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GEOHERITAGE VALUE AND CONSERVATION POTENTIAL OF GEBEL EL DIST, BAHARIYA OASIS, EGYPT: A PRELIMINARY ASSESSMENT

Gebel El Dist, located in the Bahariya Oasis, represents the type locality of the lower Cenomanian Bahariya Formation in the Western Desert of Egypt, and it serves as one of the most significant vertebrate-bearing localities in ancient Gondwana. This study integrates lithostratigraphy and sedimentological characteristics of Gebel El Dist, identifying a transition from fluvial-dominated systems to tide-influenced mangrove swamps. Sedimentological analysis revealed a sequence of glauconitic sand-silt-clay, carbonaceous shale, and cross-bedded sandstones, with a unique vertebrate assembly. In addition, the continental siliciclastic sediments of the Bahariya Formation in Gebel El Dist provide significant clues on mid-Cretaceous paleoclimate, which was characterized by humid tropical conditions and high sea-level fluctuations. The combination of its type locality, its role in the Syrian Arc tectonic history, and its iconic paleontological record qualifies Gebel El Dist to be a world-class geosite of global geoconservation significance. Urgent protective measures are recommended to mitigate the risks of illegal rock sampling, fossil extraction, and unregulated tourism.

Keywords: Gebel El Dist, geoheritage, conservation, geotourism, Bahariya Oasis.

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Мысыр, Бахария оазисіндегі Гебель-эль-Дисттің геомұралық құндылығы және оны сақтаудың әлеуеті: алдын ала бағалау

Батыс Мысыр шөліндегі Бахария оазисінде орналасқан Гебель-эль-Дист төменгі сеномандық Бахария формациясының типтік қимасы болып табылады және ежелгі Гондвана аумағындағы омыртқалы жануарлардың маңызды қазба қалдықтары шоғырланған нысандардың бірі саналады. Зерттеудің мақсаты – Гебель-эль-Дист аумағының литостратиграфиялық және седиментологиялық ерекшеліктерін талдау, сондай-ақ оның геомұралық және геоконсервациялық құндылығын бағалау. Зерттеу барысында шөгінді түзілу ортасының өзендік жүйелер басым жағдайдан толысу-қайту үдерістері әсер еткен мангрлік батпақты ортаға ауысқаны анықталды. Седиментологиялық талдау глауконитті құмды-алевритті-сазды қабаттардың, органикалық заттарға бай көміртекті тактатастардың және қиғаш қабатталған құмтастардың реттілігін көрсетті. Бұл шөгінділер омыртқалы жануарлардың бірегей фауналық кешенін қамтиды. Гебель-эль-Дисттегі Бахария формациясының континенттік терригендік шөгінділері орта бор дәуіріндегі палеоклиматты сипаттауға мүмкіндік береді: бұл кезең ылғалды тропиктік жағдайлармен және теңіз деңгейінің едәуір ауытқуларымен ерекшеленген. Нысанның типтік қима ретіндегі мәртебесі, Сириан доғасының тектоникалық тарихындағы рөлі және палеонтологиялық мұрасы оны жаһандық маңызы бар геосайт ретінде бағалауға негіз болады. Заңсыз тау жыныстарын жинау, қазба қалдықтарын алу және реттелмейтін туризм қатерлерін төмендету үшін шұғыл қорғау шараларын енгізу ұсынылады.

Түйін сөздер: Гебель-эль-Дист, геомұра, қорғау, геотуризм, Бахария оазисі.

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Геонаследственная ценность и потенциал сохранения Гебель-эль-Диста, оазис Бахария, Египет: предварительная оценка

Гебель-эль-Дист, расположенный в оазисе Бахария в Западной пустыне Египта, является типовым разрезом бахарийской формации нижнесеноманского возраста и одним из наиболее значимых местонахождений остатков позвоночных животных древней Гондваны. Цель настоящего

исследования заключается в комплексном рассмотрении литостратиграфических и седиментологических особенностей данного участка, а также в оценке его научной, палеонтологической и геоконсервационной значимости. Результаты исследования свидетельствуют о последовательной смене условий осадконакопления: от преимущественно речных систем к мангровым болотам, формировавшимся под заметным воздействием приливно-отливных процессов. Седиментологический анализ позволил установить разрез, представленный глауконитовыми песчано-алевритово-глинистыми отложениями, углеродистыми сланцами и песчаниками с косой слоистостью. Указанные породы содержат уникальный комплекс ископаемых позвоночных, имеющий особое значение для реконструкции палеогеографических и палеоэкологических условий среднего мела. Континентальные терригенные отложения бахарийской формации в районе Гебель-эль-Диста также предоставляют важные данные о палеоклимате, который характеризовался влажными тропическими условиями, активным развитием прибрежных экосистем и существенными колебаниями уровня моря. Статус типового местонахождения, роль объекта в тектонической истории Сирийской дуги и его исключительная палеонтологическая летопись позволяют отнести Гебель-эль-Дист к геосайтам мирового значения. Для сохранения данного геологического наследия необходимы срочные меры по защите территории от незаконного отбора горных пород, извлечения ископаемых остатков и нерегулируемого туризма.

Ключевые слова: Гебель-эль-Дист, геонаследие, охрана, геотуризм, оазис Бахария.

Introduction

Egypt's geosites represent critical geological archives of the Tethyan margin, providing high-resolution data for the reconstruction of the Mesozoic-Cenozoic history of the Afro-Arabian plate (Al-Dhwadi and Sallam, 2019; Ruban et al., 2019; Mashaal et al., 2020; Abd-Elhakim et al., 2021; Ruban et al., 2021; Mashaal and Sallam, 2023; Mousa et al., 2023, 2024a, b; Errami et al., 2024; Ayoub and Sallam, 2025). These geosites are scientifically significant due to their ability to bridge gaps in global evolutionary lineages and provide evidence for large-scale environmental shifts (Plyusnina et al., 2016; Sallam and Ruban, 2017, 2019; Sallam et al., 2018a, b, c; Sallam et al., 2020a, b, 2022; Sallam and Abou-Elmagd, 2021; Sallam, 2022). The Bahariya Oasis, located in the north-central part of the Western Desert of Egypt, has long been recognized as a “window into deep past”, offering one of the world's most significant records of Late Cretaceous terrestrial life. Among its many topographical features, Gebel El Dist stands out – not only for its iconic, symmetrical “pyramidal-shape” but as a primary source of some of the most famous vertebrate fossils in paleontological history. This site remains a cornerstone for understanding the paleoecosystems of northern Africa during the Cenomanian age.

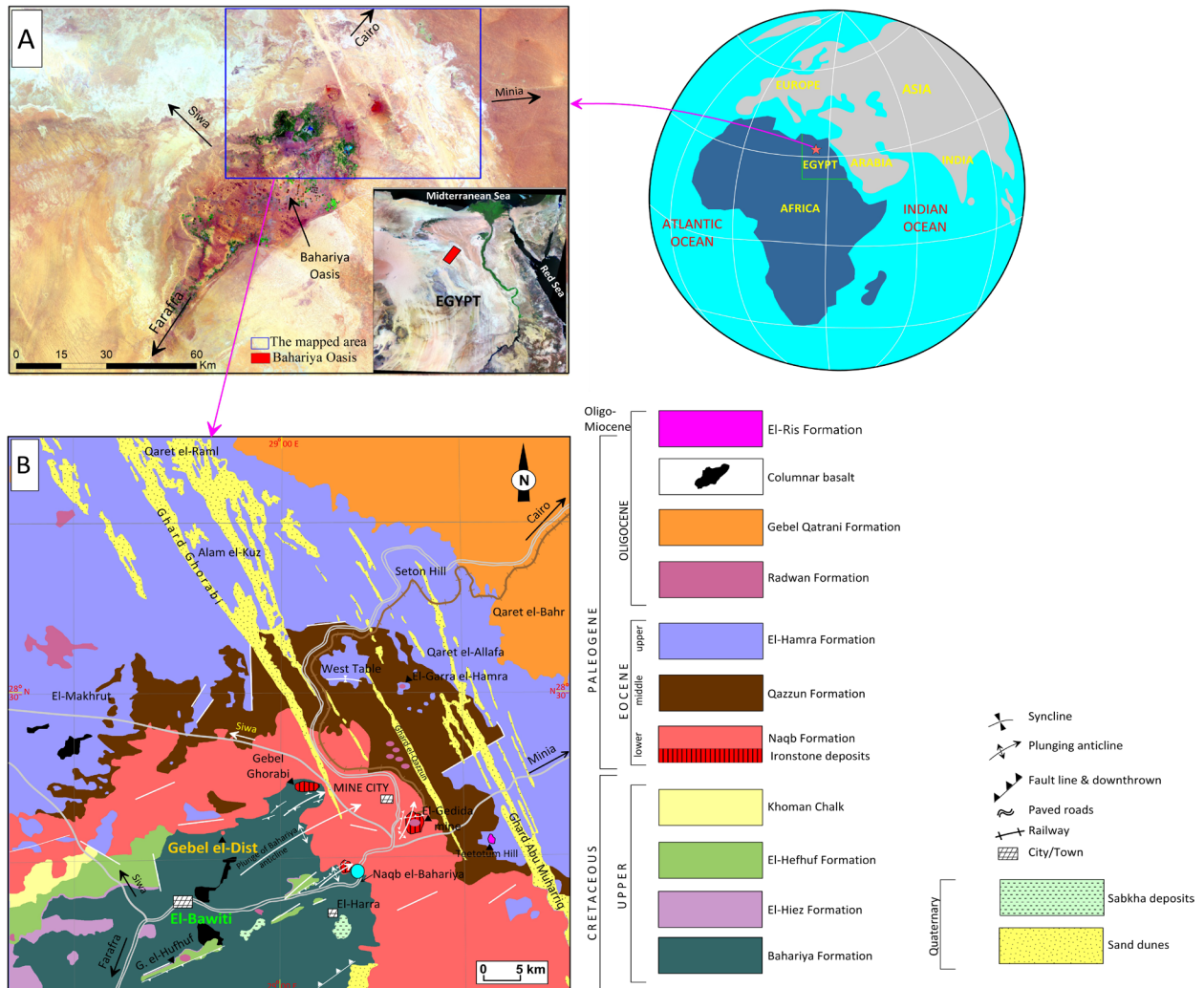
The geoheritage value of Gebel El Dist is multifaceted. Scientifically, it serves as the type locality for several iconic species discovered by Ernest Stromer in the early 20th century, documenting mid-Cretaceous giant dinosaurs and reptiles (Stromer, 1914, 1936; Said, 1962; Smith et al., 2001; Ibrahim et al., 2020; Salem et al., 2022). Stromer (1914,

1936) first introduced the term “Baharije Stufe” to describe the Cenomanian siliciclastic sediments in the floor and lower escarpments of the Bahariya Depression, highlighting fossil discoveries including dinosaur bones at Gebel El Dist, and linking the region to a fluvio-marine environment (Stromer, 1914, 1936). Stromer's detailed observations laid the groundwork for all subsequent geological studies of the Bahariya Depression. Later, Said (1962) replaced the term “Baharije Stufe” with the Bahariya Formation, whose type section is Gebel El Dist. The integration of stratigraphy, paleontology and paleogeography makes Gebel El Dist more than just a hill; it is a global geosite of exceptional preservation. Its role in the Syrian Arc folding also provides crucial data for structural geologists studying the tectonic evolution of North Africa (Moustafa et al., 2003). While its geological and paleontological riches are vast, the site lacks a formal status as a “geosite”, leaving it vulnerable to natural degradation and increasing anthropogenic pressures. The absence of structured assessment has hindered the implementation of effective conservation measures. Without a documented inventory of its features and a clear evaluation of its risks, the site remains at the mercy of unregulated fossil collection and environmental weathering.

This paper presents a preliminary assessment of the geoheritage value of Gebel El Dist. By evaluating its scientific significance and assessing its current conservation potential, this study aims to provide the necessary framework for its designation as a protected geosite. Through this assessment, we argue that Gebel El Dist is not merely a relic of the past, but a vital advantage for future education and sustainable development in Egypt.

Figure 1

A) ETM+ Landsat image of the Bahariya Depression, and B) Geological map showing the stratigraphic rock units cropping out in the northern part of the Bahariya Depression (after Said and Issawi, 1964).



Note: Compiled by the author

Geological setting

The Bahariya Depression is a large excavation in the western Eocene Plateau, formed by a combination of tectonic folding (the Syrian Arc Fold System) and subsequent extensive erosion (Moustafa et al., 2003). Gebel El Dist is the type section of the Bahariya Formation (early Cenomanian), which reaches a thickness of roughly 173 m. The Bahariya Formation is composed mainly of fluvio-marine sediments, containing abundant skeletal remains of reptiles, dinosaurs and other vertebrate fossils. In addition, the siliciclastic beds of the Bahariya Formation yielded plant remains of macro-charcoal, which give important evidence about palaeo-wild-

fires occurred repeatedly along the northern margins of Gondwana (El Atfy et al., 2019). At Gebel El Dist, the Bahariya Formation is unconformably overlain by lagoonal and shallow-marine sediments of the lower Eocene Naqb Formation (Ayoub et al., 2025 a, b). A simplified geological map showing the stratigraphy of the northern part of the Bahariya Depression is presented in Fig. 1.

Methodology

This study employs a multi-disciplinary approach that integrates sedimentary, geomorphology, stratigraphy, and paleontology with Geosite As-

assessment Model (GAM). The assessment utilizes a qualitative and semi-quantitative approach, evaluating the site based on four main criteria: scientific/educational value, geomorphological and aesthetic appeal, additional values, and vulnerability and risk assessment. Field observations and direct data collection at Gebel El Dist and literature reviews were integrated to document its physical status and scientific value.

Lithostratigraphy and sedimentary characteristics

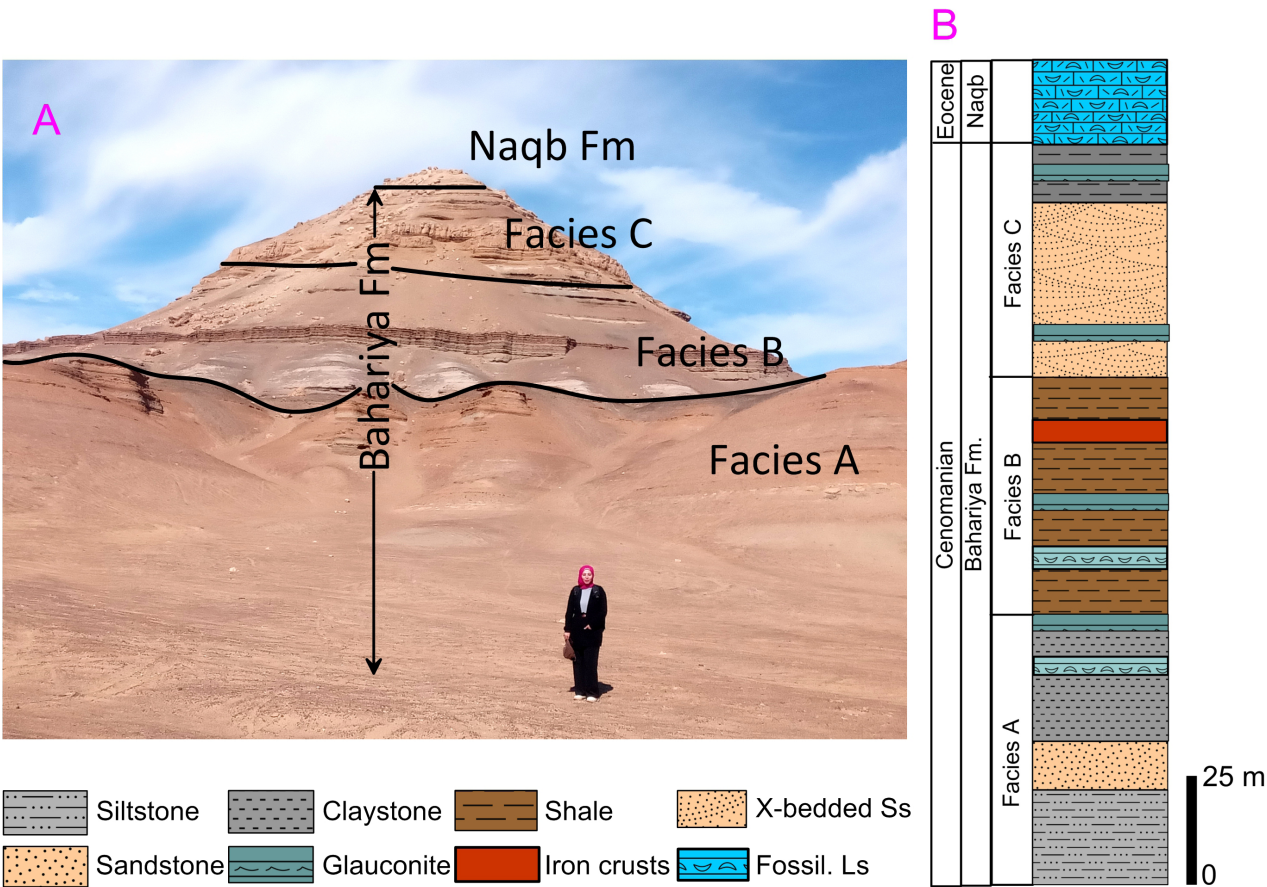
Gebel El Dist is the type locality of the lower Cenomanian Bahariya Formation. The hill exposes a thick succession of fluvio-marine sediments including coastal swamps, estuarine, and delta systems. The Bahariya Formation, forming the major part of Gebel El Dist, consists of a complex mosaic of sedimentary

facies that tell a story of fluctuating sea-level (Cătușanu et al., 2006). Sedimentological analysis of the Bahariya Formation resulted in the recognition of three main facies types (Fig. 2). The description of these facies types can be summarized as follows:

1. Facies A: Glauconitic sand-silt-clay interbeds

This facies consists of rippled very fine-grained sandstones alternating with thin layers of glauconitic siltstone and claystone (Fig. 3A, B). Flaser and lenticular bedding are common, indicating tidal flat cycles in which high-energy tides depositing fine sand, followed by slack water periods where fine mud (silt and clays) laid down. The presence of glauconite facies indicates shallow-marine tidal flats where fluvial water met the Tethys Ocean. The presence of large sauropods and fluvial cross-bedded sandstones suggests a large river system flowing from the south to the northeast.

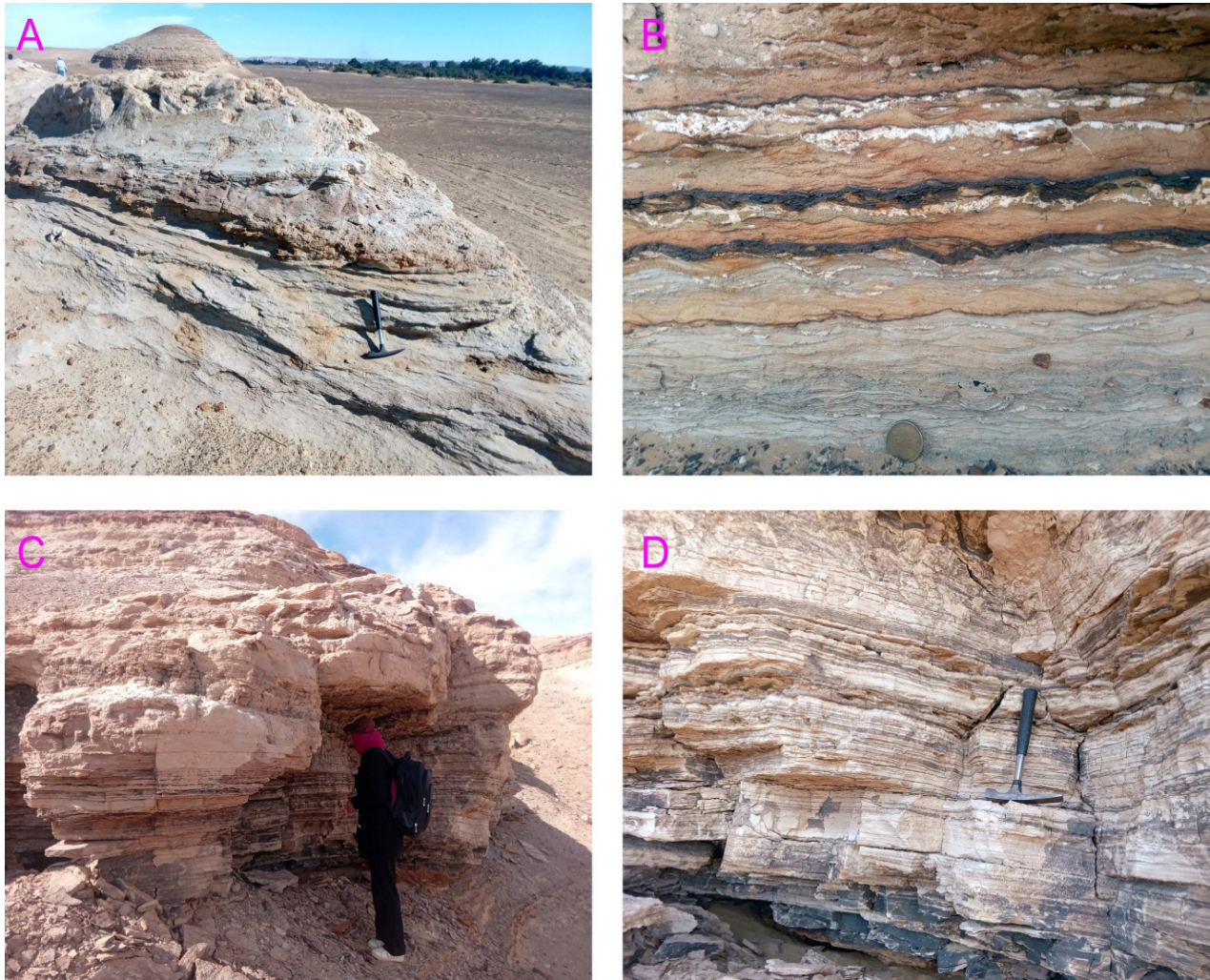
Figure 2
A) Field photograph showing the sedimentary facies of the Bahariya Formation in Gebel El Dist, and B) Columnar lithostratigraphic section of Gebel El Dist in the Bahariya Oasis.



Note: Compiled by the author

Figure 3

Field photographs of the Bahariya Formation in Gebel El Dist showing: **A, B)** Glauconitic siltstone and claystone displaying flaser and lenticular bedding, Facies A, and **C, D)** Black, organic-rich shales and laminated claystone containing leaf imprints and occasionally low-grade coal, Facies B



Note: Compiled by the author:

2. Facies B: Carbonaceous shales/claystone and fossil plant-rich mudrocks

This facies is composed of black, organic-rich shales and laminated claystone containing fossilized wood fragments, leaf imprints, and occasionally lignite (low-grade coal), indicating a mangrove-dominated coastal ecosystem and lagoons of stagnant, low-oxygen environment (Fig. 3C, D).

3. Facies C: Massive and cross-bedded sandstones

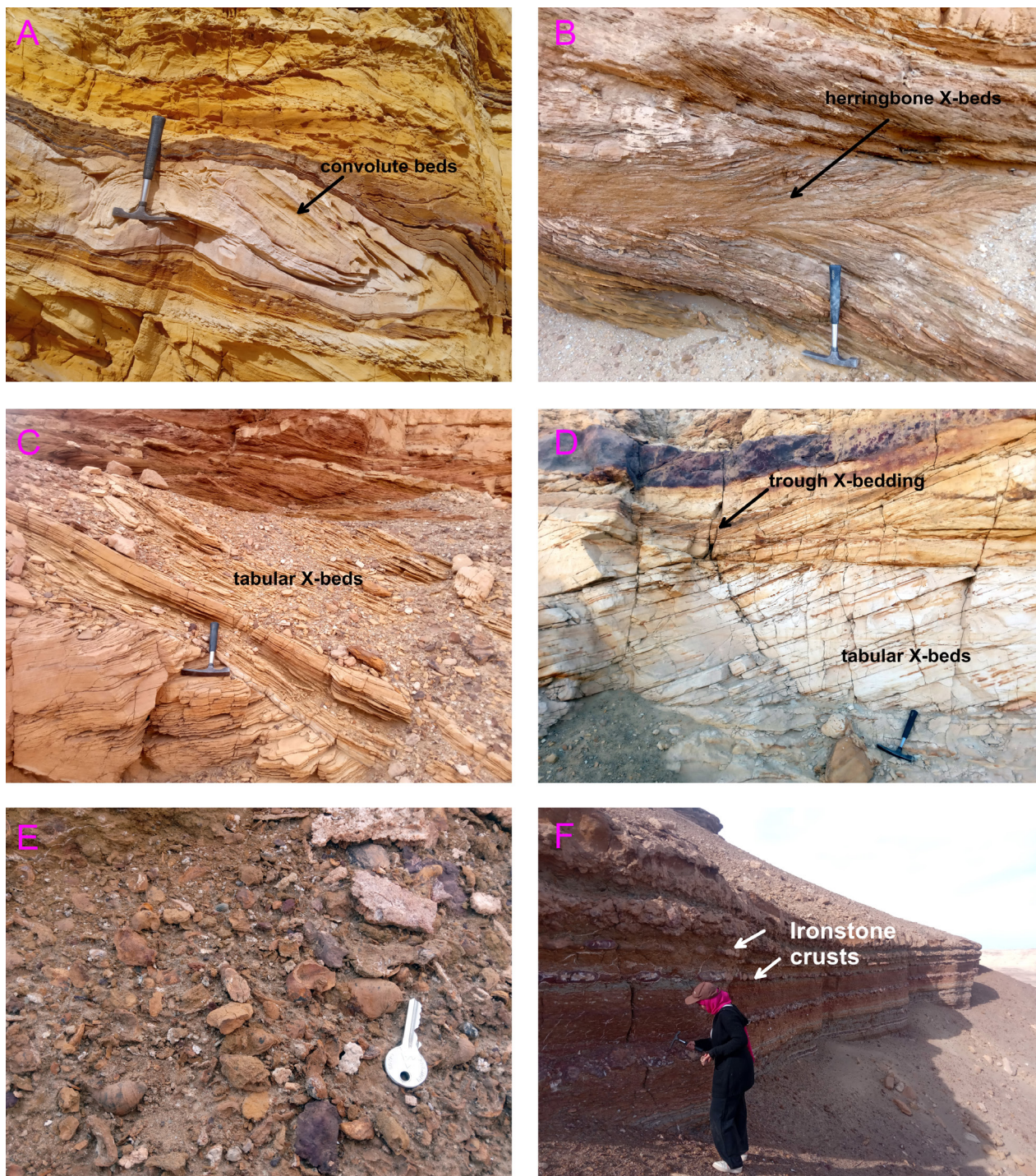
This facies consists of coarse to medium-grained, poorly-sorted sandstones with large-scale convolute, herringbone, tabular, and trough cross-bedding (Fig. 4A-D), indicating high energy flu-

vial channels. These represent the large paleorivers flowed from the southern African craton during the Cenomanian.

In conclusion, the sedimentological and facies evidence from the Bahariya Formation in Gebel El Dist suggest a highly dynamic transgressive-regressive cycles during the Cenomanian. The presence of coarse, cross-bedded sandstones indicates a fluctuating shoreline (Catuneanu et al., 2006). Gebel El Dist of the Late Cretaceous was a sprawling estuarine/delta ecosystem (Said and Issawi, 1964). The abundance of organic-rich mudrocks and fossilized plant remains (mangrove-like flora) supports a model of low-energy, humid coastal plain.

Figure 4

Field photographs of the Bahariya Formation at Gebel El Dist showing: **A)** Convolute bedding in sandstones of the Bahariya Formation, Facies C, **B)** Herringbone cross-bedding, Facies C, **C)** Tabular cross-bedding, Facies C, **D)** Tabular cross-bedded sandstone overlain by trough cross-beds, Facies C, **E)** Invertebrate fossils-bearing beds within the Bahariya Formation, and **F)** Ironstone crusts within the clastic succession of the Bahariya Formation,



Note: Compiled by the author.

Paleontology

In addition to its characteristic Cenomanian invertebrate fossils, e.g., *Exogyra flabellata*, *Exogyra mermeti*, and *Plicatula reynesi* (Ball and Beadnell, 1903) (Fig. 4E), the Bahariya Formation in Gebel El Dist is most famous for its giant Theropod fauna. During the mid-Cretaceous, this area supported an unusually high concentration of large carnivorous dinosaurs including *Spinosaurus aegyptiacus*, *Caracodontosaurus saharicus*, *Paralititan stromeri*, *Bahariasaurus ingens*, and recently discovered *Abelisauridae* (Stromer, 1914, 1936; Said, 1962; Smith et al., 2001; Ibrahim et al., 2020; Salem et al., 2022).

Paleoclimate and paleogeography

Gebel El Dist is a paleo-analog for modern climate change. By studying the rapid sea-level rises and extreme tropical heat recorded in these rocks, scientists can better predict how modern coastal ecosystems (e.g., the Nile Delta) might respond to rising temperatures. The dominance of angiosperm leaf fossils and the presence of lateritic ironstone crusts (Fig. 4F) within the Bahariya Formation in Gebel El Dist suggest a humid tropical climate with high seasonal rainfall (Khalifa and Catuneanu, 2008; El Atfy et al., 2023).

Paleogeographically, Egypt during the Cenomanian was located further south than it is today. The Tethys Ocean (the precursor to the Mediterranean) was invading from the north (Khalifa and Abu El-Hassan, 1993). Northern Africa was then a passive continental margin. Gebel El Dist was a part of a vast wetland system stretching across what is now the Sahara, providing a green corridor for the Cretaceous life

Geoheritage significance

Gebel El Dist is not merely a research site; it is a pillar of Egyptian geological heritage. It holds scientific, geo-educational, and geo-touristic values (Plyusnina et al., 2016). It provides a unique window into the mid-Cretaceous; a period often poorly preserved elsewhere in Africa. The isolation of Gebel El Dist as a “monadnock” or “pyramid-like mountain” provides evidence of the long-term denudation of the depression floor since the early Neogene,

marking it as a vital site for studying the geomorphological history of the Western Desert. The clear layer-cake stratigraphy and accessible fossil strata make it an ideal outdoor classroom. Its proximity to the Black Desert and its iconic status in dinosaur history offer immense potential for sustainable geotourism development.

1. Semi-quantitative assessment of Gebel El Dist

A semi-quantitative assessment of Gebel El Dist in the Bahariya Oasis typically utilizes numerical scoring methods designed to evaluate geoheritage value. A detailed description of its quantitative standing based on the standard Geosite Assessment Model (GAM) is given, and summarized in Table 1.

1.1 Scientific/educational value

Gebel El Dist typically scores near-perfect in scientific and rarity indicators. It often scores 8/10 or higher in scientific/educational value due to its rarity and the global rank of its fossil record (Table 1).

1.2 Geomorphological & aesthetic value

Gebel El Dist is a classic example of residual landforms, and its unique pyramidal shape makes it a landmark in the Bahariya Oasis. Its near-perfect conical symmetry is the result of differential erosion. The harder protective cap rock (nummulitic limestone of the lower Eocene Naqb Formation) protects the softer underlying clays and sandstones from wind and water erosion (e.g., Ruban and Sallam, 2024).

1.3 Additional values

- Accessibility: very high; it is located near the main road and El-Bawiti town, which increases its use value for geotourism, but also its protection risk.

- Infrastructure: low; there are no visitor centers, interpretative panels, or formal walking paths directly on the site.

- Proximity to other sites: high; it sits a cluster of mountains such as Gebel El-Englez and the Black Desert in the El-Heiz region.

1.4 Vulnerability & risk assessment

In the semi-quantitative risk analysis, Gebel El Dist scores high for degradation susceptibility. While the mountain itself is stable, the fossil-bearing strata are susceptible to illegal extraction and erosion. Unregulated fossil extraction and off-road driving around the base of the mountain are the primary threats to this site.

Table 1.
Semi-quantitative assessment of Gebel El Dist in the Bahariya Oasis.

Criteria	Rank	Estimated score (0-10)
Scientific/Educational value	Global. It is a key site for Cretaceous dinosaur and reptile fossils.	10
Stratigraphic value	Regional; perfect exposure (the type section) for the Bahariya Formation strata.	9
Aesthetic value (geomorphological)	High; pyramid-like landform contrast against the flat depression floor.	9
Accessibility	High; accessible via the road from El-Bawiti town, but requires 4X4 drive-wheels for close approach; no formal parking or facilities.	7
Infrastructure	Moderate; no visitor center, interpretative panels or official maps.	7
Vulnerability & Anthropogenic risk	High; unregulated fossil extraction and off-road driving around the mountain.	6

Note: Compiled by the author

Conclusion

Gebel El Dist in the Bahariya Oasis represents the standard for Cenomanian siliciclastic sequences in northern Africa, the site of the Bahariya “Dinosaurs” reshaping our understanding of Mesozoic predator-prey dynamics, and a centerpiece for the developing “Bahariya Oasis Geopark” capable of driving sustainable development through high-value scientific geotourism. Its rocks tell a story of rising seas, ancient large rivers, and the most terrifying ecosystems to ever exist on Earth. Gebel El Dist is unique because it combines world-class paleontology (dinosaur bones) with significant stratigraphic unconformities. Preserving this geosite is essential for future generations to understand the climatic and biological shifts of our planet.

Recommendations: The semi-quantitative assessment of the geoheritage of Gebel El Dist concludes that it meets the essential criteria for designation as a protected geological site. On a 10-point composite scale (scientific + additional + protection), Gebel El Dist settles at 8/10. However, the site is currently facing significant threats from unmonitored desert trekking and unregulated tourism and illegal fossil digging. Therefore,

we recommend an urgent conservation strategy focusing on monitored access, public awareness, and the integration of the site into a sustainable geotourism circuit to balance scientific preservation with local economic development. We propose the following immediate actions to protect Gebel El Dist geosite:

1) Working seriously to include and adjoin Gebel El Dist geosite to the UNESCO Global Geoparks network, which will certainly elevate its status from a locally managed protectorate to an internationally recognized site of geological importance.

2) Establishing an open-air “Dino-Trail” with the educational signage provided in this dossier to promote sustainable geotourism.

3) Integrating the local community of the Bahariya Oasis as “Geoguardians” to provide both security and guided geo-educational field trips.

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Author Contribution

Nada A. Ayoub: fieldwork, writing—original draft. Emad S. Sallam: fieldwork, methodology, writing—review and editing.

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