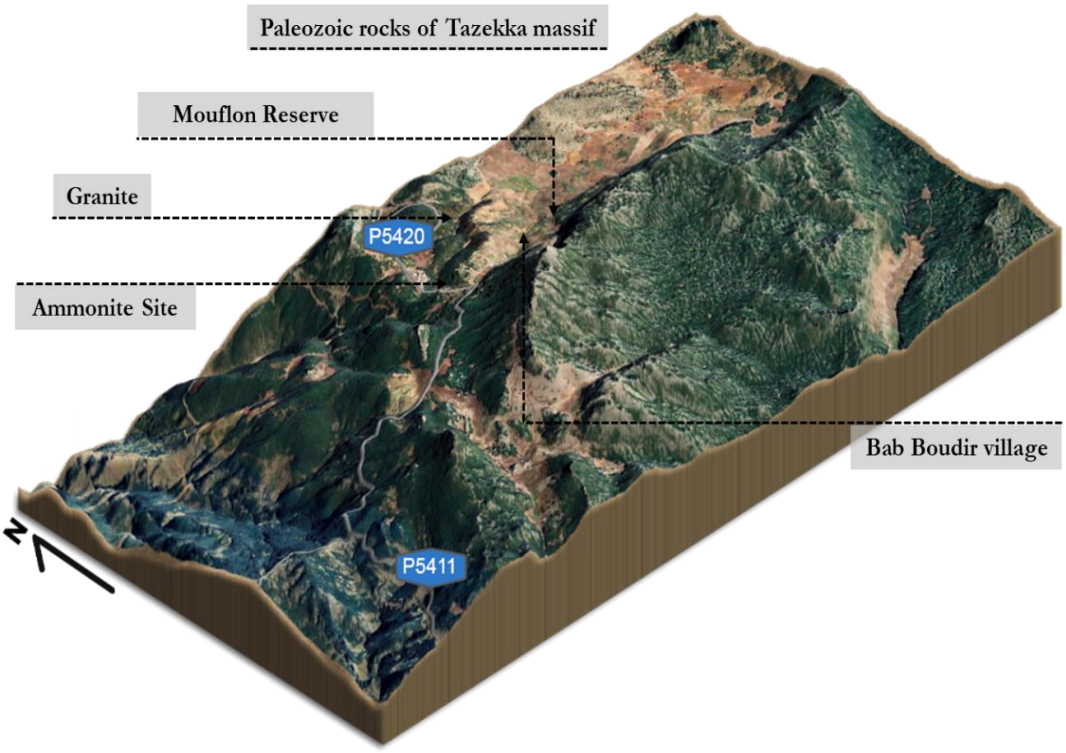
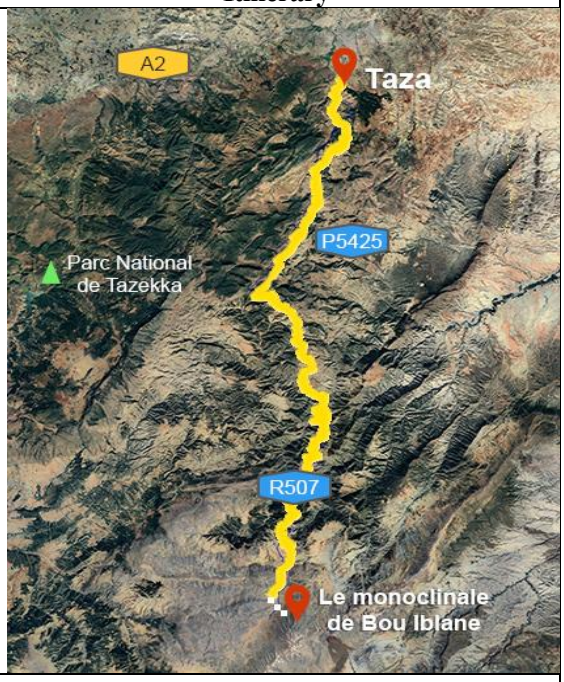
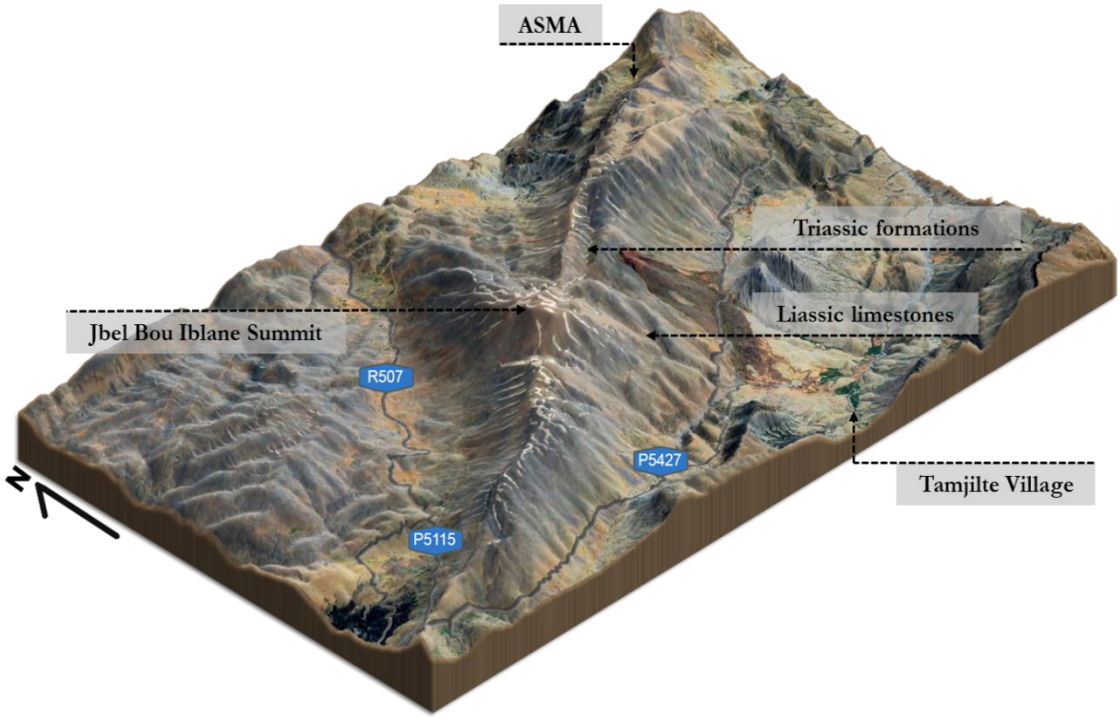


Identification	
Geosite: Bon Iblane	
Serial number: GEO 02	**Typology**: Geological (Structural) and geomorphological
Location	**Itinerary**
Administrative province: Sefrou, Taza	
Location: NE of Imouzzer Marmoucha, 100 km from Taza on the R507 national road (Central Middle Atlas)	
Cartographic references: Topographic map of Ribat El Kheir (1/100.000)	
coordinates: 33° 41' 30''N / -04° 03' 40''W	
Terms and conditions of access	
Legal protection: Area protected as a Site of Biological and Ecological Interest (SIBE), Taffert Park (Refuge).	
Accessibilité: the geosite is less than 100 m from the R507 regional road.	
Observation conditions: visible from a distance	
Site description	

Geological description: The folded Middle Atlas is characterized by brittle and flexible tectonics, in the form of east-west faulted folds corresponding to anticlinal ridges, including the Bou Iblane ridge, which delimits the Taffert and El Mers basins to the northwest and the Berkine and Imouzzar Marmoucha basins to the southwest. The anticlinal structure is affected by two major faults with a steep dip (70°) and orientations of N50° to N70°, belonging to the ASMA (Agglomeration of the Middle Atlas Massif), with a small overthrust of the ridge towards the northwest. This is the second highest mountain range in the Middle Atlas, culminating at over 2980m at Jbel Tanout and 2920m at Jbel Bou Iblane. The northwest compartments of the range are represented by blackish dolomitic slabs and marly limestones of Lower Liassic reef origin, and the southeast compartments by Liassic limestones with Toarcian marls.
Additional interest
Variety of geological features: Structural, Sedimentological, Paleontological and Landscape
Rarity: National
Utility: Geosite of scientific, geotourism (hiking) and educational interest
Fragility and vulnerability: Soil degradation due to water erosion
3D model description



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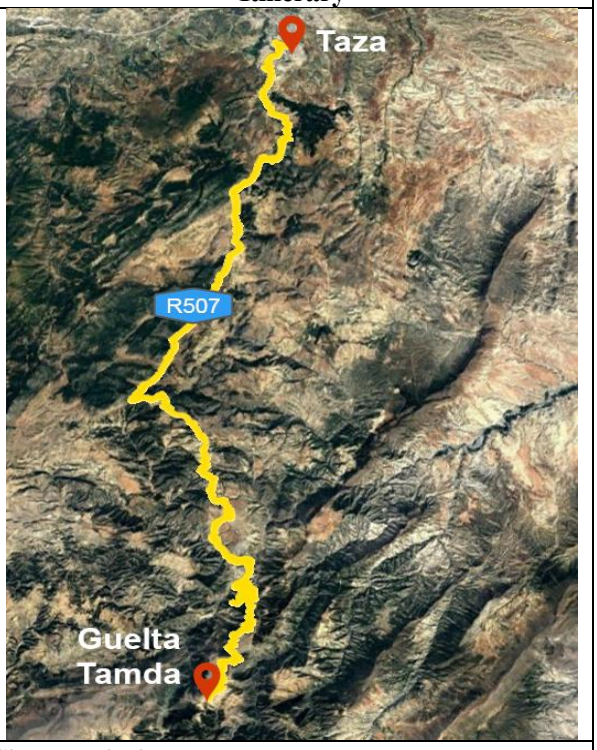
<tr><td>Serial number: GEO 03</td><td>Typology : Hydrologic (Natural surface site)</td></tr>
<tr><th>Location</th><th>Itinerary</th></tr>
<tr><td>Administrative province: Taza</td><td rowspan="8"> 
</td></tr>
<tr><td>Location: 28 km Sud of Maghraoua village on the R507 regional road linking the city of Taza and Jbel Bouiblane (Eastern Middle Atlas)</td></tr>
<tr><td>Cartographic references: Topographic map of Maghrawa (1/50.000)</td></tr>
<tr><td>coordinates: 33° 49’ 02" N / -04° 04’ 53"W</td></tr>
<tr><th>Terms and conditions of access</th></tr>
<tr><td>Legal protection: Protected area, such as a Site of Biological and Ecological Interest (SIBE).</td></tr>
<tr><td>Accessibilité: The geosite is 5km (on a hiking trail) from the R507 regional road.</td></tr>
<tr><td>Observation conditions: visible from a distance</td></tr>
<tr><th colspan="2">Site description</th></tr>
<tr><td colspan="2">Geological description: The Guelta Tamda geosite lies within the Liassic formations, primarily composed of dolomitic limestone resting on the Triassic claystones of the eastern part of the folded Middle Atlas Mountains. It is a vast tectono-karstic collapse covering more than 2,000 hectares (plus an additional 100 hectares of floodplain), surrounded by steep terrain (reaching 2,000 meters in altitude) covered with holm oak and cedar forests. The natural dam of Guelta Tamda is designated as a site of biological and ecological importance, given its abundant faunal and floral diversity.</td></tr>
<tr><th colspan="2">Additional interest</th></tr>
<tr><td colspan="2">Variety of geological features: Hydrology, karst system, structural and landscape</td></tr>
<tr><td colspan="2">Rarity: National</td></tr>
<tr><td colspan="2">Utility: Geosite of scientific, educational and geotourism (Hiking) interest</td></tr>
<tr><td colspan="2">Fragility and vulnerability: Some traces of degradation from natural erosive activity</td></tr>
<tr><th colspan="2">3D model description</th></tr>
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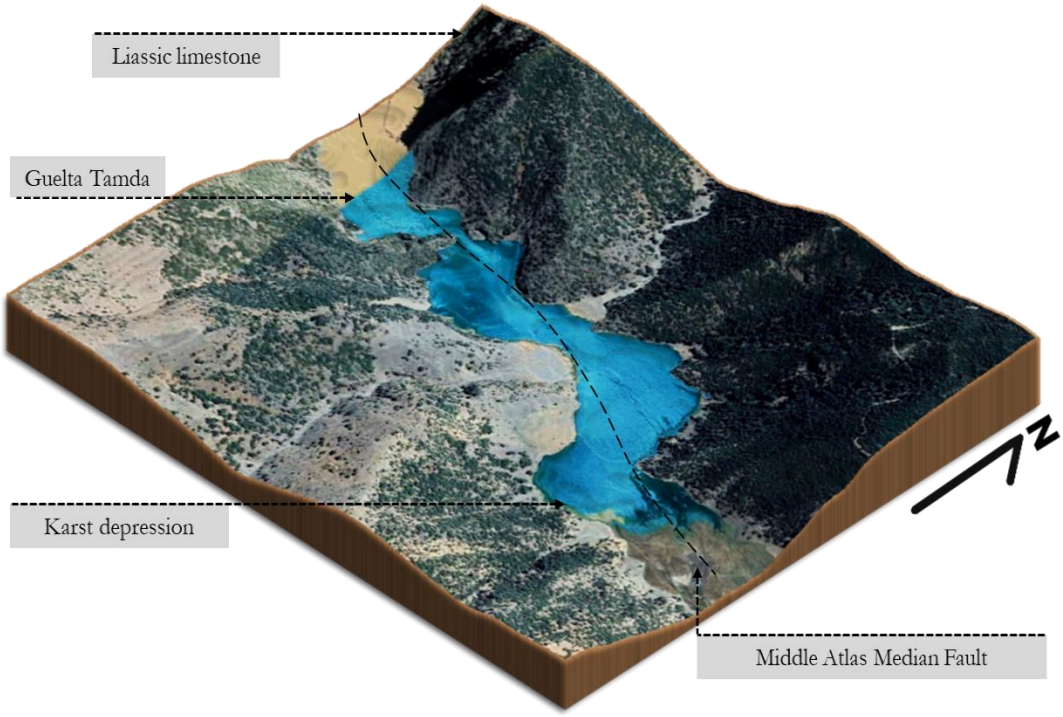
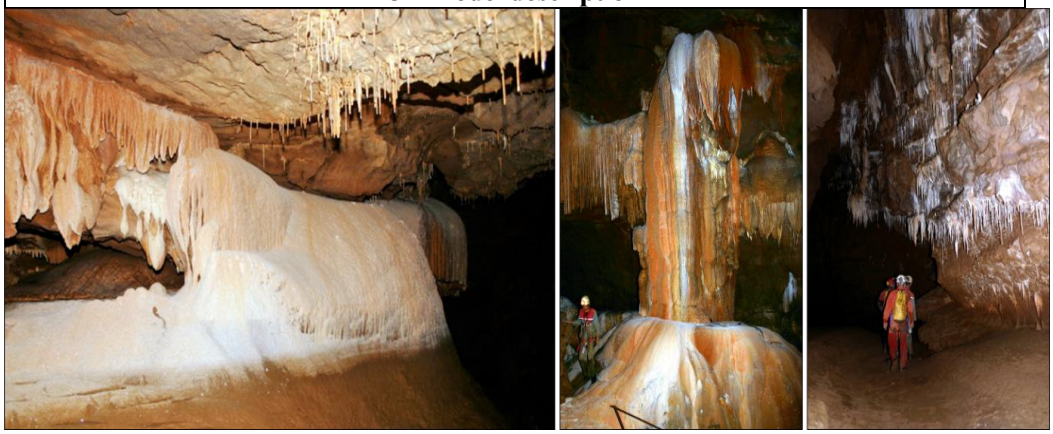


Identification	
Geosite: The Chiker Cave	
Serial number: GEO 04	**Typology**: Karst (Linear, Underground)
Location	**Itinerary**
Administrative province: Taza	
Location: 20 km Sud of the city of Taza (Eastern Middle Atlas)	
Cartographic references: Topographic map of Taza (1/50.000)	
coordinates: 34° 06' 04" N / -04° 03' 01" W	
Terms and conditions of access	
Legal protection: Protected area, such as a natural site within Tazekka National Park.	
Accessibilité: the geosite is less than 100 m from the P5420 provincial road.	
Observation conditions: Limited visibility (Underground site)	

Site description
Geological description: The Chiker Chasm (-146m), with a length of 3856m, presents the most attractive karst landscape for experienced speleologists. It collects the waters of the Daya Chiker, especially during periods of flooding, which continue to shape several extensive networks of underground and surface cavities (sinkholes, caves, chasms, dolines, poljes, and underground rivers). The geodiversity and richness of the Jurassic limestone formations constitute a significant water reservoir in the eastern Middle Atlas, acting on areas of rock weakness, particularly at the intersection of synthetic and antithetic faults (nodes), where the dissolution of carbonates by water occurs in a directed manner, utilizing the geometric pattern of pre-existing fractures.
Additional interest
Variety of geological features: Geomorphology, karst system, structural and landscape
Rarity: National
Utility: Geosite of scientific, educational and geotourism (Hiking) interest
Fragility and vulnerability: Threat of excessive tourism exploitation (Uncontrolled)
3D model description



<table>
<tr><th colspan="2">Identification</th></tr>
<tr><td colspan="2">Geosite: Ifri Ouatou Chasm (Wind Chasm)</td></tr>
<tr><td>Serial number: GEO 05</td><td>Typology: Karst (Linear, Underground)</td></tr>
<tr><td>Location</td><td>Itinerary</td></tr>
<tr><td>Administrative province: Taza</td><td rowspan="8"> 
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<tr><td>Location: 24 km Sud of the city of Taza (Eastern Middle Atlas)</td></tr>
<tr><td>Cartographic references: Topographic map of Taza (1/50.000)</td></tr>
<tr><td>coordinates: 34° 06' 17"N / -04° 04' 21"W</td></tr>
<tr><td>Terms and conditions of access</td></tr>
<tr><td>Legal protection: Protected area, such as a natural site within Tazekka National Park.</td></tr>
<tr><td>Accessibilité: the geosite is less than 100 m from the P5420 provincial road.</td></tr>
<tr><td>Observation conditions: Limited visibility (Underground site)</td></tr>
<tr><th colspan="2">Site description</th></tr>
<tr><td colspan="2">Geological description: The Ifri Ouatou chasm, at -271 m, is considered the deepest chasm in the region. It is an impressive example of North African geomorphosites, due to the great diversity of karst landforms (sinkholes, caves, sinkholes, dolines, poljes, ponors, underground rivers, and paleokarstic depressions) represented by an underground lineament 3,500 m or more in length, as the cave is the outlet of an underground river. The resurgence of surface water in the eastern Middle Atlas is closely linked to the fracture networks characteristic of the upper structural style. The geomorphology of the Middle Atlas is a landscape shaped by groundwater and surface water in Jurassic carbonate terrains, folded and fractured during the Atlas orogeny. This is a domain structured by a succession of synclinal basins separated by fractured anticlinal ridges with a general NE-SW orientation.</td></tr>
<tr><th colspan="2">Additional interest</th></tr>
<tr><td colspan="2">Variety of geological features: Geomorphology, karst system, structural and landscape</td></tr>
<tr><td colspan="2">Rarity: National</td></tr>
<tr><td colspan="2">Utility: Geosite of scientific, educational and geotourism (Hiking) interest</td></tr>
<tr><td colspan="2">Fragility and vulnerability: Threat of excessive tourism exploitation, and some traces of degradation from natural erosive activity</td></tr>
<tr><th colspan="2">3D model description</th></tr>
</table>

Discussion

The elements of geodiversity identified in the Middle Atlas possess a wide spectrum of values, ranging from material (economic, functional, scientific, and educational) to immaterial (intrinsic, cultural, and aesthetic) (Gray, 2013). While visiting areas of exceptional natural beauty is a long-standing practice, geotourism as a formal discipline is centered on leveraging geoheritage to achieve sustainable preservation through education and public engagement (Stoffelen and Vanneste, 2015; Brilha, 2016).

In the specific context of the Middle Atlas, our results highlight several networks of sites with diverse characteristics. These findings align with recent efforts to establish quality labels that guarantee the qualification of the regional offer and promote the dissemination of geotourism (Mounir et al., 2019; Mounir, 2020; Baadi et al., 2021).

This conceptual framework introduces innovative practices and tools—such as the 3D modeling and GIS databases developed in this study—focused on the discovery of territorial heritage resources. This is particularly relevant given that educational institutions and the scientific community in the Fes-Meknes region are increasingly seeking sites that combine high scientific and pedagogical value with practical accessibility. The detailed inventory and spatial representation provided in this work directly address these needs, offering a concrete platform for both academic field trips and sustainable tourism development.

Conclusion

The geological heritage of the Atlas regions currently faces significant threats, including vandalism, the unregulated trade of fossils, and a lack of local awareness regarding the intrinsic value of these Earth archives. Furthermore, uncoordinated territorial development over the last decade has accelerated the degradation of these unique sites.

The diverse geosite elements identified in this study are the result of the complex geological evolution of the Middle Atlas from the Mesozoic to the Quaternary. To safeguard this heritage, we propose to highlight these riches through scientific mediatization and their promotion as a high-quality "Geotourism" product. Our ultimate goal is the establishment of a UNESCO Global Geopark in the Eastern Middle Atlas. Such a framework would provide the necessary scientific and pedagogical structure to assist students, researchers, and the general public in deciphering the history of the Earth as recorded in the Middle Atlas.

In this context, the creation of museum spaces is essential to valorize geoscientific data and meet the demands of natural resource management, territorial planning, and geohazard mitigation. These spaces will serve as concrete levers for regional development. Significant milestones in this direction include the museum inaugurated by geologists from the Faculty of Sciences and Technology of Fez (2013), the Cultural and Natural Heritage Exhibition in Azrou (2016), and the Great Science Museum of the Fez-Meknes region, currently under construction.

By integrating modern tools such as the GIS-based 3D modeling and detailed inventory sheets developed in our doctoral research (2020), this project provides a robust technical foundation for the sustainable management and international recognition of the Middle Atlas heritage.

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