

The Geosite of Travertine Waterfall of El Ksiba (Morocco): A Heritage to Enhance and Preserve [†]

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Abstract: The travertines of El Ksiba form 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 ($\cong 0.88$) and aesthetic ($\cong 0.88$) values related to the strong representativeness of the regional geological phenomena. The assessment also shows the high economic ($\cong 0.75$) and cultural value ($\cong 0.81$). 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

1. Introduction

Geotourism is an activity that today qualifies as innovative, and it could lead to the sustainable development of society and 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 the identification and refinement of information about climatic, hydrological and vegetation cover variations through paleo-environment changes. These travertines are of 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 travertines, there are cavities, caves and shelters of variable dimensions, some 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 facilitate the reconstruction of the bioclimatic conditions of their establishment. It has long been the preferred type of rock for construction, ornamental purposes and aggregate in the region [4]. The abundance of resurgences, waterfalls, caves with an importance cultural value (Hyena Cave), exceptional ruiniform landscapes, cliffs and stone arches, 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 also 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 Refs. [3,5,6]. This inventory builder utilized the Reynard (2016) method [7]. Besides 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, geotourism facilities have



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also been proposed to promote this rich geoheritage. This promotion can popularize the geosciences and create income-generating activities, which will improve the socio-economic situation of the local communities in 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 quarrying of materials represent one of the most 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.

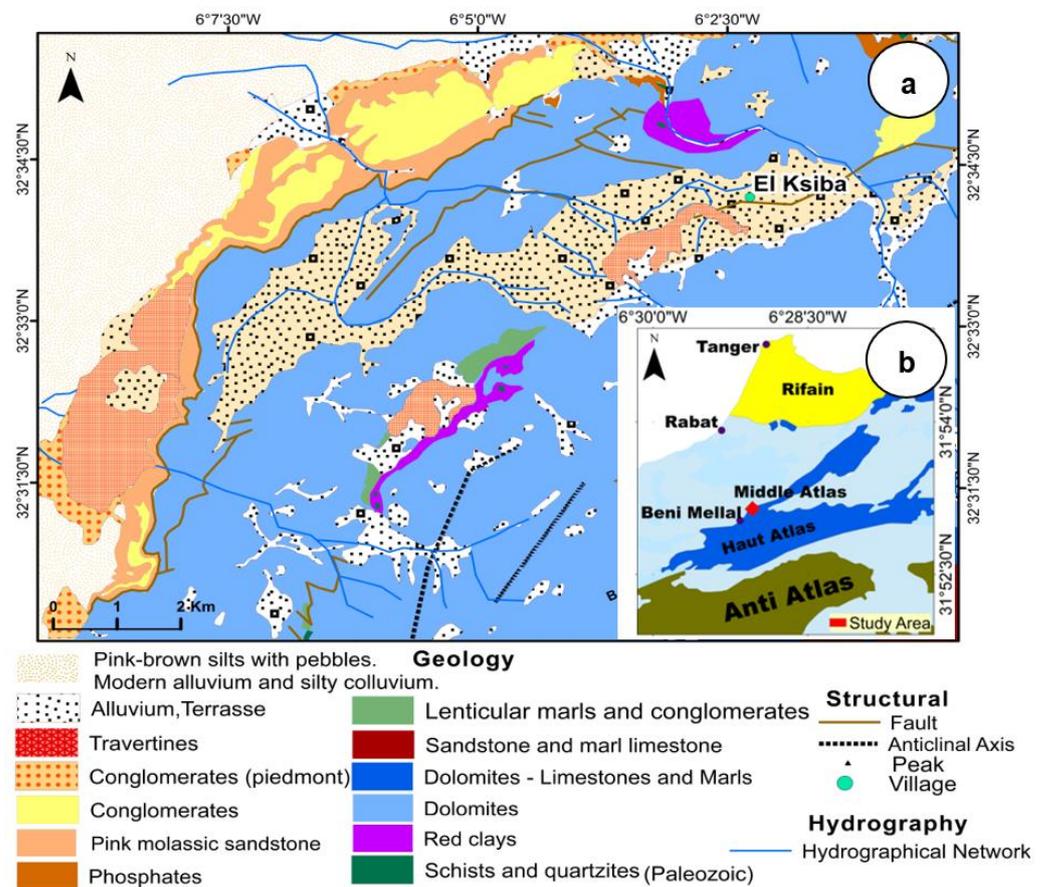


Figure 1. (a) The geological map of the study area. Extracted from the geological map of Morocco 1:100,000. Sheet of Kasba Tadla; (b) geographical location of study area.

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, which 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 are 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.

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 conducting an inventory of 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 subsequent evaluation. The selection was based on literature reviews and field visits, and a code is used to locate each 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. Each geosite was evaluated according to the following criteria [9]: the central value (scientific value), i.e., representativeness, integrity, rarity and paleogeographic value, and additional values (i.e., ecological, aesthetic, cultural, economic and rarity value). Each of these criteria was independently evaluated according to a numerical score in the following range: 0 (none), 0.25 (low), 0.5 (medium), 0.75 (high) to 1 (very high). The final value of the object was obtained by taking the average of the four criteria that compose the central value and additional values (Table 1).

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	ruiniform landscapes	0.75	1	1	1	0.94	0.75	1	0.75	0.75	0.812
Travertine Value		0.75	0.88	0.75	0.63	0.88	0.81	0.88	0.81	0.75	0.81

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

5. Results and Discussion

The travertine of El Ksiba is one of the outstanding geosites of the region, owing to its waterfall abundance. It is chosen in this study as a geosite for its large surface area (Figure 2a,b), richness in resurgences, seasonal waterfalls, caves (Figure 2d) with important cultural value (e.g., Hyena Cave), exceptional ruiniform landscapes (Figure 2c), cliffs and stone arches, and fascinating panoramic views. Despite all these wonderful natural features, undesirable pressures affect this castle, such as the quarrying of building materials. These travertines are very porous due to holes measuring millimeters to several meters ornamented by stalagmites and stalactites. These formations relating to the rapid precipitation of carbonates are caused by the release of CO₂ from karstic water, thus revealing its abundant remains of plants and animals (leaves, trunks, mollusks, etc.), making it possible to reconstruct the bioclimatic conditions of their establishment. The study of these travertine formations is of scientific interest in many aspects (≅0.88), including information on its past functioning, paleo-climate and paleo-topography. Therefore, a geosite reveals the historic value (≅0.81) in the region by the abundance of caves. These caves are 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 they 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 ($\cong 0.81$); the Hyena Cave, which shows the power of a former leader of the tribes in Atlas. On the other hand, the travertine of El Ksiba is of important economic value ($\cong 0.75$). 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 hunt in this region the different types of animals and birds, in addition to its wealth of different types of trees and medicinal plants (ecological value).

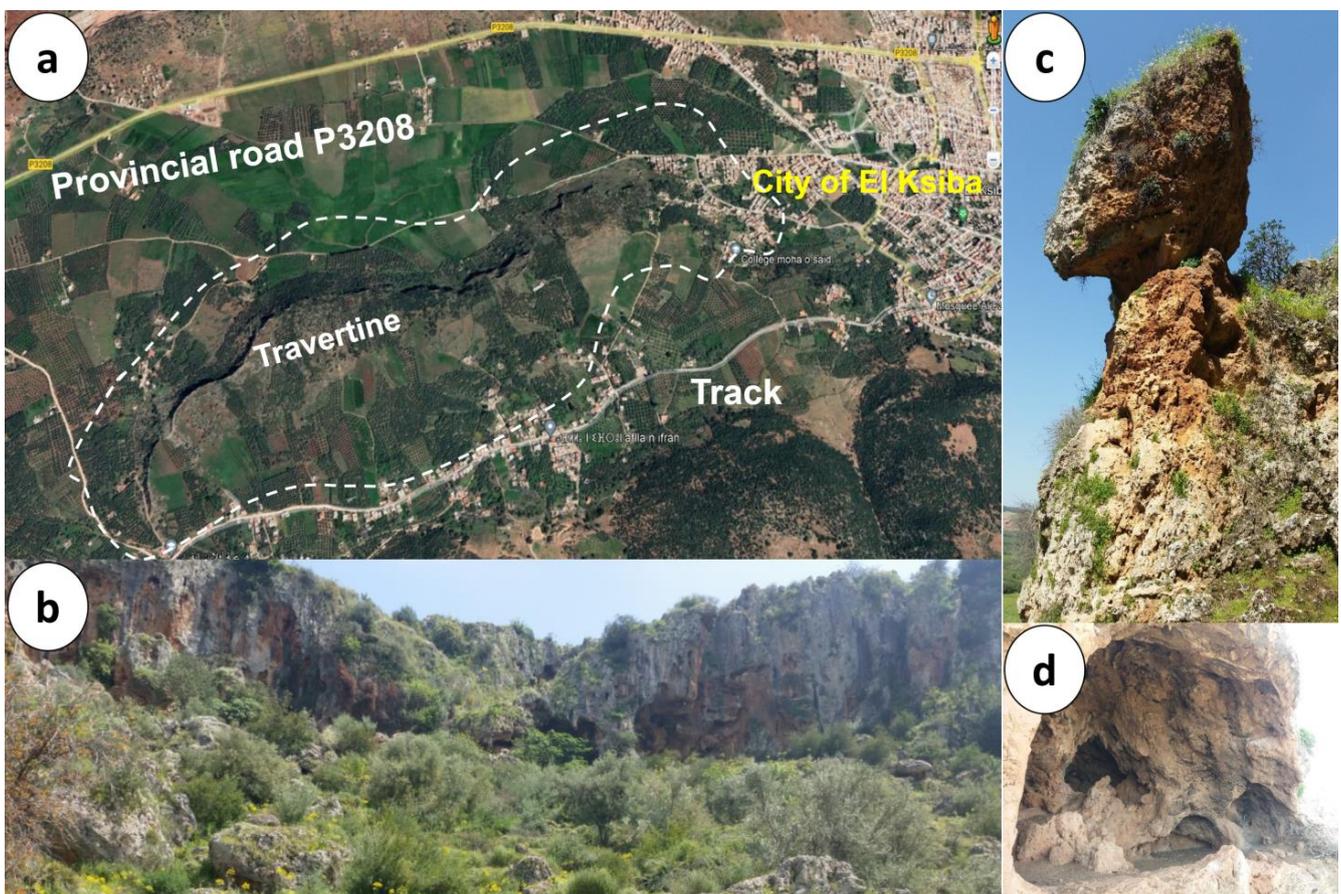


Figure 2. Travertines of El Ksiba: (a) area occupied by travertines (Google Earth image, 20 October 2022); (b) view of the travertines; (c) ruiniform landscapes; (d) the Hyena Cave.

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

6. Conclusions

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 help 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. Further proposals include developing tourist infrastructures such as ecological guest houses and creating new outlets to sell local products, in addition to stopping the installation of quarries for building materials in this area.

Supplementary Materials: The presentation materials can be downloaded at: <https://www.mdpi.com/article/10.3390/IECG2022-13865/s1>.

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