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ORIGINAL ARTICLE

Lateral and "Vertico-Lateral" Cave Dwellings in Haddej and Guermessa: Characteristic Geocultural Heritage of Southeast Tunisia

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Abstract Southeast Tunisia is known for different types of cave dwellings developed for centuries on the Matmata-Dahar plateau. Their formation takes into account the geological and geomorphological context of the sites. They thus provide an interesting example of geoheritage on which was developed an important cultural and architectural heritage. An interdisciplinary research—crossing geomorphological and historical/architectonical approaches—was carried out in two sites: Haddej and Guermessa. The Haddej site belongs to the Matmata area located in the northern part of the plateau. It is characterised by cave dwellings dug vertically and then laterally in the Quaternary aeolian silty deposits filling the valleys that dissect the plateau surface, which corresponds to the backslope of a cuesta. This geomorphological context gives a "vertico-lateral" cave dwellings in "*Flower* architecture". The Guermessa site belongs to the Tataouine region, located in the southern part of the plateau. Cave dwellings were dug laterally in alternations of limestone, clay, marl and dolomite strata that appear on witness buttes and outliers slopes. The result is lateral cave dwellings in "*Foot* architecture". Both sites offer favourable conditions for geomorphological study. They exhibit a wide range of structural landforms within the monocline structure and their surroundings present a variety of forms and Quaternary formations. These geomorphosites were assessed using the method developed by the University of Lausanne, which allowed us to assign them a strong scientific, aesthetic, cultural, educational and tourist value. Proposals for their tourist promotion were then made taking into account the lack of maintenance that reduces their cultural and tourist value.

Keywords Geoheritage · Cultural geomorphosites · Assessment · Cave dwellings · Troglodyte · Southeast Tunisia

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Introduction

Cultural geology may be defined as a sub-discipline of Earth sciences that "explores the nexus between geological phenomena, landscapes and cultural beginnings" (Andersen et al. 2015). A cultural geology approach considers that the cultural identity of a society can be influenced by geology. Rocks may serve as canvases for paintings, landforms as markers for migrations and minerals have influenced the establishment of historic mining towns (Andersen et al. 2015). Also, earth processes (e.g. earthquakes, landslides, floods) interact with cultural assets (historic monuments, archaeological sites, etc. and also social interactions and institutions; Reynard and Giusti 2017). Examples of profound links between geology and cultural features are for instance the use of volcanic assets by American Indians in Yellowstone (use of obsidian, legends and supernatural powers linked with landforms) (Sweatwater Now 2015), geological sites considered as sacred places

(Kiernan 2015), historical stone industries, as in Ticino (Switzerland) (Scapozza 2012) or stone use practice in agriculture, as in Vaucluse (France) (Triat 2015).

Also, geomorphology has a cultural component, what is known under the term "cultural geomorphology" (Panizza and Piacente 2003). On the one hand, geomorphology can be considered as a component of the cultural heritage (in a wide sense) of a territory. On the other hand, the relationships between certain cultural components (in a narrower sense) of a territory (historical monuments, archaeological sites etc.) and the geomorphological context, which they occur in, may also be taken into account. Cultural geomorphology can be defined as the study of the geomorphological component of a territory, either as a cultural element of a landscape or in interaction with archaeological, historical or architectural cultural objects (Panizza and Piacente 2003, 2004, 2005). Cultural geology and geomorphology may also be considered by broader cultural geography approaches, in particular through the concept of cultural landscape, viewed as a landscape "fashioned out of a natural landscape by a culture group" (Sauer 1925).

Geoheritage itself has also a cultural component. Landforms or geological structures being considered as geosites are the result of a social-cultural process through which various actors (scientists, policy makers, administration, tourism sector etc.) intervene and consider the importance of geo-elements as part of heritage ("heritage making" process; see for instance Portal 2010, 2012; Reynard et al. 2011). Not all the societies recognise the importance of geoheritage as a witness of Earth history or the place of geoheritage as full part of natural heritage with the same importance as bioheritage. When considering this process through time, one can observe that geosites often follow non-linear trajectories (Gauchon 1997, 2002; Duval 2007; Portal 2010, 2012; Reynard et al. 2011). They may be considered as geoheritage during some periods and then be forgotten in other periods. Also, the reasons guiding the heritage making process may be different through time. As an example, spectacular landforms (e.g. earth pyramids, cliffs, structural landforms) have often been classified as "natural monuments" for aesthetic or picturesque reasons (Giusti 2010; Giusti and Calvet 2010; Portal 2010, 2012, 2014; Reynard and Giusti 2017), and not really for their interest for the Earth history. During the last 2 decades, geoconservation has mainly been initiated and carried out by scientific circles (university researchers) more than conservation sector, and it is only very recently that the International Union for Conservation of Nature (IUCN) has recognised the fragility of geodiversity and geology has been introduced as an integral part of "nature" in the definition of protected areas (Dudley 2008; Larwood et al. 2013; Crofts and Gordon 2015).

Geoheritage may be studied in relationship with various types of cultural heritage:

1. natural monuments and historical towns (e.g. Bertacchini et al. (2003a) studied the impacts of ophiolite outcrops on the development of historical towns and castles in the Emilian Appenines (Italy); Del Monte et al. (2013) and Pica et al. (2016) analysed Rome development and its links with geology and Del Lama et al. (2015) studied the importance of geology in the historical centre of São Paulo);
2. historical travels (e.g. Geyer et al. (2007), Reynard et al. (2009) and Panizza and Coratza (2012) worked on Goethe's travels through the Alps and in Italy in the eighteenth century, and his observations on geology and geomorphology);
3. literature, poetry, art and music (e.g. Bertacchini et al. 2003b; Gordon, 2012);
4. archaeological sites (e.g. Fouache and Rasse 2009; Moroni et al. 2015; Melelli et al. 2016)

The research presented in this paper concerns cave dwellings in Southeast Tunisia. Two sites, situated in two different geomorphological contexts, are studied. The focus is put on the double value—geomorphological and archaeological/historical—of the study sites, which allows us to speak of geocultural heritage, and their potential for geotourism development. First, the geomorphological context and secondly, the historical and archaeological components of the two sites are described. Then, the sites are assessed with the method developed by the University of Lausanne (Reynard et al. 2007, 2016) and proposals for their tourist promotion are made taking into account the lack of maintenance that reduces their cultural and tourist value.

Methodology

The study is realised in three main steps (Fig. 1). Only steps 1 and 2 are described in this paper, and step 3 (the SWOT analysis) will be realised for the whole Gabes-Tataouine region, after other geomorphosites have been assessed.

- A geomorphological and archaeological/historical analysis of each site was carried out using specific tools of the two disciplines (geomorphology and archaeology/history) (Fig. 1.1);
- The geoheritage importance of the site was assessed with the method developed by Reynard et al. (2007, 2016). A first version of the method was published in 2007 and several improvements were then made, based on empirical studies, and a second version was published in 2016. It is this version that is used in the present study. The

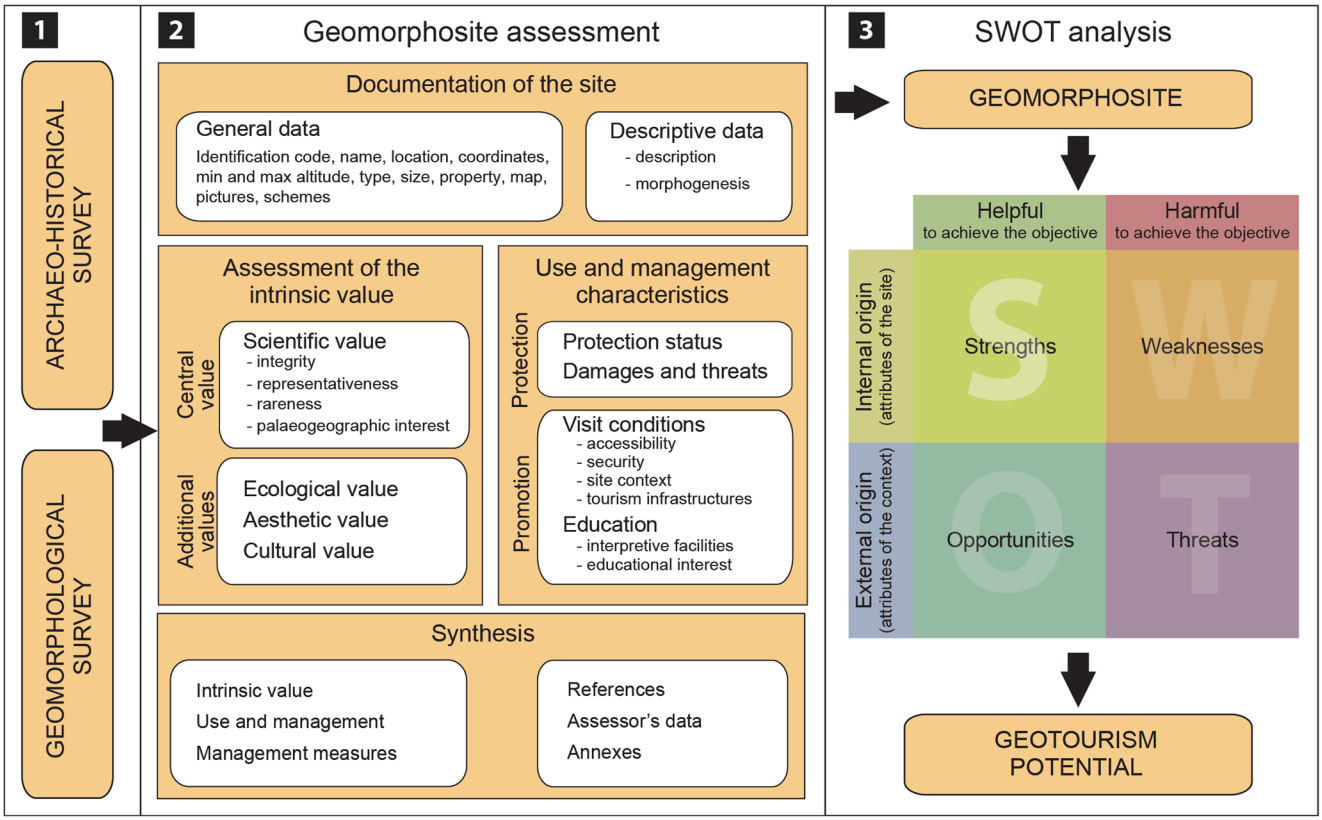


Fig. 1 Methodology in three steps: (*1*) geomorphological and archaeological/historical survey; (*2*) geomorphosite assessment (based on Reynard et al. 2007, 2016); and (*3*) SWOT analysis of the geotourism potential

assessment procedure is divided in four main stages (Fig. 1.2): (i) documentation of the site; (ii) assessment of the intrinsic value; (iii) use and management characterisation; (iv) synthesis.

- A SWOT analysis (strengths, weaknesses, opportunities, threats) of the two sites in terms of potential for geotourism will be made in a future step (Fig. 1.3).

Study Area

The Matmata-Dahar plateau is an important element in the landscape of Southeast Tunisia. It peaks at 713 m.a.s.l. in Kef Ennsoura (Fig. 2). From north to south, it extends between Gabes and the Tunisian-Libyan border. On a geomorphological point of view, this plateau corresponds to a monocline structure or cuesta with an outstanding steep slope overlooking more than 500 m the Jeffara Plain eastwards (Fig. 3) and a gentle backslope looking to the dunes landscape of the *Grand Erg Oriental* westwards.

The region was subject of several geological studies, which investigated the genesis of the structures and various lithofacies and fossils identified (Bouaziz 1995; Ouaja 2003; Tlig 2015). Other studies focused on the sedimentology and origins of aeolian silty formations (or loess) deposited during several phases of the Quaternary (Regaya 1985; Coudé-Gaussen 1989; Swezey 2001; Sghari 2012). However, until recently, the region has not been the subject of detailed geomorphological research except that of Sghari (2012) and those of Brosche and Molle (1975), Chahbani (1981) and Abichou (2002), which were site-specific and especially interested in sedimentology and micromorphology aspects.

Based on geomorphological studies by Ben Ouezdou (1983, 1986, 1987) in the plain of Gabes, which limits the region to the north, geomorphological researches in the plain of Jeffara and the northeastern part of the plateau (Ben Fraj 2012a, b) allowed demonstrating the richness of the region in landforms and Quaternary deposits, and establishing a chronostratigraphic pattern of inherited landforms and deposits. This work forms a fundamental database to study the links between geomorphology and human occupation in the region and to enhance geoheritage, as it was the case of the pioneer work by Ben Ouezdou (2001).

Many researchers including Bousnina (1977, 1986, 2001), Henia (1993) and Abderrahamane (2009) studied the regional climate characteristics. The region has an arid pre-Saharian climate, with average temperatures ranging from 36 °C in August to 7 °C in January and low annual rainfall (200 mm

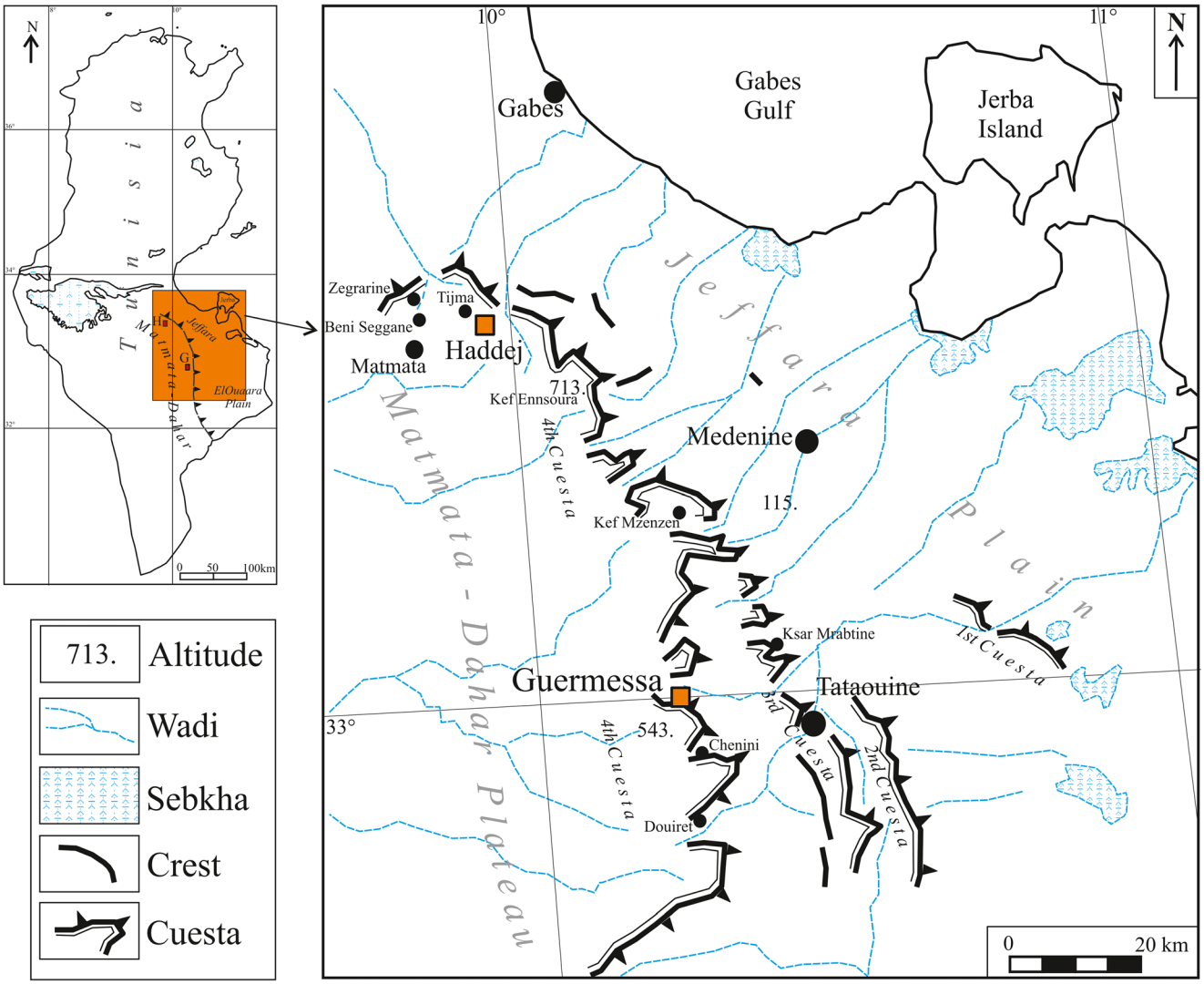


Fig. 2 Location of the study area and simplified morphological map representing the geomorphological features of the Matmata-Dahar plateau

in Matmata and 100 mm in Tataouine). Rainfall is characterised by high annual variability and by heavy rain events with short duration. On 24 September 1995, for example, quantity of rain in the city of Tataouine reached 38.5 mm in only 45 min, which engendered severe floods (Boujarra and Ktita 2010).

Between Matmata and Tataouine, on more than 100 km of distance, characteristic cave dwelling villages are visible. Depending on the geomorphological context, their aspect varies from a region to another. It is a "vertico-lateral" cave dwelling in the Matmata region and a lateral one in Tataouine. Over the past 4 decades, troglodyte habitats were progressively abandoned because of socio-economic changes and

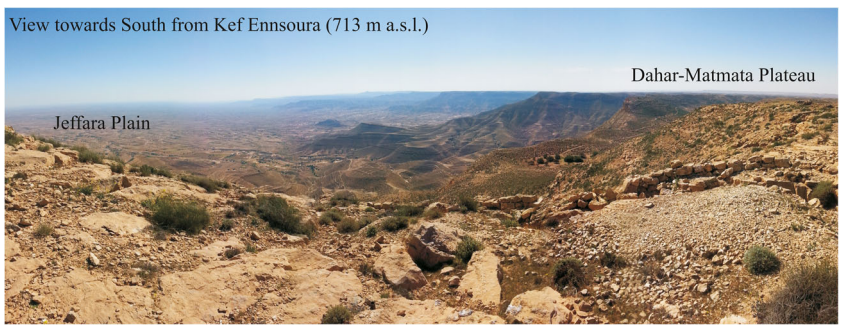


Fig. 3 A view of the Dahar-Matmata plateau from Kef Ennsoura (see the cuesta talus)

important migration trends. In Haddej, cave dwelling houses were abandoned and modern buildings were built in the perimeter of the troglodyte village, which makes this typical landscape quite ugly. In Guermessa, the whole cave dwelling village was abandoned and a modern village was built on the cuesta piedmont.

Geomorphological Analysis

The Matmata-Dahar plateau has a complicated monocline structure (cuesta morphology). Cuestas were formed in several pairs of resistant strata overlaying weaker rocks offering a succession of several parallel cuestas from east to west (Figs. 2 and 3). Pairs of rocks are varied and attributed to Triassic, Jurassic and Cretaceous periods. During the Tertiary and the Quaternary, many forms and formations were sculpted and deposited due to aeolian and fluvial morphogenic processes (Ben Fraj 2012 a, b). Pediments, terraces and aeolian silty deposits (loess) are the most coming. In the northern side of the plateau, the region of Matmata is an extended limestone and dolomitic plateau, which is the backslope of the fourth cuesta, dissected by a dense and muddled network of *wadis* (streams and rivers with intermittent flow, also called *oueds*) (Fig. 2). In the southern side, around the Tataouine region, the cuesta morphology is very well highlighted. It can be single, double or complex. Four cuestas separated by small valleys and mountain plains succeed from east to west over about 20 km:

$$1\text{st}\quad cuesta = \frac{Dolomites(Upper\ \ Carnian)}{Sandstone(Middle\ \ Carnian)}$$

$$2\text{nd}\quad cuesta = \frac{Dolomites\ \text{and}\ limestone(Bajocian{-}Bathonian)}{Gypsum\ \text{and}\ marl(Toarcian)}$$

$$3\text{rd}\quad cuesta = \frac{Limestone(Upper\ \ Callovian)}{Marl(Lower\ \ Callovian)}$$

$$4\text{th}\quad cuesta = \frac{Massive\ \ dolomites(Turonian)}{Marl,\ \ gypsum\ \text{and}\ limestone(Cenomanian)}$$

Geomorphological Context of the Haddej Site

The Haddej site is located in the middle of the northern part of the plateau around the Matmata area (Fig. 2). Several elements compose the landscape. The surface of the plateau is heavily dissected by *wadis* and presents a multitude of buttes, hills and strips separated by depressions and valleys (Figs. 4, 5, 6 and 7). The investigated site occupies a small depression. It is surrounded by hills, buttes and strips, which can reach up to 350 m in height. Level differences vary from 150 to 200 m. Slopes have values of 12 to 20%. The depression is partially drained by Wadi Jir and its tributaries, which dug and flared it during the Tertiary in dolomitic series of Turonian and alternations of marl and limestone of Senonian (Figs. 4 and 5).

During the Quaternary, fluvial processes deposited alluvial conglomerate layers with hardened surface (Fig. 6). According to the chronostratigraphic scheme proposed by Ben Fraj (2012a, b), the bottom of this formation is attributed to the Middle Pleistocene while its top is Upper Pleistocene. During this same last period, the depression was filled with thick aeolian silty deposits (loess). During pluvial periods of Quaternary, wind was able to import large quantities of silt, mostly from Sahara, and deposit them on the whole Matmata-Dahar plateau as well as in the Jeffara plain (Ben Fraj 2012a, b). The thickest deposits (reaching 20 m) are situated in the depressions of the Matmata area. These silt deposits are rich in limestone concretions. Hardened levels, calcareous crusts or red levels, interpreted as palaeosoils, are intercalated in the aeolian deposits (Regaya 1985; Coudé-Gaussen 1989). In the bed of Wadi Jir, a Holocene terrace can be distinguished besides the Quaternary deposits (Fig. 6).

Silt deposits were strongly dissected by tributaries of Wadi Jir. In unmanaged sectors, they form badlands. In managed sectors, eminences, which persist as interfluves, were used for digging vertico-lateral cave dwellings, under the most hardened level of the deposit, forming a landscape of juxtaposed craters (Fig. 7a, b). Between the small hills, gullies were managed by a hydro-agricultural system called *Jessour* (Fig. 7b) (Ben Ouezdou 2001).

Now, most houses are abandoned and are very sensitive to degradation due to the combination of heavy rainfall and lack of maintenance, which may deprive the village of its particular landscape and heritage aspects (Fig. 8).

Geomorphological Context of the Guermessa Site

The site of Guermessa hangs on the front of the western fourth cuesta (Fig. 2). The troglodyte village occupies a part of the front, a witness butte and an outlier still partially attached to the front. Towards the east, Guermessa dominates the plain of El Ferch, which is the backslope of the third cuesta. Towards the north, it dominates the Wadi El Guermessi valley that indents the front of the fourth cuesta and flows to the east (Fig. 9). At the village level, altitudes vary between 450 and 500 m.a.s.l. and can reach 543 m. a.s.l. In the plain, the average altitude is 300 m.a.s.l. This difference of altitude (200 m or more) made Guermessa a defence site and offers now panoramic views on the arid landscape (Fig. 10a).

Hillsides present strong slopes sometimes vertical at the ledge that seals the front and the witness butte. Difficult to access, the witness butte is significantly called *Ras al Motmana* ("crest of security" or "protected crest") while the outlier is called *Errbiba* ("small girl"). These local names show the interactions between geomorphology and vernacular knowledge as noted by Sellier (2013) in another

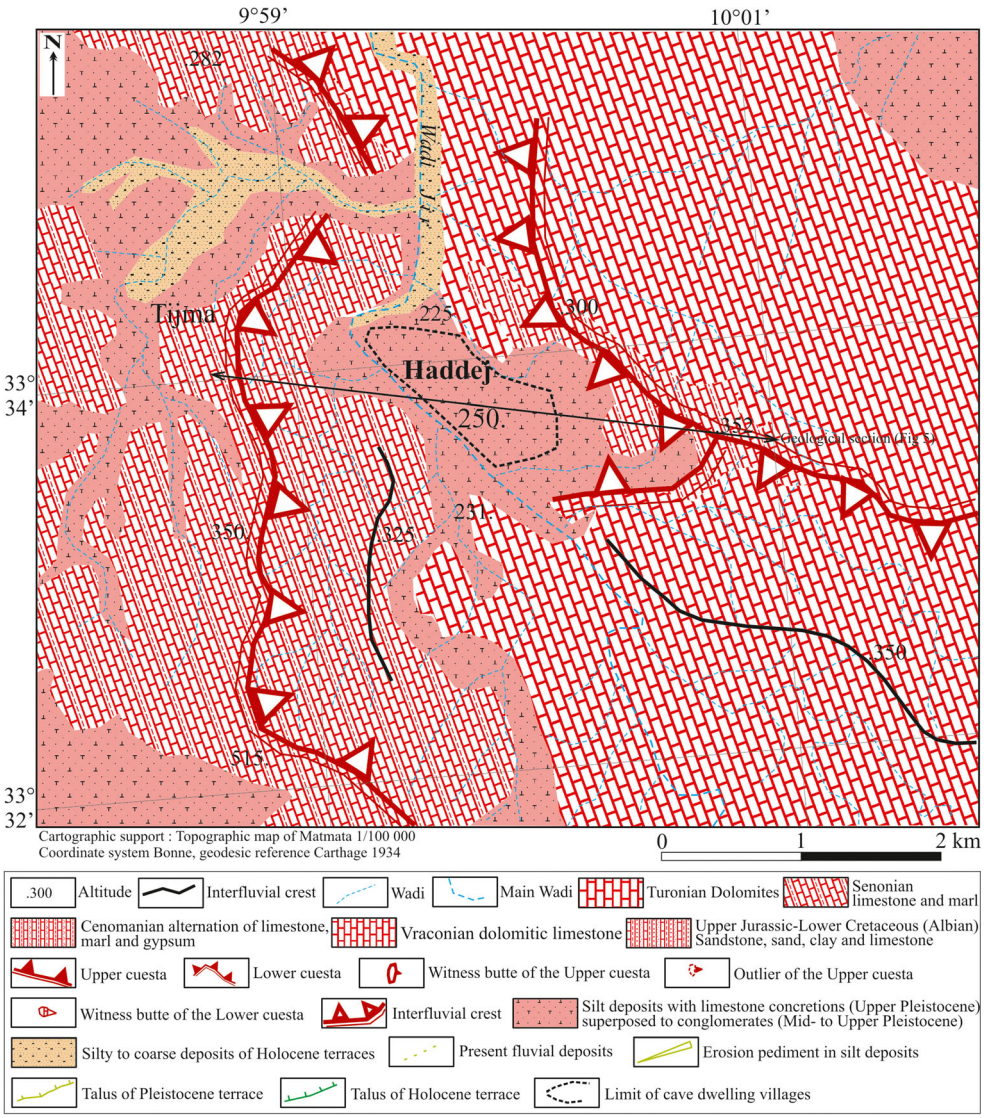


Fig. 4 Geomorphological sketch of Haddej area. The *black line with arrows* indicates the geological section of Fig. 5

geomorphological context. The hillside of the front is interrupted by horizontal surfaces at 400 m.a.s.l., insuring the passage towards the El Ferch plain. At this horizontal surface, a secondary pair of Vraconian dolomitic limestone superposed to sandstone, sand and clay layers of the Albian can be distinguished in addition to the main pair in which the fourth cuesta was sculpted. At this site, the fourth cuesta becomes double over a decametric distance (Figs. 9, 10b and 11a).

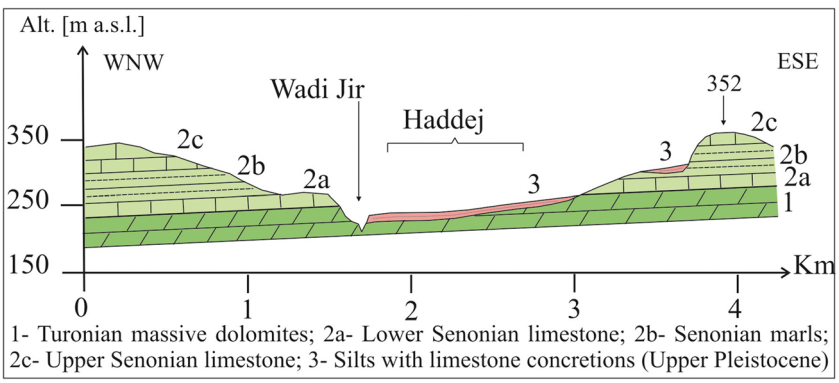


Fig. 5 Geological section of the Haddej site. Haddej is situated on the backslope of the fourth cuesta, which front, looking towards east (see Fig. 2), is shaped in massive Turonian dolomites

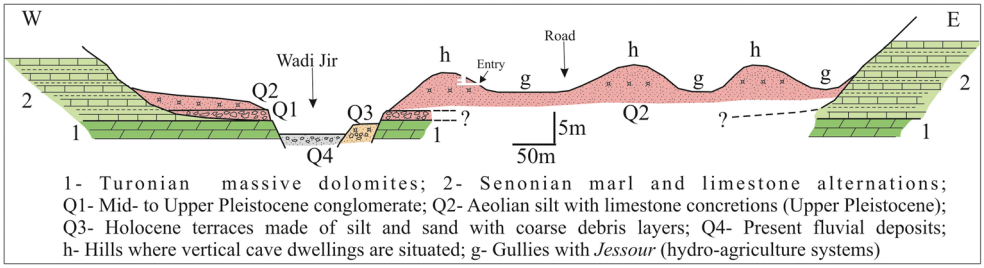


Fig. 6 Cross-section showing the relationships between Quaternary landforms and geological fomations in Haddej

It is at the expense of alternations of Cenomanian dolomitic limestone strata interbedded with layers of marl and gypsum about 100 m thick that the lateral cave dwellings were dug by removing the soft layer. From both sides, hard strata are used as floors and roofs. The caves are organised in rows that surround the slopes of hillsides (Figs. 11b, 12 and 13).

In the Wadi El Guermessi valley, quantities of wind silts deposited during the Quaternary are not as thick as in the case of Haddej to allow the digging of vertico-lateral cave dwellings. The deposits rich in calcareous concretions and sealed by a 5- to 10-cm-thick calcareous crust overlay a conglomeratic deposit with puddingstone. Other generations of wind silt and reworked silt overlay this conglomerate (Fig. 11c). All these deposits form a terrace. According to the chronostratigraphic scheme by Ben Fraj (2012a, b), the conglomerate is attributed to the Middle to Upper Pleistocene; it is the equivalent of the alluvial layer of Haddej depression. The silt deposits date from the Upper Pleistocene. Reworked silt deposits over short distances date from the late Upper Pleistocene. Not far from the site, near a trail linking Guermessa to the cave dwelling village of Chenini, these deposits have delivered flint artefacts attributed to the Epipalaeolithic (Mokaddem, in prep.). Finally, a Holocene terrace took place dominating directly the talweg. On the El Ferch plain side, silt deposits were regularised by sheet wash and formed an erosion pediment (Fig. 9).

Completely abandoned, the cave dwelling village of Guermessa confronts a process of degradation of its components due, in particular, to their mode of construction that requires regular maintenance. This degradation, which has not previously been the subject of safeguard or protection, could deprive the region of one of the most important geoheritage sites.

Archaeological/Historical Analysis

The housing model in the Dahar area and the in-depth or lateral troglodytic architecture are deeply linked to geological characteristics and geomorphological landscape in addition to historical factors. This region witnessed all civilisations, from prehistory to the present day. The Dahar plateau, populated and enhanced by Berber tribes, also witnessed a strong Roman presence. This region used to be a *Limes Tripolitanus* area. The arrival of the Arabs in the Middle Ages added another populating element which left a mark on the material culture of the region. The troglodytic housing, which is characteristic of the whole Dahar area, represents the perfect adaptation of man to his environment and summarises the long history of the whole region.

Haddej: "Vertico-Lateral" Cave Dwelling

Among the traditional dwellings of Southeast Tunisia, the cave dwelling habitat holds a central position. In the Matmata area, the prevailing type of habitat was the perched habitat. The downward movement towards the plain led to the creation of cave dwelling villages in which are witnessed a new architectural language and urbanism, which adapted to the new geographical conditions. A cultural model was set up (Boukhchim 2011).

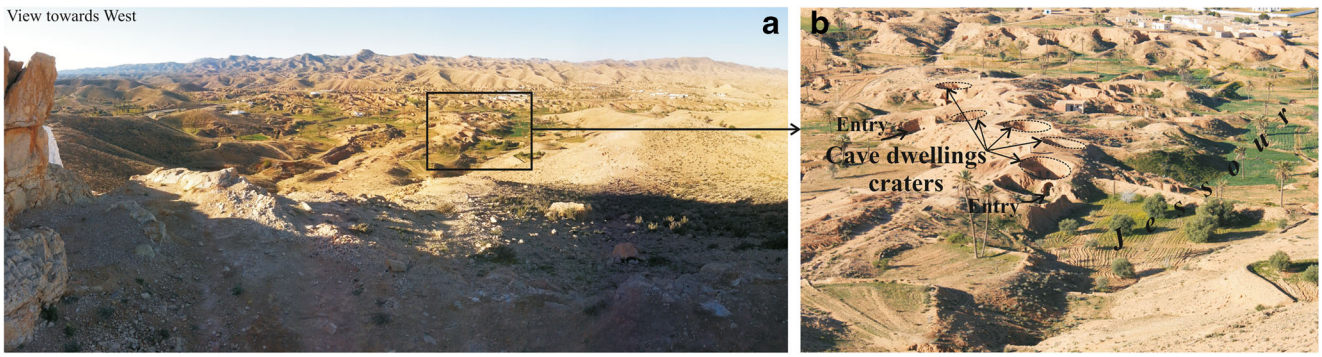


Fig. 7 **a** General view on the Haddej site. **b** "vertico-lateral" cave dwellings and *Jessour*

Fig. 8 Details of "vertico-lateral" cave dwellings in Haddej

While belonging to this type of habitat, Haddej is a cave dwelling village, which was not created by a shifting movement. One may witness the lack of a citadel. Haddej inhabitants are a faction of the Arab tribe of *Banû Hilalal* who settled within a Berber context in the Matmata area around the middle of the eleventh century (Boukhchim 2015). Near the end of the nineteenth century, Haddej used to be one of Matmata's most important administrative centres (Bruun 1898). The *Khalifa* (or caliph; i.e. "local governor") lived and ruled there, which conferred a distinguished position upon him (Bruun 1894, 1898).

The site takes up an important position on the right bank of Wadi Jir, situated on the east-oriented oriental slopes of Djebel Matmata. In the same basin, a group of villages, namely, Tijma, Beni Seggane and Zegrarine, shows the same morphological and architectural characteristics (Boukhchim 2011). Djebel Zegrarine and the Matmata citadel raise a natural barrier and protect the villages from western winds. Particularly in Haddej, vertico-lateral cave dwelling was made possible by the abundance of silts filling the basins and valleys with considerable concretions. In this region, in-depth cave dwelling houses overlook the whole landscape and impart an exceptional lunar outlook (Fig. 7).

In the Haddej village, cave dwelling habitat prevails and a few monuments were built. We note the presence of the following:

1. a mosque displaying a local and original architecture; the plan of this oratory exhibits a certain evolution in time; it is rich in decoration as well as in inscriptions (Boukhchim 2015);
2. *zaouïas* (or marabouts), among which one, *sidi ben Aissa* is semi-troglodyte.

The Haddej village takes the shape of a succession of wells. There are houses separated by more or less large-sized strips of land; they are nevertheless grouped in cities, which gather families descending from one common ancestor.

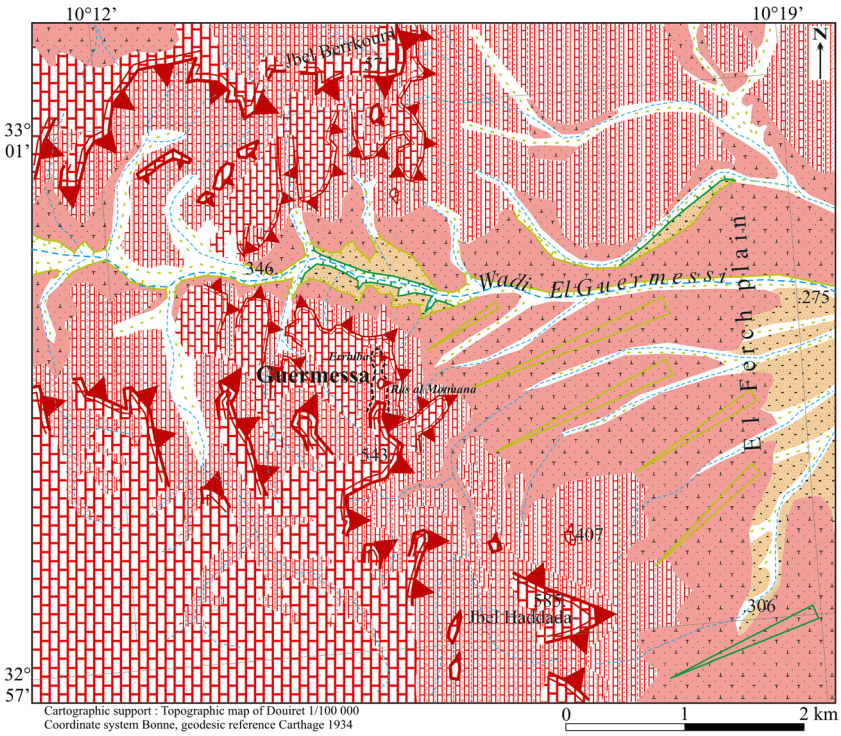


Fig. 9 Geomorphological croquis of Guermessa area (*same legend as* Fig. 4)

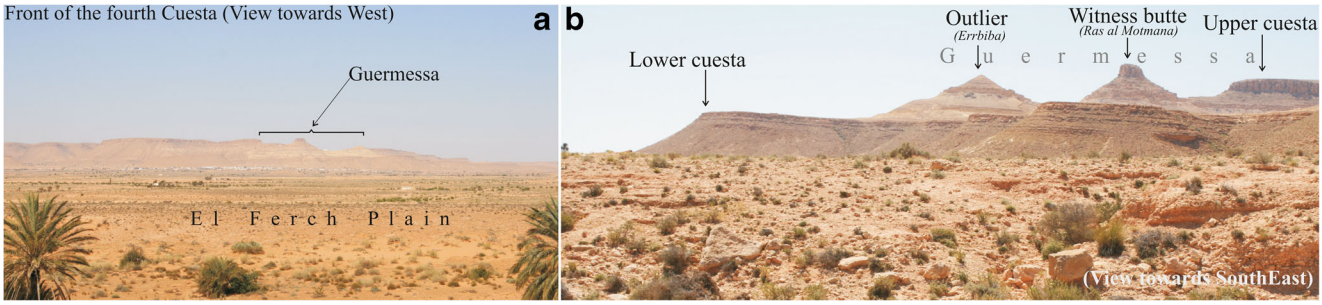


Fig. 10 **a** The front of the fourth cuesta dominating El Ferch plain. **b** Double cuesta of Guermessa

Many are the reasons behind inhabitants of Haddej establishing their dwellings under the ground and choosing to dig deep to cover all traces of human existence. It is obvious that this choice was motivated by safety reasons as there was a need to be perfectly concealed from invaders, especially because the Dahar region had known long periods of insecurity. This style of habitat was also cheaper for the inhabitants and did not require much building materials as wooden branches were sufficient for the doors. It also allowed for the inhabitants to be close to the fields and, in that regard, one may notice its development in correlation to the inhabitants' descent (from the highest part of the plateau to the lower plains). The cave dwelling habitat also represents a perfect adjustment to the climatic context characterised by unbearable heat in the summer. Cave dwelling houses are isothermal, cool in summer and warm in winter, with a temperature of about 25 °C all year round.

The excavation of a *hush* ("house in depth") is far from being a simple architectural work; there is a cultural model and skill involved. The location was meticulously selected (Boukhchim 2011). The dwelling layout requires it to be dug in a hill that is superior in height to the depth of the courtyard (that is 8 to 10 m) whose level must be lightly superior to that of the access corridor, which leads outdoors (Prost 1954; Libaud 1986) (Fig. 8). The dwelling hole was dug in the clay-sandy formations, solid in themselves, but friable under the pickaxe. It started with digging the well to a well-calculated depth, then the drawing of the openings of the ground floor rooms, which were dug horizontally, in addition to another opening to dig the access tunnel. This habitat method judiciously meets the material means as well as the needs of the inhabitants.

In Haddej, three types of large-sized cave dwelling houses may be distinguished:

– Type 1 (Fig. 14): In-depth cave dwellings are dug at the beginning in the shape of square, rectangular or circular wells. The digging of the well, which corresponds to the courtyard, must reach the depth beyond the superior part of the friable silts to the part, sufficiently consolidated, in which the rooms are excavated. In order to forestall the effects of storms on the walls of the courtyard, small stone walls are created (Ben Ouezdou 2001). The entrance is set up so as to link the courtyard with the exterior, closed off by a wooden door. On the other hand, the rooms are set up laterally, on one or two levels. The rooms are dug and set up in the shape of arches, which are supported, in case of heavy load, by a pillar preserved when the excavation took place. The shape of the room is rectangular and will meet different needs. The bed is placed in the middle of the room and seems stuck to the floor. Facing the entrance, one of its sides is graven in small columns and white edges. The bed is surrounded by furniture, which is

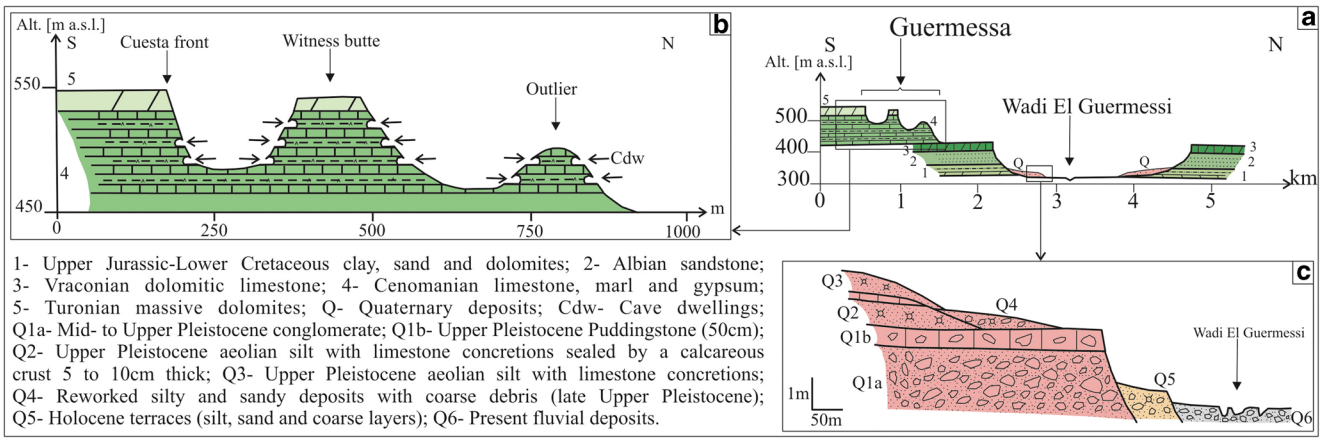


Fig. 11 Morphostructure and Quaternary inheritances around Guermessa

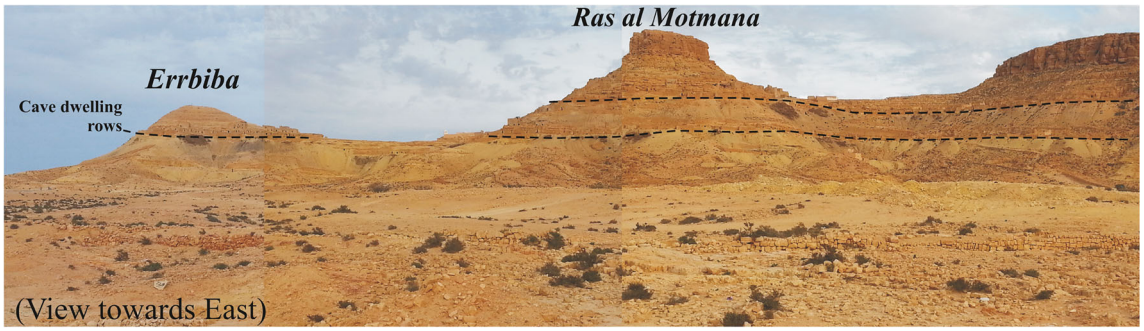


Fig. 12 Geomorphological context of cave dwellings rows

embedded in the walls of the room, with shelves used as a cabinet (Bruun 1898). The entrance is the equivalent of a hall set up in the shape of a corridor-tunnel, a pathway which is also hollowed out in the thickness of the silt, often shaped into a chicane route and may itself include little rooms and shelters for animals. Family relationships usually require the proximity of houses, which are sometimes connected by a tunnel, allowing members of the same family both proximity and autonomy. This complex architecture gives the dwelling a "Flower" form (Fig. 14).

- Type 2: The second type is partially buried and has no access corridor, which is replaced by a simple open-cast hall, slightly inclined outwards. This hall leads to the well in which the (dwelling) rooms are generally set up on one level.
- Type 3: The third type is a semi-troglodyte dwelling. In this type of house, inhabitants combine a section dug into the silts and a second one, which is built. The first dug out section is kept as accommodation, while the stone-made sections are either used as accommodation or as outbuildings sheltering domestic animals.

In cave dwelling houses, all the rooms are vaulted while in rooms designed for storage, there is an opening at the top, called *gorra* or *mçab*, allowing grains or beans to be poured directly into the granary/attic, without having to bring them in on a camel's back or through the access corridor (Boukhchim 2015).

In the village of Haddej, many families own an underground plant oil mill, quite close to the house. It is accessible through an open-cast hall as it would be difficult to lead a camel or a horse weighed down with olives through a long tunnel. The oil mill is often made up of two work areas: facing the entrance is the millstone and on the right and left are the balers. The grinding of olives is achieved by a millstone with a horizontal axis turning around a vertical one. Such a millstone is pulled by a camel or a horse whose eyes have been covered beforehand. A stone-made frame, covered in slabs, which are set up in a circular fashion, plays the role of a lower millstone. It is between these two parts that olives are ground. The first oil can be collected at that point but the essential part of the oil remains within the paste made up of ground pulp and stones (Louis 1968; Ben Ouezdou 2001; Boukhchim 2011, 2015).

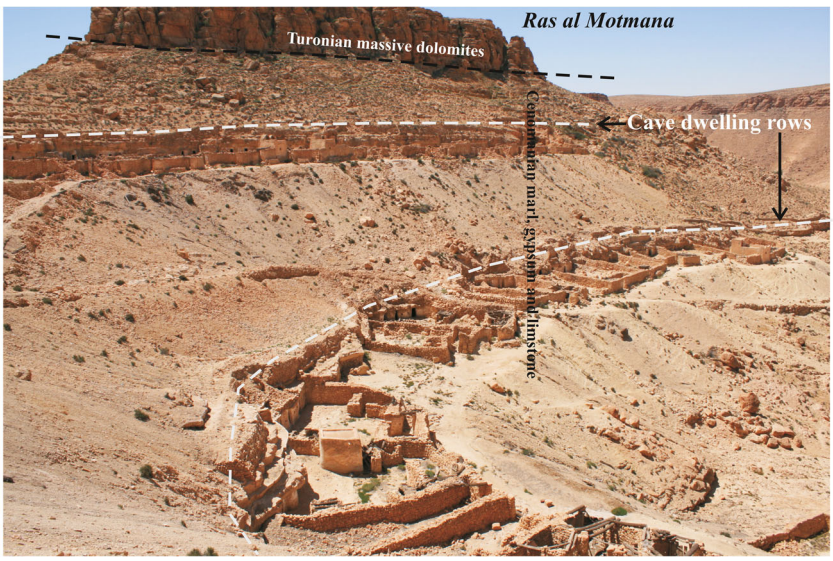


Fig. 13 Cave dwellings rows under Ras al Motmana witness butte

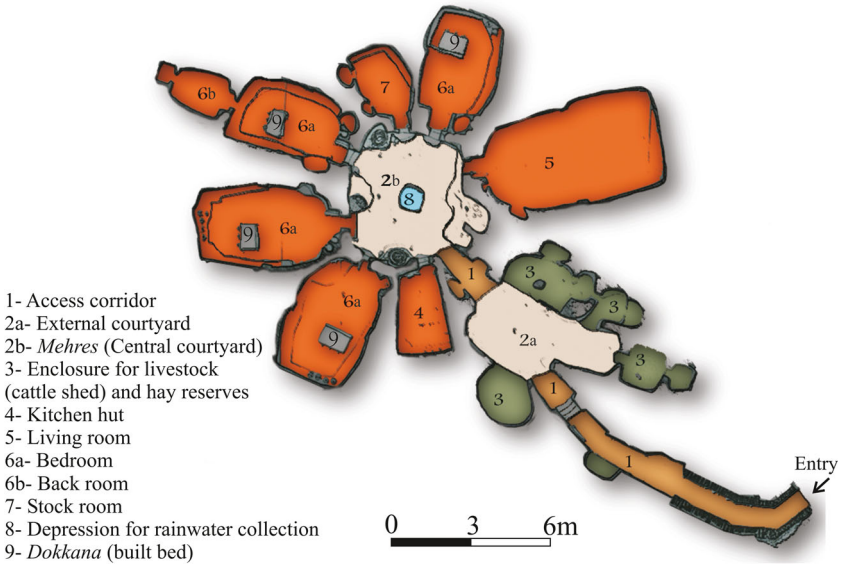


Fig. 14 "Flower" architecture of "vertico-lateral" cave dwelling in Haddej

Guermessa: Lateral Cave Dwelling

Guermessa is a fortified village, which occupies a strategic position opposite to the El Ferch plain (Fig. 10a). It gathers within the same site the necessary components of a human group. It sums up the habitat style in the cuestas of Southeast Tunisia: a refuge-citadel, a collective attic or *ksar*, a small village and a hinterland (Louis 1975). The village is situated 20 km northeast of Tataouine along the same cuesta system, which shelters the villages of Douiret and Chenini. Its foundation remains a mystery. All that is currently available about the village is a few legends alluding to the name of a certain Youssef Dahmani who supposedly came from Morocco in the eighteenth century to settle in Kairouan. His son, Ibrahim Dahmani, carried his trip to the South until he reached a location near the current site of Guermessa on a peak called Djebel el Qedim (Zaied 1992). Hamza, one of Ibrahim's sons, chose the current site of Guermessa to find a village. His tomb, still worshipped by the inhabitants of the new village, is an obvious mark of gratitude. In spite of the legendary nature of Guermessa founding story, a few historical realities may be retained. Starting from the eighteenth century, the *Ifriqia* had witnessed waves of holy men who came from Morocco with the *Almohade*. They conquered the whole territory of the country and contributed to the settlement of tribes and the urbanisation of certain regions. Many villages owe their foundation to a marabout, which represents, besides its *Zaouia*, the kernel of the inhabitants' settlement.

The natural site is a major factor in the choice to found a huge village like Guermessa. Other factors like safety, the possibility to communicate with other sites, the defensive aspect, water and a hinterland for agriculture were necessary to the settlement. The village is situated on two uneven summits:

1. The lower summit (outlier of Errbiba), conical and narrow, on which sits a marabout, with on its eastern slope rows of dwellings (Fig. 12) following contour lines and a mosque (Zaied 1992);
2. The higher summit (witness butte), with the *Galaa* (citadel) on its top, which is surrounded by the rows of horizontal cave dwelling houses (Figs. 10, 11 and 12). It plays a major role in terms of surveillance. All that remains of this refuge are ruins and traces of a rectangular cistern, which must have been used when the village was threatened or under siege. This witness butte played the role of a refuge-citadel as well as that of a watchtower, which allowed the inhabitants to control the whole surrounding territory and to communicate with the other *Galaa* of ksar Mrabtine eastwards, kef Mzenzen northwards and Douiret southwards.

About 60 m down the summit's southern slope, a fortified collective attic (the *ksar*) was built (Louis 1975). It was designed for the crop storage of all the village inhabitants. Its location was strategic and easy to protect. Such storage style, in a collective attic in the village, allowed the families to keep their food reserves within reach and in a place that was protected all year round. At the same level as the attic, southwards, the mosque of sidi Said was built on limestone slabs of the Cenomanian; there is a little marabout on its western wall. This mosque's dimensions are small as there are three bays and five naves. Two niches in the *Qibla* wall (wall oriented in the direction of Mecca, holy place of Islam, faced by a Muslim when praying) play the role of *Mihrab* (a niche in the wall of a

mosque, which points to the *qibla*), relatively simple and small. The presence of two mihrabs not only means that the oratory was expanded, but also that it witnessed the coexistence of two religious factions: the ibadites and the malikites. This mosque has a little and simple minaret. A few inscriptions on the inside walls of interior arches provide information about the name of the builders and display a date: "1277 year of Hegira /1860 C.E"; it is the date of the oratory's expansion and renovation works. On the roofs of the ksar's storage rooms as well as inside the mosque, there are ornament patterns in relief. These are drawings of a foot, a hand or an artisan builder's tool. These patterns are linked to a local art inspired by the common cultural heritage of the Tunisian South. Next to the mosque, on stone slabs, many marks of feet and shoes contours could represent the graphic memorisation of an ancestral Berber tradition related to marriage rites (Ben Nasr 2016). At the same level as the mosque, a cemetery is dedicated only to children; it is set up in such a way as to gather an important number of little graves. The other cemeteries are located below, in the western part of the village, and are distributed in a manner, which allowed each area to have its own necropolis.

Above and all around the citadel, extending along many contour lines, the cave dwelling houses which are horizontally embedded in the soft rock of the Djebel's slopes determined the linear organisation of the village (Figs. 11, 12 and 13). The floors of houses spread over almost 2 km on both eastern and western slopes. The dwellings weave through the slope and develop into horizontal rows, overlooking little fields at the bottom of the slopes. The movement downwards continued due to demographic growth, which created other rows of houses all along the cliff. In front of each cave, a landing was set up; it was used as a communication path between the dwellings and led to the mosque or the oil mills.

People used to live in dwellings, which were carefully set up by taking advantage of the alternation of the Cenomanian soft and hard layers of the hilly area. Such alternation creates a superposition of more or less horizontal platforms so that the two hard layers constitute the roof of the excavation. Whenever a floor is full, people would settle on a second floor and always start by digging the *Ghar*, an area built into soft rock.

On the eastern and western slopes, Guermessa's town planning developed on two, sometimes three floors of houses, which are carved into the stratifications. This arrangement of dwellings draws attention to its organisation, its space management and division and mostly to the coexistence of two dwelling styles, which organise themselves around a central courtyard, forming a "Foot" architecture (Fig. 15):

1. Caves dug laterally in marl layers: there were two to three rooms with small entrances, which constituted the bedrooms of family members. As the family in Guermessa included many members, the house was made up of many caves placed side by side in a parallel manner on the slope and usually limewashed, separated one from the other by a component of the Djebel, rarely by a built wall. Generally, the biggest room was devoted to the common use of the family; this was where cohabitation took place and where women did the weaving. Another cave was reserved for the parents; it approximately measured 5 to 6 ft wide and 7 to 8 m deep and allowed setting up two rooms separated by a thin wall. The caves of newlyweds were divided so as to allow for intimacy.
2. The components of the built part of the house were made up of a stable, called *ghorfa* (i.e. storage room for the foodstuffs) and a *skifa* generally covered by branches. The house had a door, which was always located on the facade. The courtyard, which was generally protected by a curved entrance and a *skifa* (i.e. an entrance hall), was the woman's domain in which she carried out her ordinary domestic tasks (Louis 1975).

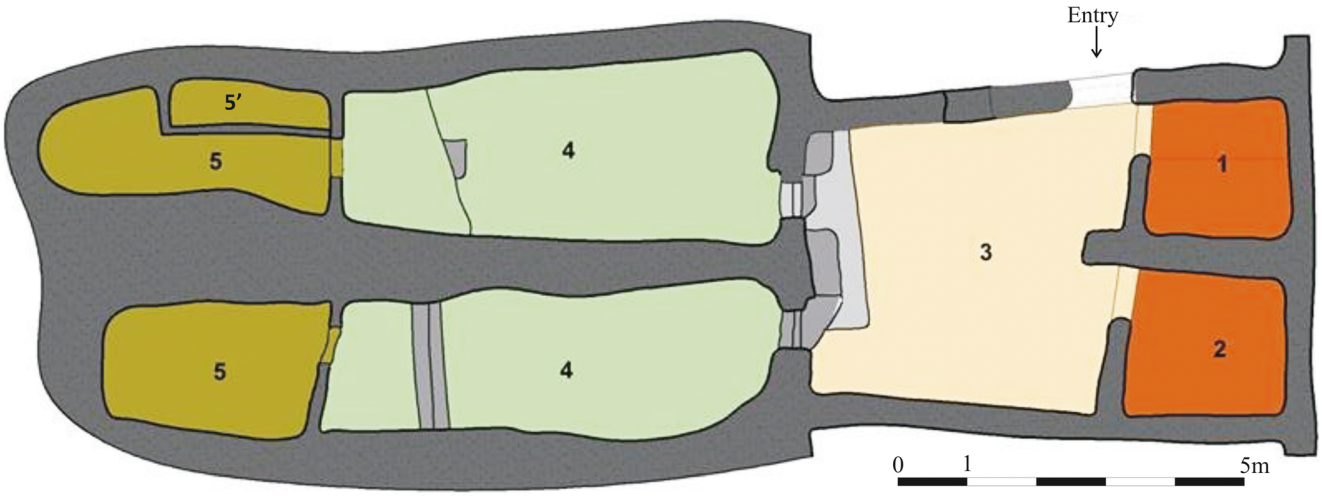
In front of each cave dwelling house, there was an expansion of the house; a shelter for cattle and a kitchen were set up. The whole arrangement is finished at the entrance by a *skifa* or entrance hall. The top of the house in Guermessa sometimes included an attic made up of many arched rooms. The presence of an area devoted to the ensilage of crops, forming one body with the rest of the house, reaches a milestone in the history of the village; it signifies the gradual relinquishment of the citadel-ksar, a collective tribal attic which is difficult to access, and the adoption of a new method that of the family's attic (Louis 1975).

Geomorphosite Assessment

The second step of the analysis was to assess each geomorphosite with the methodology developed by the University of Lausanne (Reynard et al. 2007, 2016; Fig. 1). An assessment card was filled for each site and proposals for the management were made, following the 2016 version of the method. The intrinsic value was assessed on a scale from 0 (null) to 1 (excellent). The additional values were assessed qualitatively.

Haddej Geomorphosite

Haddej geomorphosite is called "Haddej depression with reworked aeolian silts and cave dwellings". It is a relatively large site (6.8 ha) covering a large part of the aeolian deposits situated at the bottom of the depression. The intrinsic value is considered to be high, for scientific, aesthetic and cultural reasons (Fig. 16). The site is well preserved and representative



1- Shelter for cattle; 2- Kitchen; 3- Courtyard; 4- Bedroom; 5- Back room; 5'- *Khannaba*: secondary cave to store valuable things (jewellery, money, documents, rare foodstuffs)

Fig. 15 "Foot" architecture of lateral cave dwelling in Guermessa

of systems of depressions filled with aeolian silts in cuesta landscapes. It is not rare in the Matmata region, but so well-preserved sites are not so common. This geomorphosite concentrates various types of inheritances that allow the reconstruction of the Pleistocene evolution of the landscape. For all these reasons, the scientific value is high (0.88). Haddej depression has no particular ecological interest, but the aesthetic and the cultural interests are very high. For this reason, we can consider it a cultural geomorphosite. The landscape is harmonious, and vertical holes of cave dwellings give the area a lunar aspect. As developed earlier, the human infrastructures (cave dwellings, *jessour*) make this site a very interesting example of human adaptation to morphoclimatic conditions (aridity). The geomorphosite is not protected, and as the settlement is still partly inhabited, cave dwelling heritage can be damaged by human activity. Nevertheless, the threats remain low because of the very low human density and rural exodus. The threats are more related to abandonment than over-use by humans. The geomorphosite is well accessible by car, but no public transportation exists. There are no security problems for the visit of the village, except risks of roof collapses in cave dwellings. The whole landscape is very harmonious and calm, and no tourist infrastructures exist close to the site. The educational interest is high but communication on the site morphogenesis would need interpretation facilities that do not exist at the moment.

Guermessa Geomorphosite

Guermessa geomorphosite is called "Guermessa cuesta front with perched village and cave dwellings". It is a large site (18.3 ha) including the cuesta landscape and the Wadi El Guermessi valley. The geomorphosite has a high intrinsic value for scientific, aesthetic and cultural reasons (Fig. 16). The scientific value is very high (0.94): the site is well conserved and representative of cuesta landscape dissected by fluvial erosion in arid context and it is one of the best places in the region to observe cuesta landforms (double cuesta, witness butte and outlier) dissected by fluvial erosion; the Wadi El Guermessi valley allows observing several stages of Quaternary morphogenesis (Middle Pleistocene, Upper Pleistocene and Holocene deposits). The site has no particular ecological importance, whereas its cultural and aesthetic values are very high. The cuesta landscape is impressive with numerous viewpoints, and the perched and troglodyte village has a historical importance. For all these reasons, one may consider this geomorphosite as a geocultural site. As for Haddej, the site is not protected but the threats are unimportant. The geomorphosite is easily accessible by road and visits may be dangerous because of roof collapses. At the moment, the site is not exploited for tourism and there are no interpretive facilities.

Conclusion

The two investigated sites are typical geocultural sites of Southeast Tunisia, where man has adapted to the geomorphological context to create habitats integrated in the landscape, hard to spot by the enemy. These cultural geomorphosites have a high intrinsic value for scientific reasons, as well as aesthetic and cultural interests. Both sites are characterised by cave dwelling heritage, but characteristics are different: in Haddej, the presence of thick aeolian deposits allowed digging vertico-lateral caves, whereas in Guermessa, the troglodytic habitats were installed horizontally in soft layers of Cenomanian. In this sense, they are representative of two types of cave dwellings taking into account the

Fig. 16 Assessment of Haddej and Guermessa geomorphosites using the Reynard et al. (2016) method

Scientific value	HADDEJ		GUERMESSA	
Integrity	Well-conserved landscape	1	Well-conserved landscape	1
Representativeness	Representative of systems of depressions on plateau morphology	1	Representative of cuesta landscapes dissected by fluvial valley systems	1
Rareness	Kind of landscapes quite common in Southeast Tunisia	0.5	One of good sites to observe cuesta landscape	0.75
Palaeogegraphical interest	The Pleistocene evolution of landscape is particularly well visible	1	Pleistocene and Holocene stages of landscape evolution are well visible	1
SYNTHESIS	Site with a high scientific value	0.88	Well-conserved landscape	0.94

Additional values	HADDEJ		GUERMESSA	
Ecological value	Steppic vegetation not influenced by the geomorphology. Degraded soils	No	Steppic vegetation not influenced by the geomorphology. Degraded soils	No
Aesthetic value	Harmonious landscape	High	Typical cuesta landscape with impressive cliffs	High
Cultural value	Cave dwellings. Arab culture. Jessour (hydraulic infrastructures)	High	Cave dwellings. Religious and defensive site since Roman time	High

Use characteristics		HADDEJ		GUERMESSA	
PROTECTION	Protection status	No legal protection	No	No legal protection	No
	Damages/Threats	The site is partly a living village. Cave dwellings can be disturbed by the village activity	Fair	The site is abandoned. Vandalism is possible	Few
VISIT CONDITIONS	Accessibility	Good accessibility by road. No public transportation	Good	Good accessibility by road. No public transportation	Good
	Security	No security problems for the visit of the village. Risks of collapse in cave dwellings	Fair	No security problems for the visit of the site. Risks of collapse in cave dwellings	Fair
	Site context	Harmonious and calm landscape	Good	Impressive landscape. Panorama	Good
	Tourism infra-structure	No infrastructures close to the site	No	No infrastructures close to the site	No
EDUCATION	Interpretive facilities	No interpretive facilities (in situ and ex situ)	No	No interpretive facilities (in situ and ex situ)	No
	Educational interest	The interpretation of the morphogenesis needs interpretation facilities	High	The site is quite easy to decifer. Interpretation facilities should be developed.	High

geomorphological context. The two sites are easily accessible by car and inserted in calm and harmonious landscapes, which makes them interesting sites to visit. Nevertheless, at the moment, no tourist and interpretive facilities are available. The

potential for geotourism is clearly present (Ben Fraj 2017), but a SWOT analysis needs to be carried out to assess it.

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