

# The Geosite of Travertine Waterfall of El ksiba (Morocco), a Heritage to Enhancement and Preserve

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**Abstract:** The travertines of El Ksiba forming cliffs with an extension of about 8 km and a variable height that can reach about thirty meters. They are developed on lacustrine limestones and conglomerates of Early Quaternary age. The results reveal the high scientific ( $\approx 0.88$ ) and aesthetic ( $\approx 0.88$ ) values related to the strong representativeness of the regional geological phenomena. The assessment also shows the high economic value ( $\approx 0.75$ ) and cultural ( $\approx 0.81$ ). In this work, we presented the strategies of valorization and protection of this heritage in the framework of rural socio-economic development through activities related to geo-tourism and geo-education.

**Keywords:** travertines; inventory; geo-tourism

**Citation:** BARKA, A.A.; Rais, J.; BARAKAT, A.; LOUZ, E.; NADEM, S. The Geosite of Travertine Waterfall of El ksiba (Morocco), a Heritage to Enhancement and Preserve.

2022, 69, x.

<https://doi.org/10.3390/xxxxx>

Academic Editor(s):

Received: date

Accepted: date

Published: date

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## 1- Introduction

Geotourism is an activity that today qualified as innovative, which could lead to the sustainable development of society, and could contribute to the popularization of geological and geomorphological information through education, awareness of the public to geoconservation and protection of their heritage [1–2]. The travertines of El ksiba are deposits of calcium and magnesium carbonate of great interest for identify and refine information about climatic, hydrological and vegetation cover variations through paleo-environment changes. These travertines have Quaternary age, forming cliffs with an extension of about 8 km and a variable height that can reach about thirty meters. They are developed on lacustrine limestones and conglomerates of Early Quaternary age. At the level of these travertine there are cavities, caves and shelters of variable dimension formed by the advance of the top of the waterfall and others by the phenomena of the karstification. These formations are unique in the study area, containing remains of plants and animals (leaves, trunks, mollusks) [3], which allow to reconstruct the bioclimatic conditions of their establishment. It has long been the preferred rock for construction and ornamental and aggregate in the region [4]. The abundance of resurgences, waterfalls, caves with an importance cultural value (Hyena Cave), exceptional ruiniforms landscapes cliffs and stone arch and fascinating panoramic views, make this territory a suitable tourist destination for excursions, hiking and climbing. Despite all these opportunities, this heritage remains unknown to the general public and little exploited by managers, while it could be a significant natural resource for local socio-economic development. To address this gap, an inventory and assessment was conducted to provide a database to support decision makers in any geo-heritage promotion project in the region which is the subject of previous studies such as [3,5,6], This inventory-builder utilized Reynard (2016) method [7]. Beside the elevated aesthetic values of the identified geosites our approach also took the scientific values and some additional values into account to identify geosites. On the basis of geosite identification, a geotourism facilities have also been proposed to promote this rich geo-heritage. This promotion can popularize the geosciences and create income generating

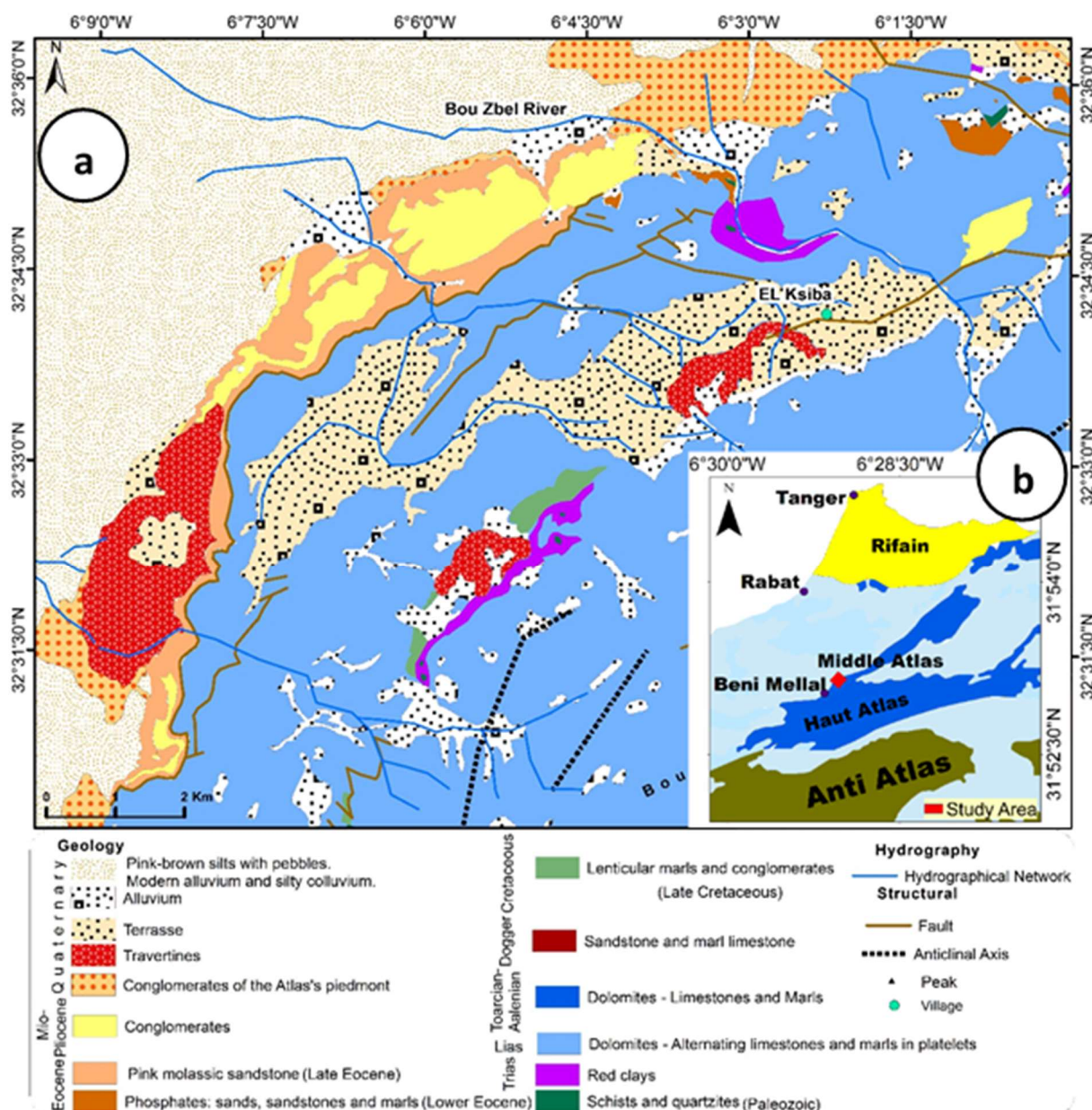
activities, which will improve the socio-economic situation of the local communities of the region.

## 2. Study Area

The study area is located in the north of the province of Beni Mellal, in the region of Beni Mellal-Khenifra (Figure 1), limited to the Atlas of El Ksiba, of which the quarries of materials represent one of the important economic activities. It is characterized by a complex geology mainly of Mesozoic age, with a mountainous topography. The dominant climate is continental; very cold in winter and very hot in summer. The study area is characterized by a dense vegetation cover represented by holm oak (*Quercus ilex*), Zeen oak (*Quercus canariensis*), Juniper (*Juniperus*) and Dwarf palm (*Chamaerops humilis*). The study area characterized by an important hydrographic network, represented by valleys and rivers, and an important groundwater table.

## 3. Geological Setting

The Triassic and Jurassic form most of the outcrops in the study area (Figure 1). The Triassic is represented by red clays and altered basalts, with intercalations of shale and quartzites of Paleozoic age. The lias is formed by massive limestones and dolomites, they constitute the most dominant geological formation at the scale of the study area. The upper lias corresponds to an essentially marly episode of Toarcian - Aalenian. The Dogger is essentially limestone. Cretaceous formations represented by marls and lenticular conglomerates. The Cretaceous formations are continued by sandstones of the pink piedmont molasse and conglomerates of the Mio-Pliocene which are concentrated in the piedmont area. The Quaternary is also well represented by alluvium and travertine deposits that lie unconformably with the formations of the Dir.



**Figure 1.** (a). The geological map of the study area. Extracted by the geological map of Morocco 1:100,000. Sheet of Kasba Tadla; (b) geographical location of study area.

#### 4. Materials and Methods

In this study, we have selected the geosites by assessing their scientific, aesthetic, ecological, and cultural relevance [7]. This approach focuses on inventory the representative geodiversity sites to select the most representative ones with high overall value. The inventory was conducted in two stages: selection of geosites and their evaluation. The selection was based on literature reviews and field visits, and uses a code to locate the geosite. This identification code consists of three parts [8]: (1) the abbreviation of the region in capital letters, (2) the processes responsible for the genesis of the geomorphic form in lower case letters, and (3) a numerical identifier for the site. The geosite was evaluate according to criteria [9]: the central value (scientific value): representativeness, integrity, rarity and paleogeographic value and additional values (ecological, Aesthetic, cultural, economic, and rarity value. Each of these criteria was independently evaluated by a numerical score ranging from 0 (none), 0.25 (low), 0.5 (medium), 0.75 (high) to 1 (very high).

The final value of the object was obtained by the average the four criteria that compose it in central value and in additional values (Table 1).

### 5. Results and Discussion

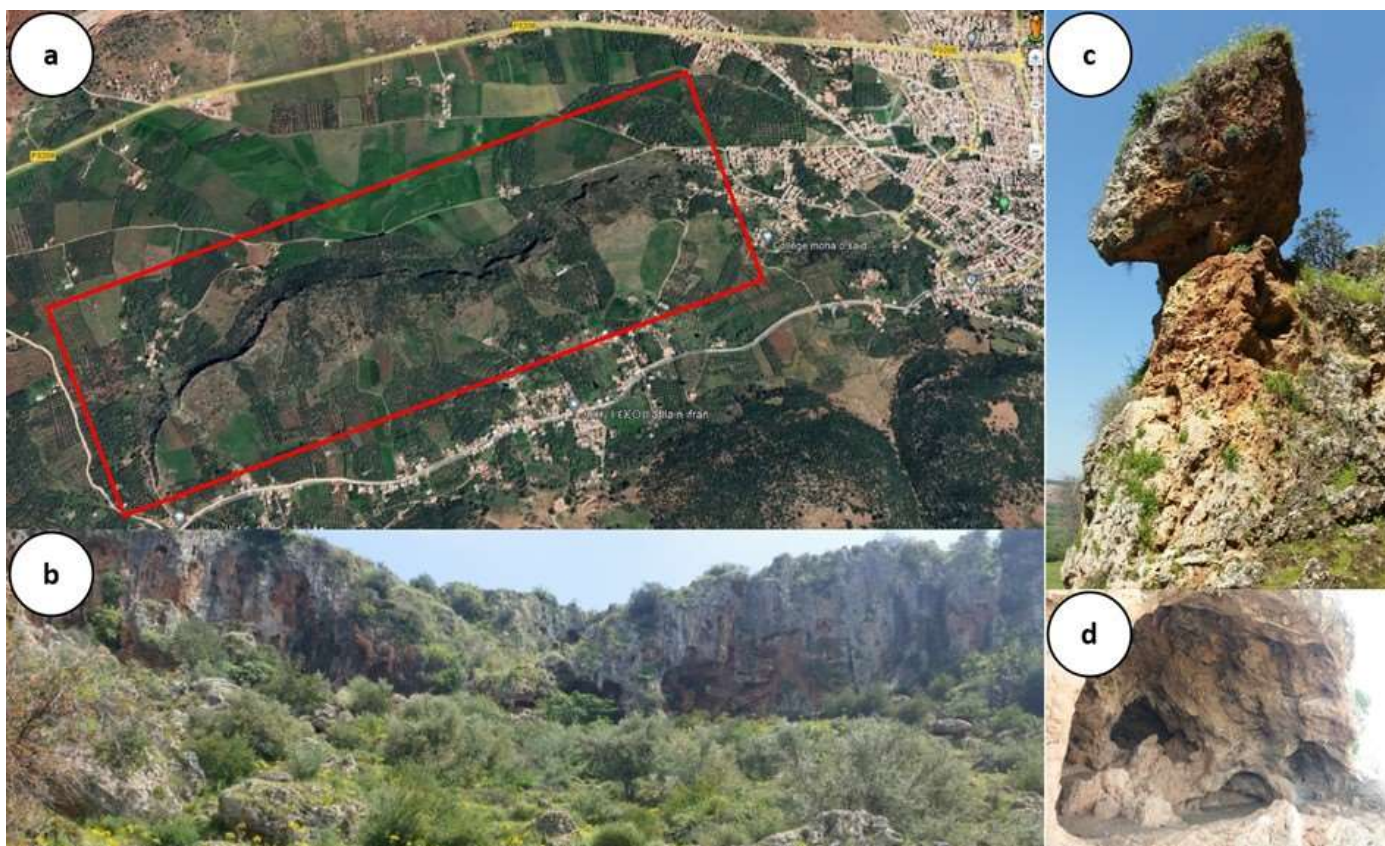
The travertine of El ksiba is one of the particular geosites of the region, as a result of the waterfall abundance. It is chosen in this study as a geosite for its large surface area (Figure 2a, b), its richness in resurgences, seasonal waterfalls, caves (Figure 2d) with an importance cultural value (Hyena Cave), exceptional ruiniforms landscapes (Figure 2c), cliffs and stone arch and fascinating panoramic views. Despite all these wonderful natural features, undesirable pressures affect this castle, such as the quarrying of building materials. These travertines is very porous by holes of size millimeter to several meters ornamented by stalagmites and stalactites. These formations related to the rapid precipitation of carbonates are caused by the release of CO<sub>2</sub> from karstic water, it revealed on all its height of abundant remains of plants and animals (leaves, trunks, molluscs...), which make it possible to reconstruct the bioclimatic conditions of their establishment. The study of these travertine formations has several scientific interests (≈0.88), including information on the past functioning, paleo-climat and its paleo- topography. Therefore, a geosite tells the history value (≈0.81) in the region by the abundance of caves. This caves were called Tighramt (a castle) [10], formed naturally in a very rugged terrain. Moreover, these caves look like collective granaries intended for the protection of everything precious during the war at that time (herds, cereals, children and women) because they are invisible to their enemies. Today most of the berber families live in these caves in the region. These caves are a priceless treasure in the study area, and are among the most important tourist assets, especially since they lead to underground galleries [3], and play an important role in speleology. These caves can also play a role in encouraging ecotourism by transforming these caves into ecological shelters. They play a major role in tourism development and participate in the local development of rural areas. In addition, this area is rich in cultural attractions (≈0.81); the Hyena Cave that show the power of a former leader of the tridus in Atlas. In other hand, the travertine of El ksiba was an important economic value (≈0.75), This is reflected in the increase in the number of local tourists due to the paving of roads and the acquisition of local products such as oil, pomegranate and other local clothing that express the local identity and heritage. It is also an opportunity for hunting and fishing enthusiasts to practice their hobby to sing this region with different types of animals and birds, in addition to its wealth with different types of trees and medicinal plants (Ecological value).

The scientific, economic, cultural and ecological importance of the travertines of El Ksiba give it a remarkable attraction, which must be integrated into the regional development activities. As well as its ease of access and its coolness, that contrasts with the overwhelming heat of the region. These travertines is a lever for sustainable development of the city and contributes to socio-economic development through the creation of new income-generating activities (ecological guest houses, traditional crafts, natural local products, ...).

**Table 1.** Quantitative assessment of the scientific and additional value of El ksiba’s Travertine.

Code	Name	Scientific Value					Additional Value				
		Int	Rep	Rar	Pal	Sc V	Ecol	Aes	Cul	Eco	Ad V
ELKhyd001	the Hyena Cave	1	0.75	1	0.75	0.88	0.75	0.75	0.75	0.75	0.75
ELKkar002	Spring	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
ELKhyd003	Panoramic view	1	1	0.75	1	0.94	1	1	1	0.75	0.94
ELKkar004	ruiniforms landscapes	0.75	1	1	1	0.94	0.75	1	0.75	0.75	0.812
<b>Travertine Value</b>		0.75	0.88	0.75	0.63	0.88	0.81	0.88	0.81	0.75	0.81

**Note:** Int means integrity; Rep means representativity; Rar means Rarity; Pal means Paleogeographical value; Sc V means Scientific value; Ecol means ecological value; Aes means Aesthetic value; Cul means cultural value; Eco means economical value; Ad V means Additional value.



**Figure 2.** Travertines of El ksiba: (a) area occupied by travertines (google earth image, october 20, 2022); (b) view on the travertines; (c) ruiniforms landscapes; (d) the Hyena Cave.

### 6. Conclusion

The quantitative evaluation shows that the travertines of El ksiba have an important scientific value (0.88); it presents an open-air museum rich in paleontological, speleological and paleoclimatic data which helps us to reconstruct the old environment. In this sense, we propose, as a tool to valorize this heritage, to install a plaque explaining the mode of origin of this travertine in its different forms, integrating the site in areas of scientific, economic and cultural importance, and directing local tourism to this area to understand these forms and thus preserve them. Developing tourist infrastructures such as ecological guest houses and creating new outlets to sell local products. In addition to stopping the installation of quarries of building materials in this area.

**Acknowledgments:** The authors wish to express their great gratitude to all those who participated in the realization of this work, also to the anonymous reviewers for their valuable and constructive suggestions during the development of this article.

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