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Geological heritage in the M'Goun geopark: A proposal of geo-itineraries around the Bine El Ouidane dam (Central High Atlas, Morocco)

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A B S T R A C T

The surrounding area of the Bine El Ouidane dam in Central Morocco, has significant potential for the development of geotourism due to its historic, geological, biological, and cultural heritage. However, these valuable resources, constituting a real opportunity for sustainable development of the local economy, remain ignored and underexploited by decision-makers. This work aimed to overcome this gap by identifying and selecting remarkable geosites in the area of the Bine El Ouidane lake, and then by proposing itineraries that help promoting this mountainous area. Two geoitineraries were developed based on the accessibility, touristic attraction and trekking opportunities. Eight highly attractive sites were highlighted according to their geological characteristics, scientific and contextual interests, and relevance. All these geosites present scientific interesting topics regarding sedimentology, stratigraphy, paleontology, magmatism, structural geology, geomorphology, hydrogeology, and karstification, belonging to the central High Atlas post-Variscan sedimentary and structural evolution. These sites can constitute a tool for the development generating work for the inhabitants to ensure their sedentarization.

1. Introduction

Heritage and in particular cultural and geological is today a central concept in debates on sustainable development and recomposition of territories. The diversity and state of conservation make the heritage important and necessary to integrate into process of development and regional planning (El Ansari, 2013). In this perspective, geological, natural and cultural heritage became widely employed as a primary attractiveness to visitors and tourists that admire the living style of riparian. Overall, the importance of this heritage in informing and educating general public, in accordance with the conservation of the sites by local community and visitors, the economic development has been widely discussed in the last two decades (Brilha, Gray, Pereira, & Pereira, 2018; Gray, 2013; Ruban, 2017; Slaymaker, Catto, & Kovanen, 2020; Stavi, Rachmilevitch, & Yizhaq, 2019; Thornbush & Allen, 2018; Turner, 2019). The added value of a heritage-rich area is assessed through a complete description of the characteristics of each heritage site (inventory and identification), then by a value evaluation based on quantitative methods (Gray, 2013; Zwoliński, Najwer, & Giardino, 2018).

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Morocco is endowed with a great diversity of reliefs and picturesque landscapes making it a paradise for geologists (Michard, Saddiqi, Chalouan, & de Lamotte, 2008). This diversity is greatly linked to its geological history modeled since the Precambrian era by four orogenies (Michard, 1976) and several cycles of sedimentary and magmatic formations with a unique lithological and paleontological richness. The country has also a very marked climatic diversity playing a large role in the landscape and geomorphological variety (reliefs, gorges, desert, waterfalls, beaches, lagoons). Consequently, the Moroccan geodiversity is an asset of remarkable interest from a scientific as well as a geotourism point of view (Beraaouz et al., 2019; Oukassou et al., 2019). In the last decades, many studies on Moroccan heritage were carried out for highlighting the sites richness and stated that Morocco has the most important diversity of cultural heritage and geoheritage (Arrad, Errami, Ennih, Ouajhain, & Bouaouda, 2020; Berred et al., 2019; Martínez, Fernández, & Hermida, 2017; Mehdioui et al., 2020; Taïbi, Aïtomar, El Hannani, El Khalki, & Reddad, 2018). Due to the rising awareness of heritage valorization and conservation and its impact on the local and national income, Morocco has started to promote sustainable regional development and tourism through the creation of natural parks.

The Béni Mellal-Khénifra region has specific assets that make it of strategic interest. It is endowed with natural (water, geological and biological), cultural, historical, architectural, and archaeological resources which constitute an interesting support for the development of tourism and in particular the geotourism. Indeed, the altitude of this region ranging between 2000 m and 4000 m allows the abundance of snow in winter offering a beautiful mountain karst landscape, flora and fauna diversity, dinosaur footprint abundance, and richness in earthen architectural heritage (attics) (AMINE, BERRAHMA, & AARAB, 2014; Bouzekraoui et al., 2016; El Hannani, Taïbi, El Khalki, & Benyoucef, 2009; Ishigaki & Lockley, 2010; Oiry-Varacca, 2013; Taïbi, Hannani, Khalki, & Ballouche, 2019). The labeled M'Goun Geopark, located in the region, constituting the first protected geological reserve in Morocco, reinforces the strategic importance of this region. In fact, the Béni Mellal and Azilal provinces constitute tourist potentials coveted by national and international visitors. The diversity of its landscapes and architectural and cultural heritage give the region an important tourist potential, especially geotourism, which deserves to be better studied and valued.

The presence of an exceptional Geopark; the M'Goun Geopark, located between the town of Béni Mellal in the North and the Ighil M'Goun ridge line in the South (Azilal town) constitutes the first protected geological reserve in Morocco. Due to the certification of M'Goun Geoparc in 2014 and UNESCO in 2019 and to guarantee the sustainable development of the region, local decision-makers and scientists have become aware of the value of this natural heritage and the need to assess and protect the sites. Nevertheless, the concept of geotourism developed, as an emerging face of tourism, is far from being achieved in Morocco, and especially in the M'Goun Geopark area. Also, there has been an important transformation of the region infrastructure making easy the accessibility to the Geopark. Moroccans have started to go out to visit their regions and practice several sports (hiking, trekking, speleology, climBing, nautical activities …). The rural population is economically integrated into this change, proof of the increase in the number of cottages and guesthouses. In the study area, the shores of the lake are well exploited for tourist purposes (hotels high-end hotels, leisure centers, nautical activities, etc.). These modifications that the region has undergone have accelerated the region's economic development.

In this context, this work aimed to: (1) identifying, inventorying and characterizing the specific heritage resources to be exploited for providing benefits for the local community, and (2) proposing suitable tourism itineraries connecting particular sites of geotourist interest. The investigation concerned the area of geotourist potential of Bine El Ouidane Dam in Azilal province, Morocco. This will contribute to provide useful data and information for any new local sustainable management plan and to formulate effective measures to improve heritage conservation.

2. Study area

The Bine El Ouidane dam is located in the Azilal mountain province (Morocco) between 32° 06′ 24″N to 32° 06′ 24″N latitude and 6° 27′ 50″ W to 6° 27′ 50″ W longitude. The Bine El Ouidane Lake is located 60 km from Béni Mellal, 30 km from Azilal, 70 km from Ouzoud waterfalls site, 200 km from Marrakech, and 200 km from Casablanca (Fig. 1). The Casablanca - Béni Mellal highway has reduced the transit time between the city of Béni Mellal and the kingdom's economic hub to 2 h, which has resulted in a significant number of visitors over the past 4 years.

The study dam, one of the main dams in Morocco, received water from Oued El Abid and El Hansal Rivers draining a catchment area of 6400 km^2. It is surrounded by some rural agglomerations, with an estimated population of 23,400 inhabitants according to the High Commission for Planning (HCP, Morocco) data (RGPH, 2014). The population of the area are Amazigh Berbers rich in millennial cultural heritage (moussems, crafts: carpets, and tools made from dwarf palm leaves), this could play an important advantage in the economic and commercial development generating income. Agriculture, arboriculture, and livestock are the main economic activities in the region. The study area offers various forms of tourism: green tourism, hiking tourism, tourism related to hunting and fishing, ecotourism, and geotourism.

The study area has a temperate to warm climate with changes between rainy conditions during the winter season (from November to April) and low moisture in the summer season. The average annual temperature of the study area is 15 °C and the average annual precipitation is 560 mm. The driest and hottest month of the region is in July. Important snowfall budgets are observed at altitudes of about 800 m (USAID, 2010). The vegetation cover in the Azilal province is composed of an imposing mantle of endemic spurge mixed with dwarf palm (Doum) and Lentisques, green oak, Aleppo pine, carob, thuja, juniper, olive and almond trees. This diverse vegetation constitutes an important heritage to be taken into account in all geotourism circuits.

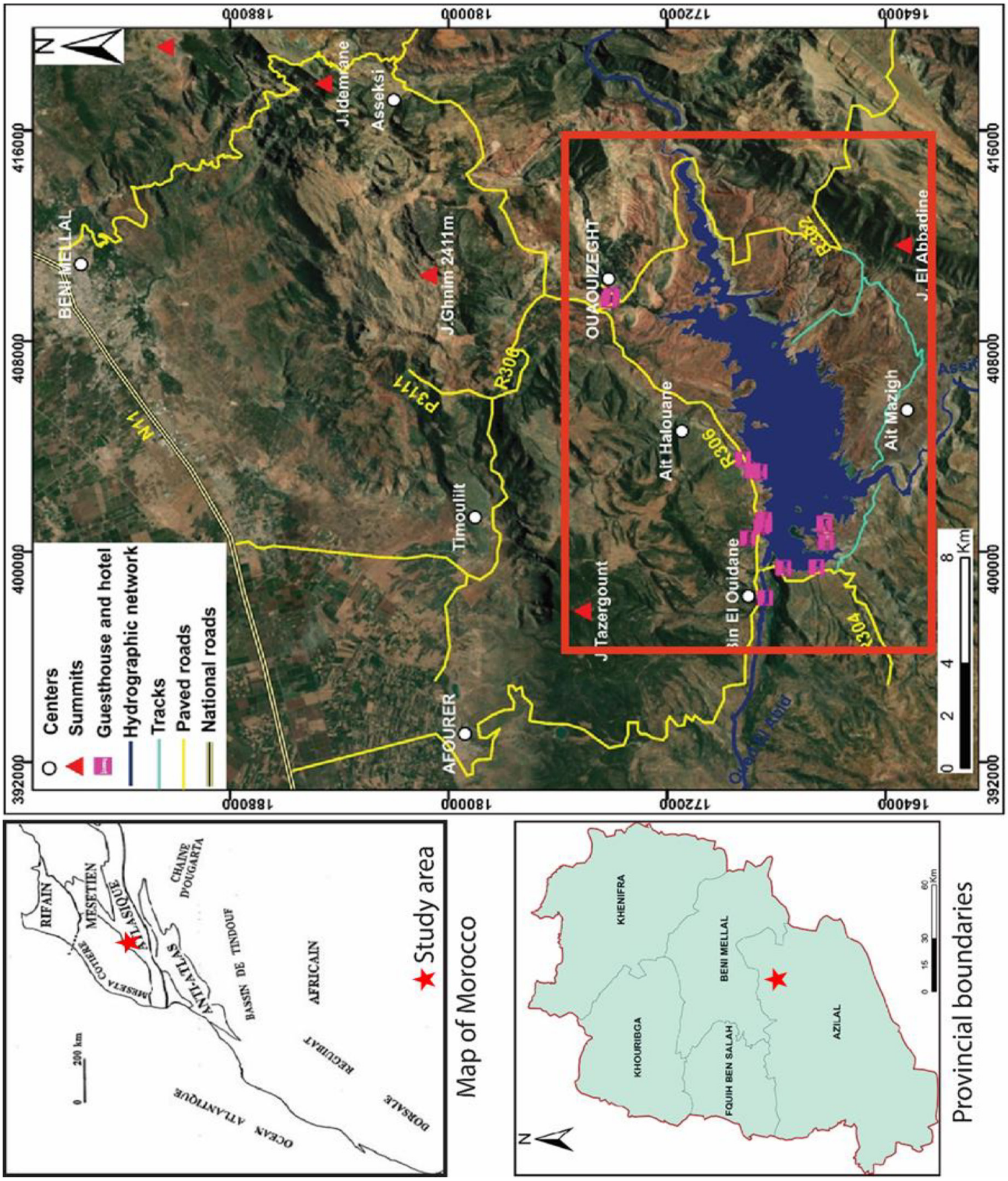

Fig. 1. Location of the study area.

2.1. Geology

The Bine El Ouidane Dam is a mountainous area located in the North of Azilal city and to the South of Beni Mellal city. It is part of the Central High Atlas chain. The dam is surrounded by relatively high mountains: Tazerkount (1730 m a.s.l.), the Rhnim (2411 m a.s.l.), and the Tassemit (2148 m a.s.l.) in the North and El Abbaddine (2150 m a.s.l.) in the South.

Regarding geology, the Central High-Atlas has already been the subject of numerous geological works from a sedimentological, stratigraphic, structural, magmatic, and mining investigations (Andreu, Colin, Haddoumi, & Charrière, 2003; Charrière, Haddoumi, & Mojon, 2005; Dresnay, 1971; Du Dresnay, 1975; Guezal, El Baghdadi, & Barakat, 2013, 2015; Guezal, El Baghdadi, Barakat, & Raïs, 2011; Haddoumi, 1988; Haddoumi, Charrière, Feist, & Andreu, 2002; Haddoumi, Charrière, & Mojon, 2010; Jenny, Le Marrec, & Monbaron, 1981a; Jenny, Le Marrec, & Monbaron, 1981b; Laville, 1981; Laville, 1985; Monbaron, 1978; Monbaron, 1983; Mouguina, 2004; Nouri, Pérez Lorente, & Boutakiout, 2000; Pique et al., 1998; Septfontaine, 1984; Souhel, 1987; Souhel, 1996; Souhel, El Hariri, Chafiki, & Canerot, 1998). The Central High-Atlas corresponds to an intracontinental chain associated with the Alpine compression system related to the collision between Europe and Africa (Mattauer, Tapponnier, & Proust, 1977; Michard, 1976). In the upper Triassic an important Atlas rift system (High and Middle Atlas) was developed, followed by Liassic carbonate sedimentation. Then, in the Upper Toarcian, a second extensive episode dislocates this platform. However, from Cretaceous to Neogene, the convergence between Africa and Europe caused the uplift of the High Atlas basin, and the post-Hercynian cover composed of thick red continental series and limestones was folded giving large synclines with a flat bottom and calcareous wrinkles oriented E-W.

In the study area, the panoramic views of the geological formations allow retracing the geological history of the Atlas of Béni Mellal- Afourer from the Triassic to the Lower Cretaceous. The main formations are of lower Jurassic-Cretaceous age, the division of which takes into account the major terrigenous-marine cycles (Souhel, 1996) (Fig. 2). As represented in the stratigraphic scheme of Fig. 2, these formations can be divided into Bine El Ouidane Group, Tilouguite Formation, Guettioua, Iouaridene, Jbel Sidal, Ouaouizaght and Ben Charrou (Haddoumi et al., 2010; Monbaron, 1982; Monbaron, Dejax, & Demathieu, 1985; Souhel, 1996).

The **Bine El Ouidane group** represents with the Tilouguite Formation the last major transgressive Jurassic event in the High Atlas Central ((Monbaron, 1982; Monbaron et al., 1985; Souhel, 1996). The Bine El Ouidane group of Upper Aalenian - Bajocien age (Souhel, 1996) is made up of three superimposed formations named Fm BI, Fm BII, and Fm BIII.

The Fm BI with a thickness of 110 m is a set of dolomitic limestones, greenish gray, forming the cliffs of the gorges of Oued El Abid on which the dam dike was built. The Fm BII having a thickness of 120 m is composed of beige marls, sometimes greenish, and intercalations of fine limestones loaded at the top with lamellibranchs, brachiopods, gastropods and gorgonians. The Fm BIII of thickness 45 m consists of alternating bioclastic marls and limestone-lined onchoid limestones with local coral masses, and rhynchonelles at the base.

The Upper Bajocian-Lower Bathonian **Tillouguite Fm** (Souhel, 1996) overlapping the Fm BIII represents the last Jurassic marine witnesses. It contains sandy marl and carbonated silts rich in brachiopods and lamellibranchs, and at the top, by sandstone, silts, and red clays. Its yellow to beige color on the surface announces the Upper Jurassic regression marked by upper terrigenous deposits or red layers (Jenny, 1985).

The Guettioua Fm (Jenny et al., 1981a) of Bathonian age (Souhel, 1987; Charrière & Haddoumi, 2016; Haddoumi, 1988; Haddoumi et al., 2010; Souhel, 1996) is represented by an alternation of lenticular sandstones, clays, silts, conglomerates and microconglomerates reflecting a continental alluvial environment. This formation contains better deposits of bones and footprints of theropod and sauropod dinosaurs (Monbaron, 1983; Monbaron, Russell, & Taquet, 1999; Souhel, 1996); (Amine, Berrahma, & Aarab, 2018; Nouri et al., 2000; Souhel, 1996). Many gabbroic intrusions, veins, dykes and basaltic lavas have also been produced through important magmatic events (Bensalah et al., 2006; Beraaouz, 1995; Bertrand, 1991; Bougadir, 1998; Dubar, 1943; Guezal et al., 2011; Guezal et al., 2013; Zayane et al., 2002).

The **Iouaridene Fm** of the Upper Jurassic – Lower Baremian age occupies the axes of the high-Atlas synclines (Haddoumi et al., 2010; Jenny et al., 1981a). It is characterized by meter-thick series of red clays and pelites and beds of fine sandstone overcome by greenish clays and beds of whitish to greenish sucrosic gypsum. These deposits illustrate an environment of playas at the base and evaporitic at the top (Souhel, 1996).

The Guettioua, Iouaridène and Jbel Sidal Fms are made up of superior terrigenous, witnesses of a general regression during the Middle-Upper Jurassic (Choubert & Faure Muret, 1962); (Jenny et al., 1981a), (Souhel, 1996).

The **Jbel Sidal Fm** developed during lower Cretaceous age is made up of an alternation of cross-stratified red sandstone (2–7 m thick) with current ripples, and of floodplain red clays (1–6 m thick). These rocks mark a fluvial environment ((Haddoumi, 1988; Souhel, 1987). At the base of this formation, the basalt flow B2 related to the major effusive Upper Barremian event linked to the third extensive tectonic phase at the Lower Barremian - Upper Barremian passage (Haddoumi et al., 2010).

The **Ait Tafelt Fm** corresponds to the first Cretaceous marine manifestation in the Ouaouizaght syncline; it has a thickness of 50 m and represented by yellow marls and bioclastic marl-limestones. The facies are rich in Bedoulian Ammonites brachiopods and echinoderms (Souhel, 1987).

The **Ouaouizaght Fm** of Albanian - Cenomanian age is made at the base of an alternation of sandstone and clayey banks, typical of floodplain deposits, then of red clays with gypsum intercalations, typical of evaporitic lagoon sedimentation, and finally of yellowish limestones and marls (Souhel, 1987, 1996). These formations are surmounted by the Cenomano-Turonian stratum of the Ben Charou Fm, consisting on a set of metric benches of fine yellowish limestones with planktonic foraminifers and rare ammonites of Turonian (Souhel, Canerot, & Andreu, 1986).

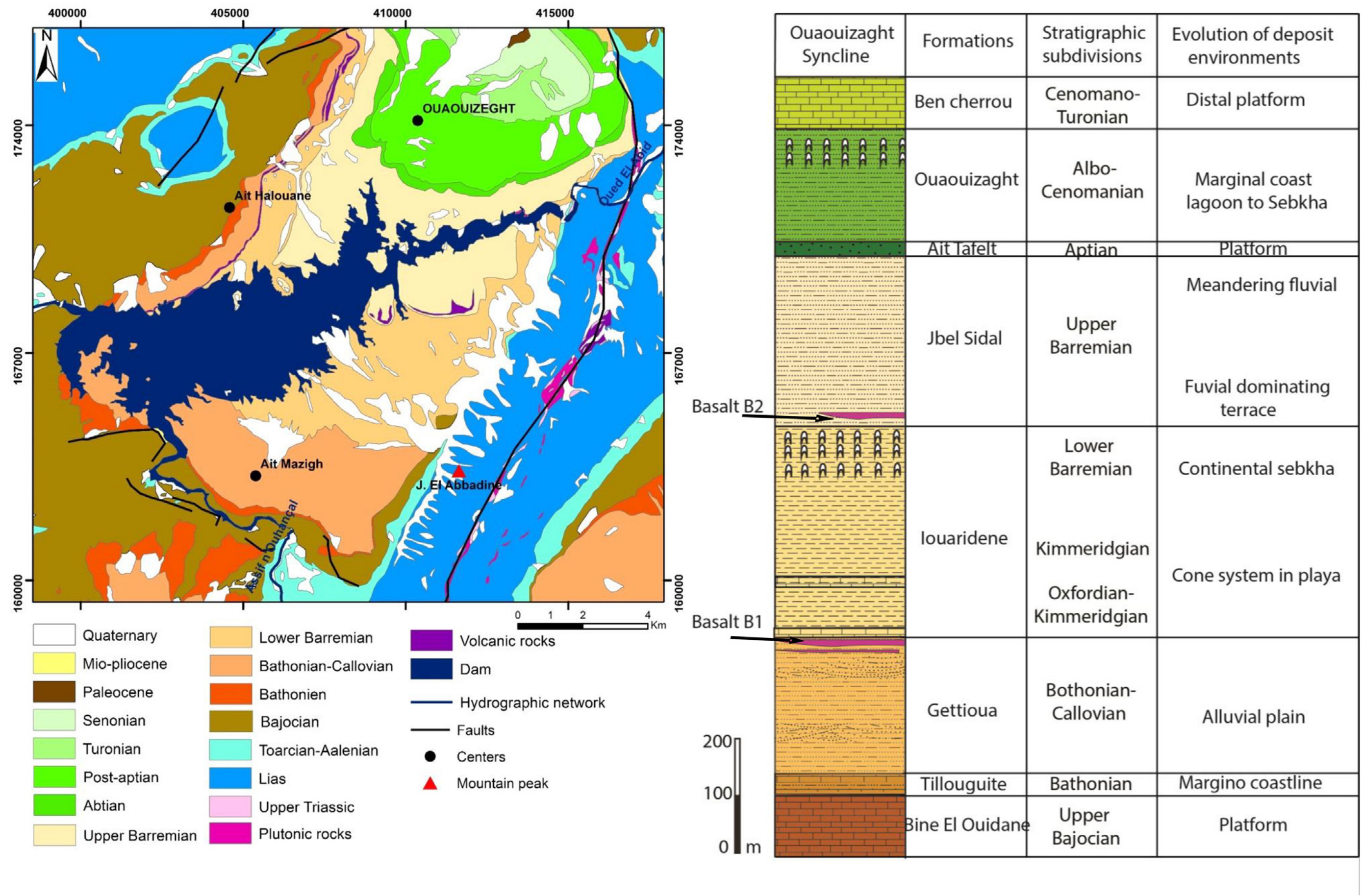

Fig. 2. Geological map (from geological map of Béni Mellal 1:100000) and stratigraphic column of the study area.

From the Cretaceous to the Neogene, the convergence between Africa and Europe caused the uplift of the High-Atlas, and the post-hercynian cover was folded, thus giving wide synclines with flat bottoms, filled with thick Jurassic and Cretaceous formations composed of continental red series that are most often strongly eroded and calcareous wrinkles oriented EW.

2.2. Methodology

The present investigation included in addition to geosites cultural and architectural heritage. The methodology adopted is based on a step sequence aiming to inventory, identify, descript, and evaluate sites with interest for their valorization and conservation. Inspired by previous research works (Brilha et al., 2018; Grandgirard, 1999; Mucivuna & da Glória Motta Garcia, 2018; Zwoliński et al., 2018), the methodology is based on scientific, educational and tourist criteria.

After an analysis of existing literature on the region and fieldwork, many specific geosites with a potential interest have been selected and studied using the above-mentioned criteria.

The detailed heritage inventory, the first step in the study, is accompanied by the complete framework of geodiversity, geoheritage, national geosites, and geotourism (Bouzekraoui et al., 2018; Bouzekraoui, Barakat, Touhami, Mouaddine, & El Youssi, 2018; De Waele & Melis, 2009; El Hadi et al., 2011; El Wartiti, Malaki, Zahraoui, Di Gregorio, & De Waele, 2009; Errami, Brocx, Semeniuk, & Ennih, 2015; Oukassou et al., 2019; Saddiqi, Rjimati, Michard, Soulaimani, & Ouanaimi, 2015); and international (Brilha, 2018; Brilha et al., 2018; Grandgirard, 1999; Gray, 2004, 2013; Mucivuna & da Glória Motta Garcia, 2018; Reynard, Perret, Bussard, Grangier, & Martin, 2016). The regional geological framework of the study area has been widely already discussed in previous research works (Du Dresnay, 1975; Dresnay, 1971; Jenny et al., 1981a, 1981b; Laville, 1981; Monbaron, 1983; Monbaron, 1978; Septfontaine, 1984; Laville, 1985; Souhel et al., 1998; Souhel, 1996, Souhel, 1987; Pique et al., 1998; Mouguina, 2004; Nouri et al., 2000; Haddoumi, 1988; Haddoumi et al., 2002; Haddoumi et al., 2010; Andreu et al., 2003; Charrière et al., 2005; Guezal et al., 2013, 2015). Without a doubt, the study region boasts by a complex geological history coinciding with the Mesozoic Era (Era of reptiles), and, thus, they possess various types of picturesque geoheritage that deserve being assessed and valorized, hence the interest in the present study.

To locate the sites and their access, geological (scale 1:1,000,000), topographic (scale 1:50,000), and road maps, satellite, and Google Earth images of the study area were used. On the field, the identified sites were georeferenced using a portable GPS, and their detailed description is complemented by taking photographs.

The scientific interest (SI) of the different sites along the proposed itineraries are assessed based on our scientific knowledge on the subject, and on the scientific data previously published on inventoried geosites. Other criteria such as representativeness, rarity, and relevance, have also been used to quantitatively evaluate the scientific interest (SI) of the stations of interest. Each criterion is separately scored from zero (0) star, corresponding to the lowest, to 4 stars, corresponding to the highest. The goatherd information following this approach allowed later to establish map and tourist circuits with interesting heritage types requiring enhancement and conservation.

3. Results

3.1. Identification of sites of interest

The results of analyzed heritage sites are presented as geo-itinerary. The proposed geo-itinerary estimated at 65 km is made of asphalted and passable roads linking several selected sites with stratigraphical, paleontological, structural, geomorphological, architectural, and cultural values (Fig. 8). This geo-itinerary can be used for educational, scientific, and tourism purposes. The eight heritage sites inventoried in the study area are described below.

The Bine-El-Ouidane Lake occupies the Ouaouizarth syncline basin. It is an asymmetrical syncline oriented NE-SW (Monbaron et al., 1985) (Figs. 1 and 2). Its North-west flank is well exposed in the landscape with the Limestone-cornices of the Bajocien (Fm BI-BIII) which support the dam, the multicolored marly-limestone deposits (Tillouguite Fm), then the red sandstones (Guettioua Fm) which constitute the first exclusively continental deposit of Bathonian-Callovian age (Stops 1, 2, 3 and 4) (Fig. 2). Its South-east flank, Red ocher, shows the progressive discordance of the red layers (Guettioua Fm, Iouridène Fm, Jbel Sidale Fm) on the anticline Liassic ridge of Jbel Abbadine.

This ridge constituted a permanent threshold during the sedimentation of the continental red layers (Monbaron, 1981; Monbaron, 1988). It would have been created by the "Bajoço-Bathonian paroxysm" of a compressive-transpressive type tectonics.

3.1.1. Geotouristic circuit

The proposed geotouristic circuit of Bine El Ouidane dam is 65 km long, this circuit contains 8 stops and it is divided into two itineraries that can be done by car or on foot. The first itinerary of 55 km is along the R306 and R302 road and carries stops 1 to 6, the second itinerary of 10 km is located at the South-west of Ouaouizaght syncline, there are stops 7 and 8 and ends at the outlet of river Oued Ahansal in front of stop 6 (Fig. 3). The trekking on the slopes NW and SE will allow discovering the Berber douars rich by their architectural heritage of stone and adobe and their history. This much diversified architectural treasures can be introduced as an activity of historical cultural tourism around Lake Bine El Ouidane. So, several easy hiking trails exist in the NW and SE slopes. Two architectural circuits (Ait halouane and Ait el Bakour) are proposed in this geotouristic circuit (Fig. 3).

- First Itinerary

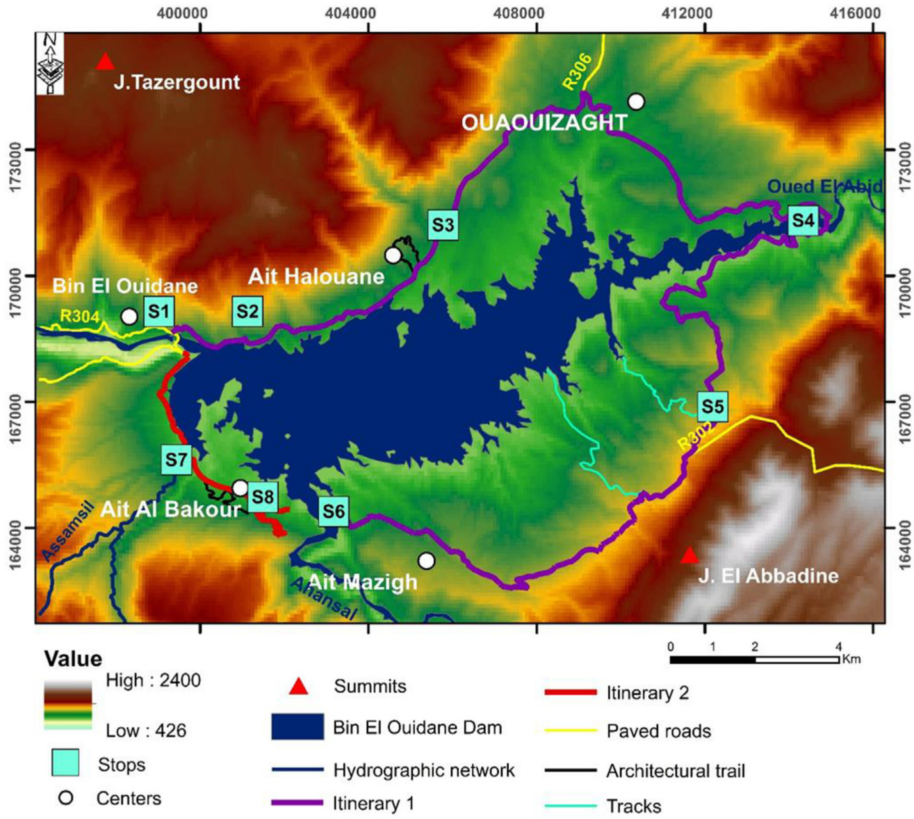

Fig. 3. Location of the two proposed itineraries including highly attractive sites for tourists and hikers.

The itinerary skirts alongside the dam lake via Ouaouizaght village.

Stop 1: Bine El Ouidane dam

The dike of Bine El Ouidane dam (32°6′32.20″N; 6°27′48.03″W) represents the starting point for the proposed geotour that may be done by car or on foot (Fig. 3A). This stop 1 offers a fabulous panoramic view of the lake, the dam, the river Oued Al Abid and the Bine El Ouidane Groups (Fm BI; Fm BII and Fm BIII) of Upper Aalenian - Bajocien age (Haddoumi et al., 2010; Souhel, 1996). With its 290 m length and 132 m height, the Bine El Ouidane dam dike has long remained the highest-arch dam in Africa. The Bine El Ouidane dam, built in 1949 and put into water in 1953, is a historical heritage, and was designed by engineer André Coyne. The dam is anchored in massive oncolithic limestones of the Fm BI (Fig. 4a). Constructed for energy and irrigation purposes, the dam has a lake surface of 37.4 km^2 with a maximum depth of 120 m. and a capability of storing 1.5 billion m^3. The water source of the lake is Rivers of Oued Ahansal and Oued El Abid (the name Bine El Ouidane means between rivers). The turbinated water at its foot is collected a few kilometers downstream and led by a 20 km gallery crossing of the liassic formations to the Afourer plant (the pumping station of energy transfer) start up in 2005, or released towards the two main canals NE and W of the irrigation system and allow, through an immense mesh of several hundreds of kilometers of channels, the irrigation of 112,000 ha in the large plain of Tadla (Fig. 4b).

The water reservoir is the seat of several water sports such as jet skiing, swimming, windsurfing, and sport fishing (carp, pike-perch, pike…) on an international scale. The reservoir also has a much diversified biological and ecological heritage. The lake has become thus stressed for nautical and leisure activities and fishing. Therefore, the dam that constitutes one of the indispensable destinations to visitors presents significant tourism and economic values.

At this point in the geotour, it is possible to observe different structural elements (high cliffs, faults, folds, strata dipping). Not far from there, a weekly market (Souk), still authentic, is held every Sunday and offers a weekly opportunity for trade (local products like fines, olive oil, honey, authentic baskets made by palm leaves (doum) …) and social exchanges between residents. The souk thus, represents the additional interest that should be used with the above-mentioned criteria in local economic development.

Stop 2: Dinosaur footprints

Located at about 1 km from the first stop, the stop 2 extending over 1.3 km can be reached on foot or by car enjoying along the way beautiful panoramic views of the lake and its SE side (Fig. 3). Also, it is possible to observe the transition from the carbonate BII and BIII Fms, marking the last Jurassic transgression of the Central High-Atlas, to the red detritic Tilouguite and

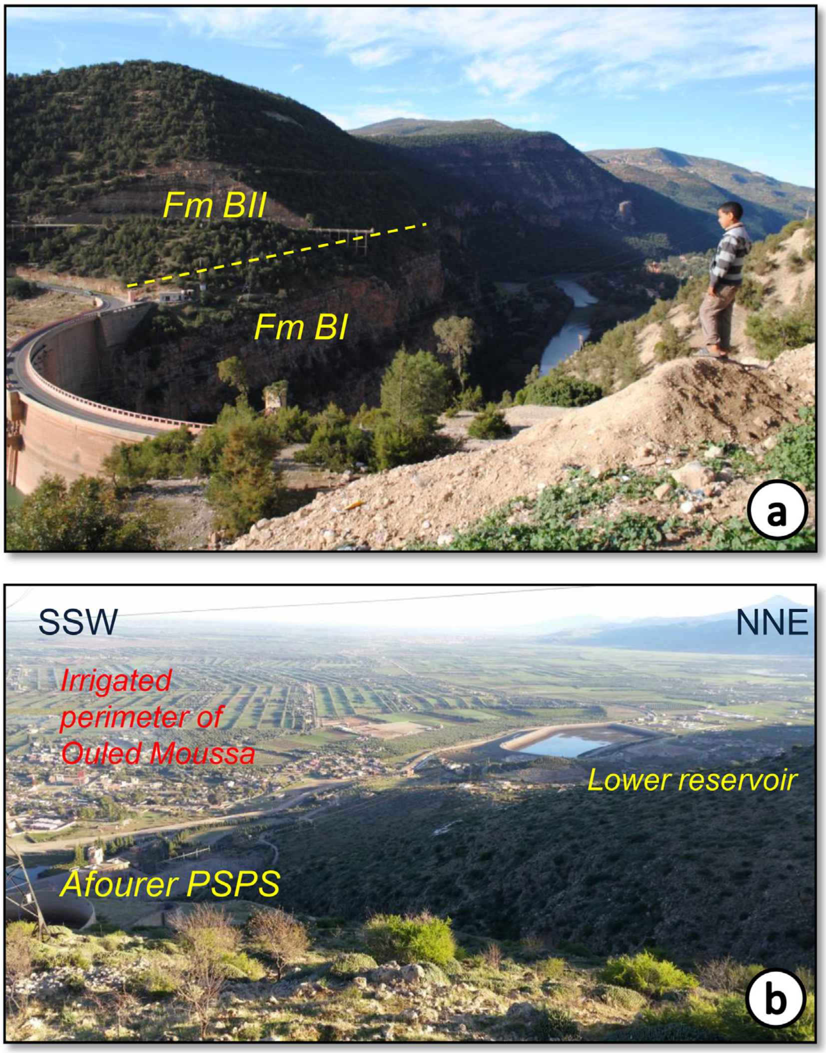

Fig. 4. Location of stop 1 offering a panoramic view on the dam dike and the surrounding landscape (a), and a panoramic view on the Tadla plain and the Afourer pumped storage power station (PSPS) (b).

Guettioua formations of the Upper Aalenian – Bajocien-lower Bathonien, reflecting a general Middle and Upper Jurassic regression (Souhel, 1996).

At the point located at 32° 6′24.89″N–6°27′29.98″W, it is possible to observe an overfold affecting the marl-limestones of Fm BII (Fig. 5a), reflecting alpine compression. To the top, this formation contains three rich condensed limestone levels (10 to 20 cm) made entirely of Rhynchonella-type brachiopods and big gasteropds (Fig. 5b). These condensed levels denoted “mfs” represent the maximum flooding of the platform (Souhel, 1996). The last fine black limestone beds of Fm BII contain a lot of large ammonites on its roof (Fig. 5c) as well as large lamellibranchs, gasteropods, and polypiers. This station is an important paleontological site due to its rich and diverse fossil records. At the turning point situated at 32° 6′23.08″N - 6°27′6.69″W, the road intersects the massive oncolitic limestones of Fm BIII. The last decametric beds are affected on their surfaces by yellowish meteoric dolomitization (Souhel, 1996) announcing the beginning of the regression of the Middle-Upper Jurassic (Fig. 5d).

When the Widian hotel is exceeded, the panoramic view (32° 6′24.85″N; 6°26′49.91″W) shows the passage of the marine carbonate deposits from FmBIII to the red layers (Jenny, 1985) forming the Upper terrigenous witnesses of a general regression of the Middle and Upper Jurassic (Jenny et al., 1981a; Souhel, 1996). The yellowish Tilouguite Fm of Upper Bajocian-Lower Bathonian age (Souhel, 1996) is visible and surmounted by the red alluvial continental deposits of the Fm Guettioua (Jenny et al., 1981a) of Bathonian age (Charrière & Haddoumi, 2016; Haddoumi, 1988; Haddoumi et al., 2010) (Fig. 5e).

The Tilouguite Fm contains a famous fossiliferous site with tracks of footprints of Theropod and Sauropod dinosaurs preserved in silt beds of Bathonian-age (165 Ma). On the roof of a whitish silt bed, there are four footprints of theropod dinosaurs with perfectly printed tridactyl footprints (Fig. 5e). These footprints are attributed to small-sized Saurischia dinosaurs (Nouri & Alemany, 2008). A meter above, oval footprints (of 30 to 40 cm in diameter) of a large herbivorous sauropod dinosaur lie on the roof of a

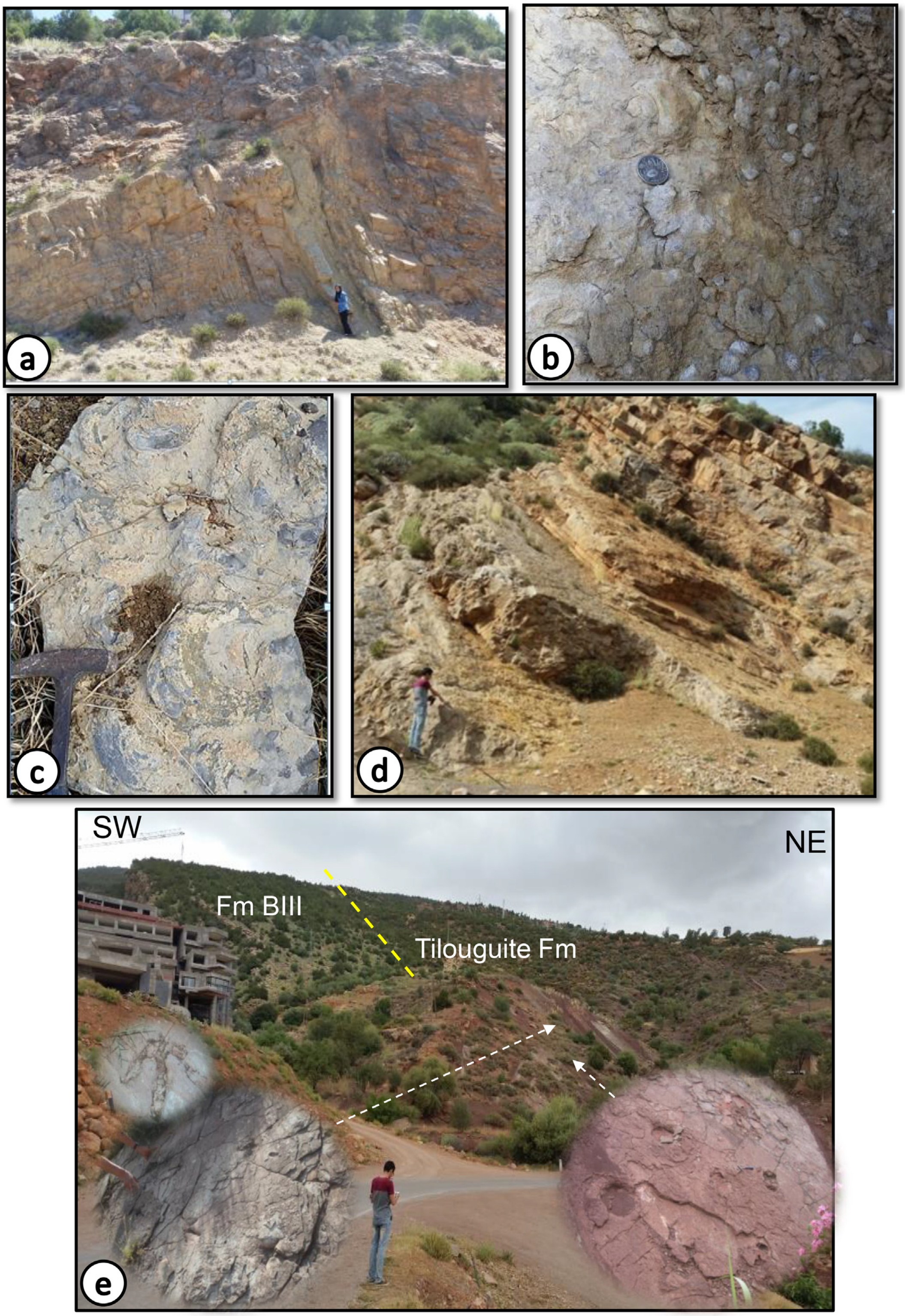

Fig. 5. Stop2 section: coffred fold (a), condensed level with rhynchonella brachiopods and gasrteropds (b), large ammonites (c), dolomitization surface (d), and footprints of Theropod and Sauropod dinosaurs (e).

red ocher silt bed (Fig. 5e). The polarities criteria indicate that the footprints of theropods are older than those of sauropods (Fig. 5e). The presence of its varied and well-preserved theropod and sauropod dinosaur footprints indicates that the syncline of Ouaouizaght was populated by its giant animals and the living environment was shallow in the form of a swamp and also the fossilization conditions were favorable at Middle Jurassic age. So, this shows the scientific interest of this station, allowing an understanding of geological and geomorphological processes that the region experienced.

Stop 3: Panoramic viewpoint of the Ouaouizaght Syncline

Before reaching the stop 3, the road R306 crosses the Guettioua Fm represented by layers of red clays, sandstone channels and silt with cross-stratification, and first basalt flow B1 (32°6′46.64″N - 6°24′59.70″w) corresponding to the major effusive event of Middle Jurassic age (Haddoumi et al., 2010). The beautiful sceneries along the lake road, and Liasic limestone slopes covered with tufts of resinous spurge, as well as granaries and mud houses of Ait Halouane village are possible.

Located at seven km from stop 2, stop 3 (32° 7′54.04″N; 6°23′49.67″w) offers a panoramic view of the Ouaouizaght syncline representing the Cretaceous formation (Fig. 6). This interesting view clearly shows the two marine intercalations of the Aptian (Taflet Fm) and the Cenomano-Turonian (Ben Cherrou Fm) (Fig. 6). This section illustrates well the Lower Barremian Cretaceous marine intrusion (Jbel Sidal Fm) that is pronounced in the Cenomano-Turonian (Ben Charrou Fm). The Cretaceous formations only occupying the North - East of the syncline are linked to the opening cycle of the Cretaceous basins (following the extensive Lower Barremian - Upper Barremian tectonics (Haddoumi et al., 2002; Haddoumi et al., 2010).

Stop 4: Oued el Abid bridge

At the exit of the Ouaouizaght town, the road R302 leading to Tilouguite village crosses the Aptian yellowish limestones of the Tafelt Fm marking the first transgressive phase of the Lower Cretaceous, then an alternation of pelites and red sandstones of the Jbel Sidal Fm (Upper Barremian age) and finally the gypsum summit of the Iouaridene Fm of Lower Barremian age. Located at about 14 km from the stop 3, the stop 4 extends over 2 km (32° 8′1.74″N - 6°18′42.41″W) and offers two important panoramic sceneries Oued el Abid River (Fig. 7).

To the North-East of stop 4 (Fig. 7a), we can see the Iouaridene Fm. composed of whitish beds of gypsum (Fig. 7a1) intercalated with pelites and silts, overlaid by alternating layers of sandstone and red pelites of the jbel Sidal Fm. The presence of gypsum characterizes a sabkha environment during the sedimentation of the Iouardene Fm. Some specific plants including essentially Euphorbia resinifiera (in Arabic Zakoum) covered these rocky outcrops. This plant Euphorbia on these red formations attracts attention by the contrast of plant-rock color and by its development on detrital and evaporitic rocks while it is often associated with dolomitic carbonate rocks (Fig. 7a2). Considered as a medicinal plant, its yellow flowers attract and nourish bees and honey with a strong and pronounced taste known for its medicinal properties.

To the South-West, a panoramic view clearly shows the meanders of Oued El Abid and the flood plain covered by plants. Due to the decrease in water level of the Lake Bine El Ouidane and erosion, the black basaltic flow B2 appears in the river bed at the border between the Iouaridene gypsum Fm and the Jbel Sidal red-sandstone Fm (Fig. 7b). It is related to the major effusive Upper Barremian event linked to the third extensive tectonic phase at the Lower Barremian - Upper Barremian passage (Haddoumi et al.,

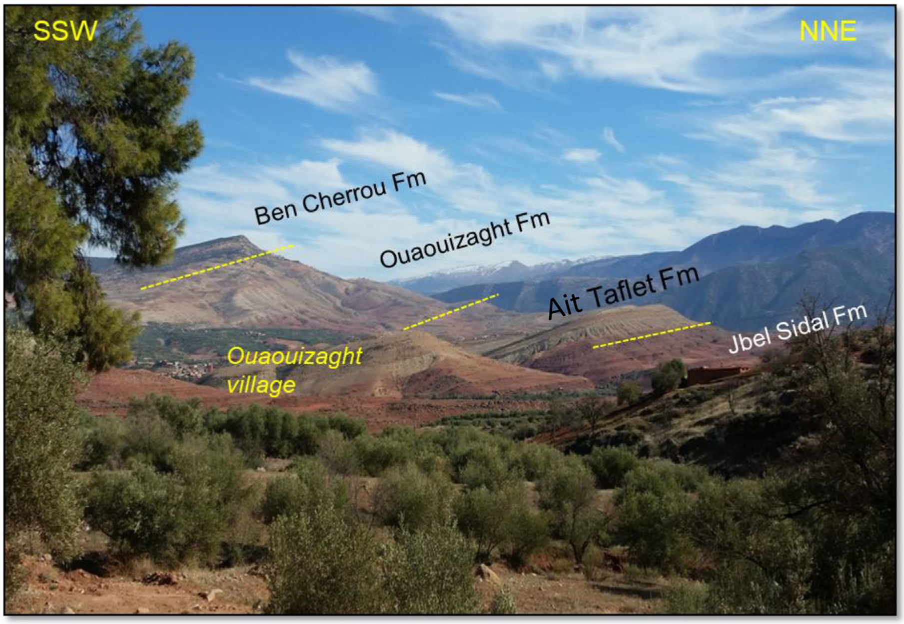

Fig. 6. Ouaouizaght synclinal view illustrating the Cretaceous transgression.

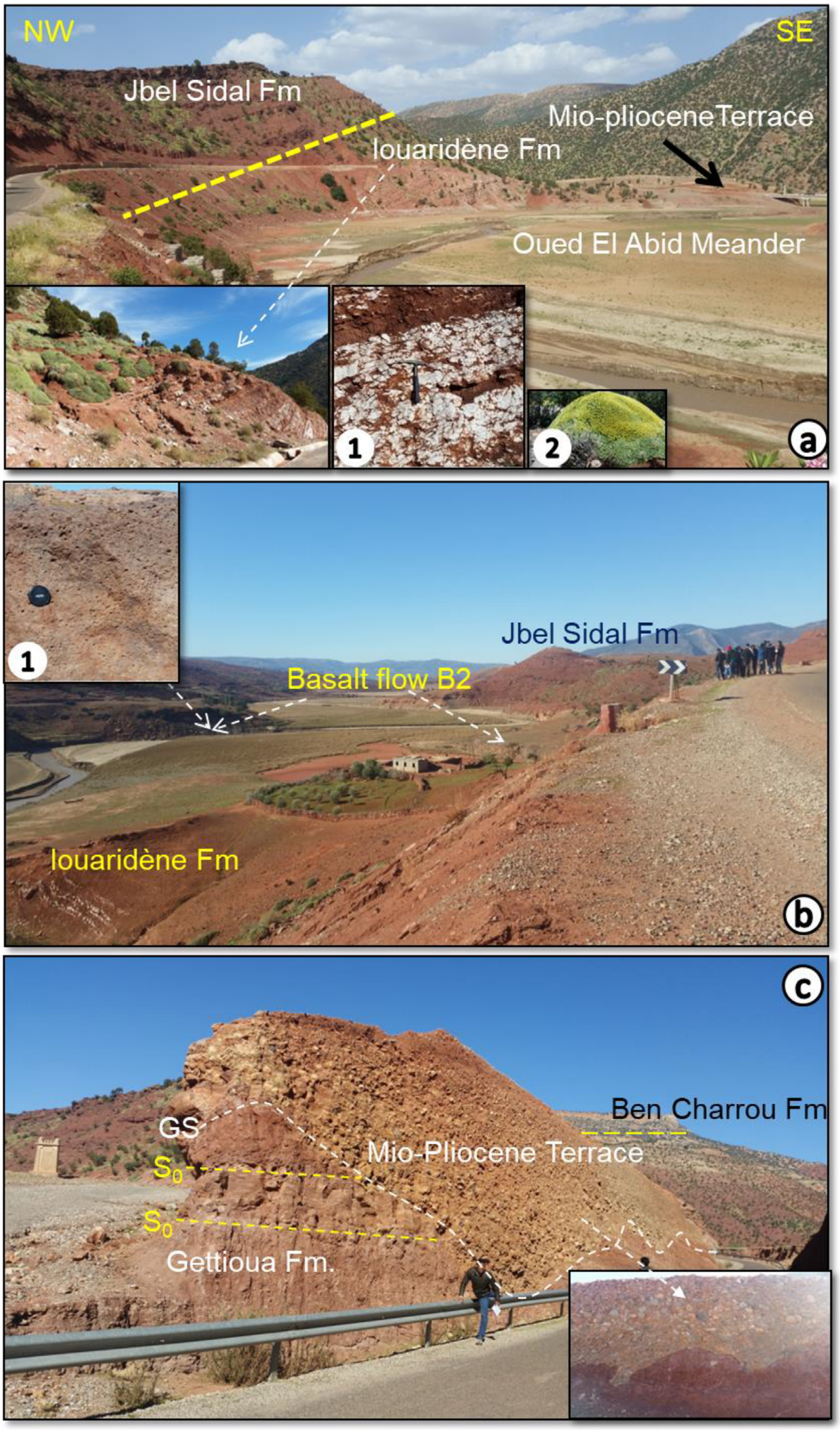

Fig. 7. Stop 4: NE panoramic view on the bridge of Oued El Abid river (a), SW panoramic view of basaltic flow B2 (b), and panoramic view from the Mio-Pliocene terrace (c). S0: stratification plan, gully surface (RS).

2010). These massive and vacuolar basalts (Fig. 7b1) are surmounted by alluvial terraces from Mio-Pliocene. These Mio-Pliocene alluvial terraces also appear at the entrance to the bridge (32° 7′58.88″N - 6°18′0.93″W), and acted conglomerates deposited by the ancient Oued El Abid River (Fig. 7c). The pebbles (elements) in conglomerates have an extremely varied origin and come from the erosion of the Jurassic cover levels. The upward-fining of these elements reveals variations in the energy of the stream of water that deeply dug its bedrock on sandstones, clays, and microconglomers of the Gettioua Fm. At the base of the terraces, the irregular gully surface highlights an oblique unconformity (Fig. 7c).

Stop 5: Panoramic viewpoint

The itinerary continues from stop 4 to stop 5 through the Iouaridène Fm with always beautiful panoramic sceneries changing according to the seasons on the lake and the Northern syncline slope (Fig. 8).

After about 14 km from the stop 4, on the right side of the road to Ait Mazigh village (douar), the views of spectacular landscapes overlooking the entire Bine El Ouidane dam are panoramic (Fig. 8a) (32° 5′30.55″N–6°19′53.61″W). The badlands wind the clays and pelites of the Guettioua and Jbel Sidal Fms by regressive slope erosion (Fig. 7b), and show the erosive action by wind and water over time. The erosion of these formations leads to different shades of the sedimentary layers which contrast with the blue of water, the sky, and the green of the plant cover, thus giving beautiful landscape paintings.

Several quiet walking trails allow in a few hours to reach the lake by observing crossing the different geological formations (red layers, layers of gypsum, interstratified basalt flow B2) (Fig. 8b). Also, visitors can admire stone and adobe constructions reflecting a very important architectural heritage reflecting the community lifestyle. The houses and the granaries cover the summits of the red brick hills surrounding the lake (Fig. 8c). At the edge of the lake, visitors can remarks on the surfaces of silty and sandstone strata tracks of footprints of theropod and sauropod dinosaurs.

From the Ait Mazigh village, the road becomes passable and stops at the right bank of Oued Ahansal. The route, which can be done on foot or by car, runs through the red layers of clays and sandstones (with cross-stratification and current ripples) of Guettioua and Jbel Sidal Fms. The red and ocher earth of these formations is the millennium-old cradle of olive, almond, carob, and holm-oak trees. This harmony of colors red and green of rocks, blue of sky and water, and sometimes white of snow offer picturesque landscape paintings.

The stop 5 presents an important scenery value due to the rural landscape beauty and ecological, cultural, and architectural benefits.

Stop 6: Ahansal river (Oued Ahansal)

Located at 4 km from the stop 5, the stop 6 (32° 4′11.81″N - 6°25′26.51″W) (Fig. 9) corresponds to the outlet of the river Ahansal that originates from the karst springs located at the bottom of the Liassic limestone cliffs. The river flows for 250 km, mostly on steep land (interrupted by a few flat portions), from the Taghia village (a tourist site of great value). It intercepts waters of Assif Mellou North of the Cathedral rock (Imsefran rock) and its discharge increases. The watershed summits, rising to an elevation of about 2200–3600 m a.s.l., offer exceptional panoramic views of deep valleys with steep slopes and mountain oases occupied by local communities. Its alluvial plains are fitted out for seasonal crops, irrigated in a traditional way, providing resources where sustainability reflects age-old know-how.

This stop offers one of the beautiful views of the lake, the outlet and the meanders of Ahansal river. Access to the bed of this river is via a pedestrian path (Fig. 9a and b) passing over the pelitic sandstone alternations of the Guettioua Fm. The river bed includes several interlocking terraces composed of whitish silt and alluvial plains. On the other bank of the river, the meanders and the Bine el Ouidane group, and Guettioua Fms are well exposed (Fig. 9b). This view clearly shows the progressive discordance of the continental Guettioua Fm on the marine Fm BIII with a gap in the Tilougite Fm (Fig. 9b). On the left bank of the Ahansal meander, a coffee built on the massive limestone of BIII can be accessed by small boat or on foot via the river bed in dry periods (Fig. 9c).

- Second itinerary

The second itinerary serves the southwest part of the dam lake through its dike.

Stop 7: Assif Assemssil Bridge

After crossing the dam (32° 6′29.98″N; 6°28′21.93″W) and right after the tunnel that crosses the massive limestone of Fm BIII, on the left side of the road R304 leading to Azilal city there is a way that leads to the village of Ait El Bakour and the stop 7 and stop 8. Along this way, which can be done by car or on foot, there are several hotels, chalets and guest houses, coffee shop, and restaurants, offering beautiful panoramic views of the lake and the landscape (Fig. 10a).

The road leading to the stop 7 located at 4 km from the tunnel (R304) crosses massive limestones, with large oncolites, lamellibranchs and Ammonite, of the Bine El Ouidane group. The limestones are water shaped, giving picturesque karstic landscapes that can be seen on either side of the road in the form of lapiaz and ruiniform landscape of varying size and shape. This karstification phenomenon is very abandoned in the Sinemurian dolomitic limestones of the Jbel Rat Fm and the massive limestones of the Bine el Ouidane Fm (Jenny, 1985; Souhel, 1996). It developed cavities and caves of variable sizes and shapes (the largest being 10 m in size), that can be observed on the left bank of the Assif Assemsil (Fig. 10c). Bakalowicz (1999) and Gilli (2015) defined the karst as the set of superficial forms (Lapiaz, sinkholes, Ouvalas, ruiniform landscapes, dry valleys, losses, resurgences) and underground (caves and caves) resulting from the dissolution of carbonate rocks (limestones, dolomites) favored by water, climate, water content of CO_2, water-rock contact time, vegetation cover and rock porosity. This dissolution of carbonate

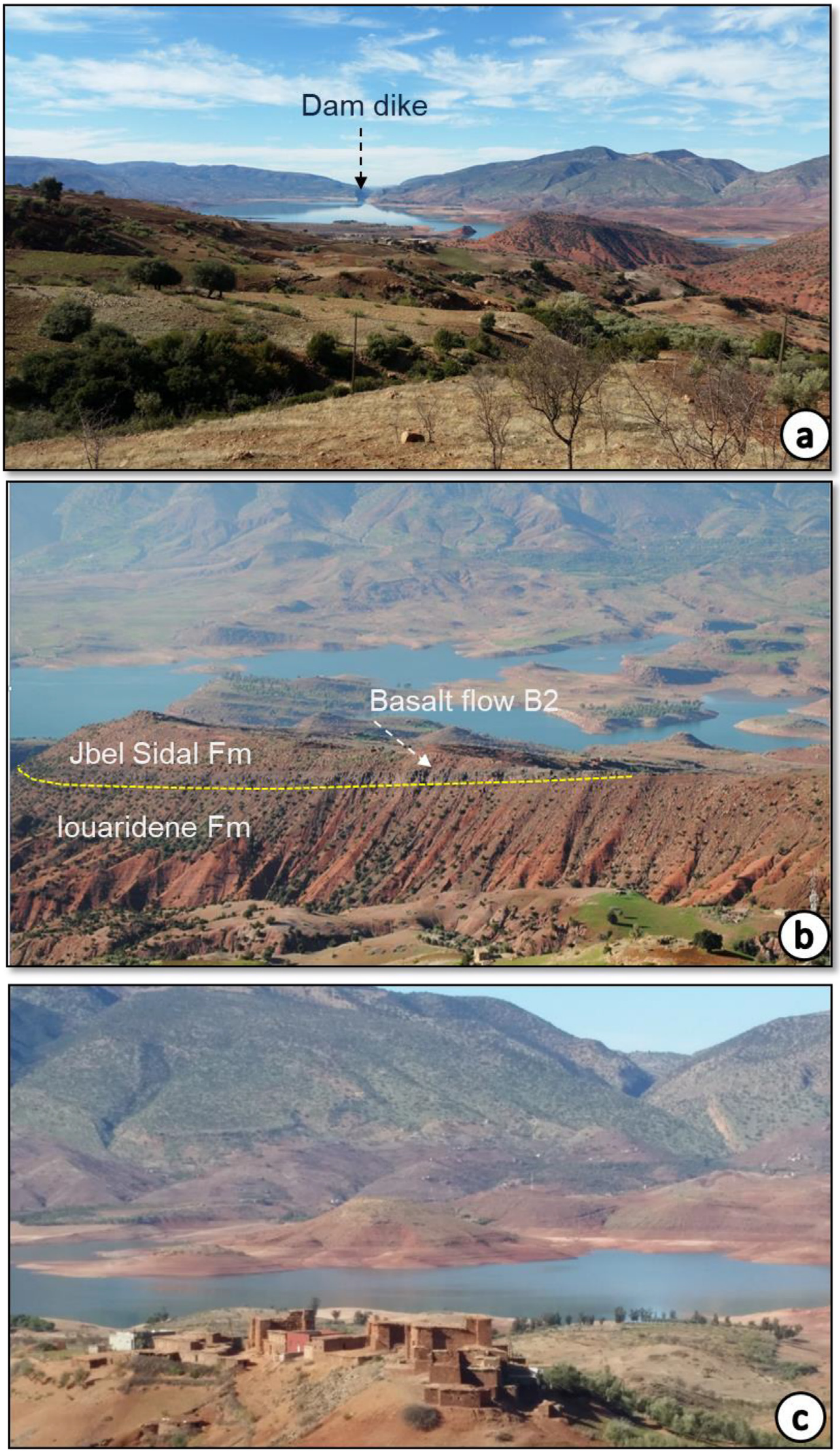

Fig. 8. Stop 5: panoramic view of the dam dike (a), panoramic view of the badlands and basalt flow B2 (b), Granary of Ait Aissa Ou Ichou (c).

rocks of the High-Atlas formed during the Secondary era thus created picturesque karst landscapes. At the bridge level, the Assif (river) Assemssil dug deep gorges in Fm BIII limestones (32°4′49″N - 6°27′36″W) (Fig. 10b).

The large cave (about 10 m) was used as a cave dwelling. This troglodyte construction (Fig. 10 c&d) is similar to those of the Aoujgal traditional granaries dug in the cliffs of Tiwina-n-Aoujgal, in the Bou Tferda commune. Built centuries ago by the Ait Abdi tribes, these granaries were hiding places for food, wheat, and even treasures. The troglodyte construction observed in this stop 7 was a granary for the inhabitants of the Ait Aloui and Ait Izza douars (villages) given its location in the limestone cliff at a height of 10 m from the river bed and given the presence of many rooms in the interior and a single entrance door (Fig. 10d).

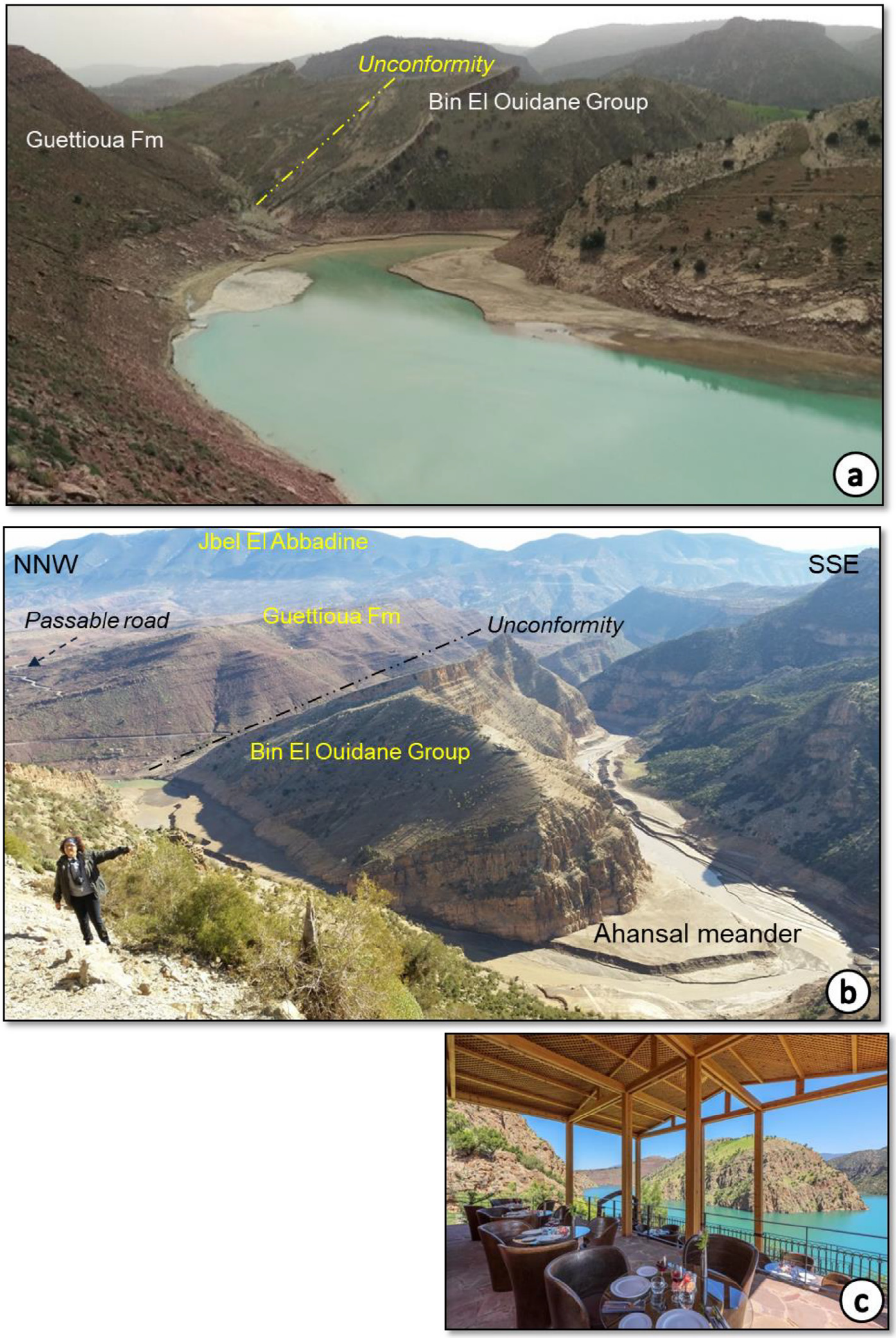

Fig. 9. Stop 6: panoramic view of the outlet of Oued Ahansal river and unconformity (discordance) (a), panoramic view of the meanders and unconformity (b), and coffee and restaurant in front of the meander (c).

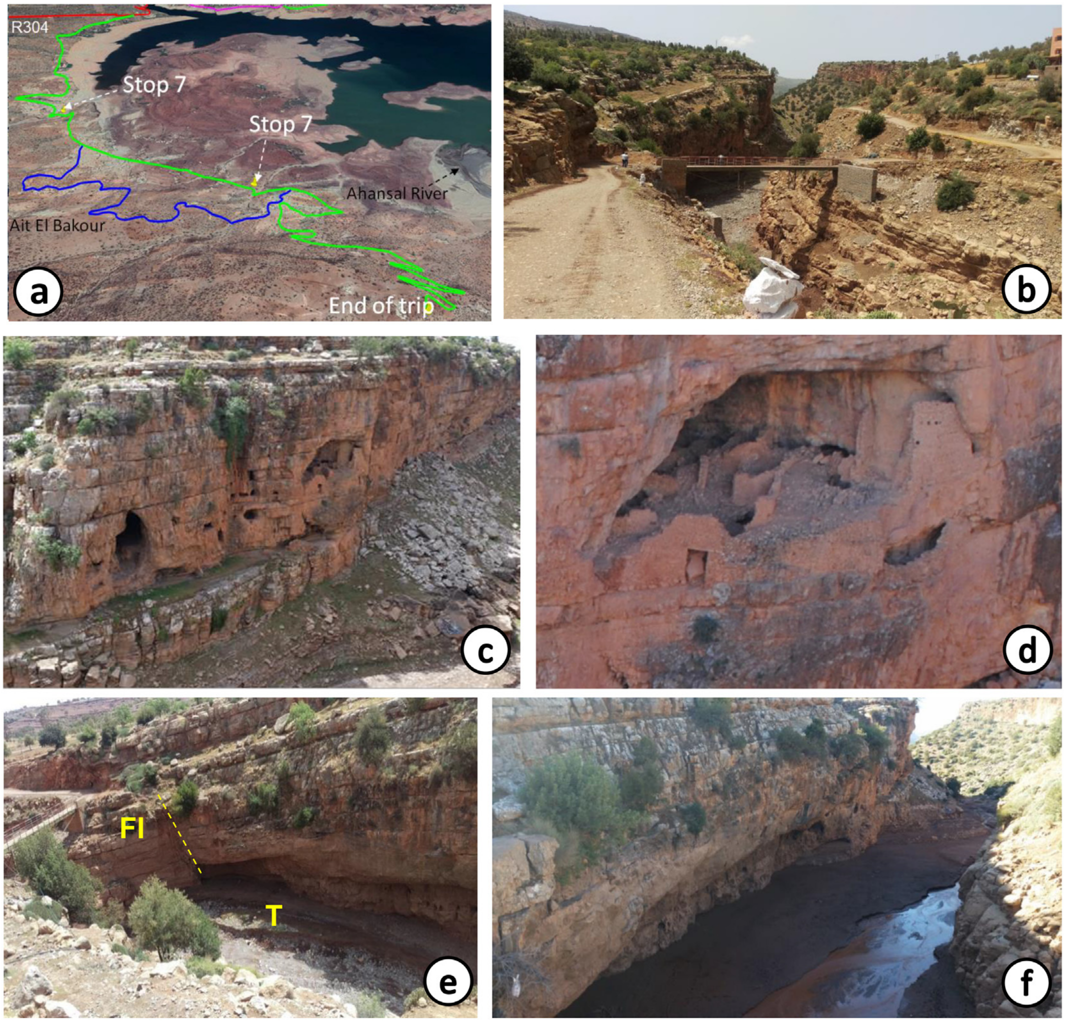

Fig. 10. Location of stop 7 (Assif Assemssil Bridge) (a), panoramic view of Assif Assemssil (b), solid limestone BIII Fm showing very intense karstification (c), cave transformed into granary (d), and river bed in dry periods (F: reverse fault;T: terrace) (e) and in rainy periods (f).

At the Assif Assemssil Bridge; a non-permanent stream, the bed filling of the river changes according to the annual rainfall, and can be consisted of a plain alluvium (red silt) (Fig. 10e) or of coarse sediments (pebble and sand) poorly sorted, sometimes deposed as small terraces (Fig. 10e).

Stop 8: Ait Idir granary

The road leading to the stop 8 located at 2 km from the stop 7 becomes passable and crosses the red layers of the Gettioua Fm. From the road, adobe and mud houses can be seen everywhere in harmony with the landscape and earth color, and a little further away appears the Ait Idir granary perched on a 920 m high hill (Fig. 11a).

At the stop 8 (32′4′22″N - 6° 26′43″W), a well-distinguished fault makes contact between the Fm. BIII and the Guettioua Fm. A walking path of a few meters allows visiting the Ait Idir granary constructed from silty limestones of the Tilouguite Fm (Fig. 11a and b). On the granary stone blocks contain oblique and cross-stratification and bioclasts of brachiopods and lamellibranchs (Fig. 11a). Then, an easy path leads to earthen houses built on the axis of a conical fold, which affects the oncholitic limestones of Fm. BIII, and illustrates the Tertiary compression. The limestone banks are rich in fossils of gastropods, lamellibranch, brachiopods, ammonites, and in some places polypiers. The hills offer superb panoramic views of the lake and the Ouaouizaght syncline (Fig. 11c). The road continues to the left bank of Ahansal river offering a panoramic view of meanders and outlet of stop 6.

3.1.2. Architectural heritage

The adobe and stone architectural heritage of the mountainous areas of the provinces of Béni Mellal and Azilal is known for its richness and diversity. It is a fundamental element of the High Atlas Amazigh identity. This architectural heritage highlights the deep relationship between humankind and its environment (geological outcrops, landscapes, forests, etc.).

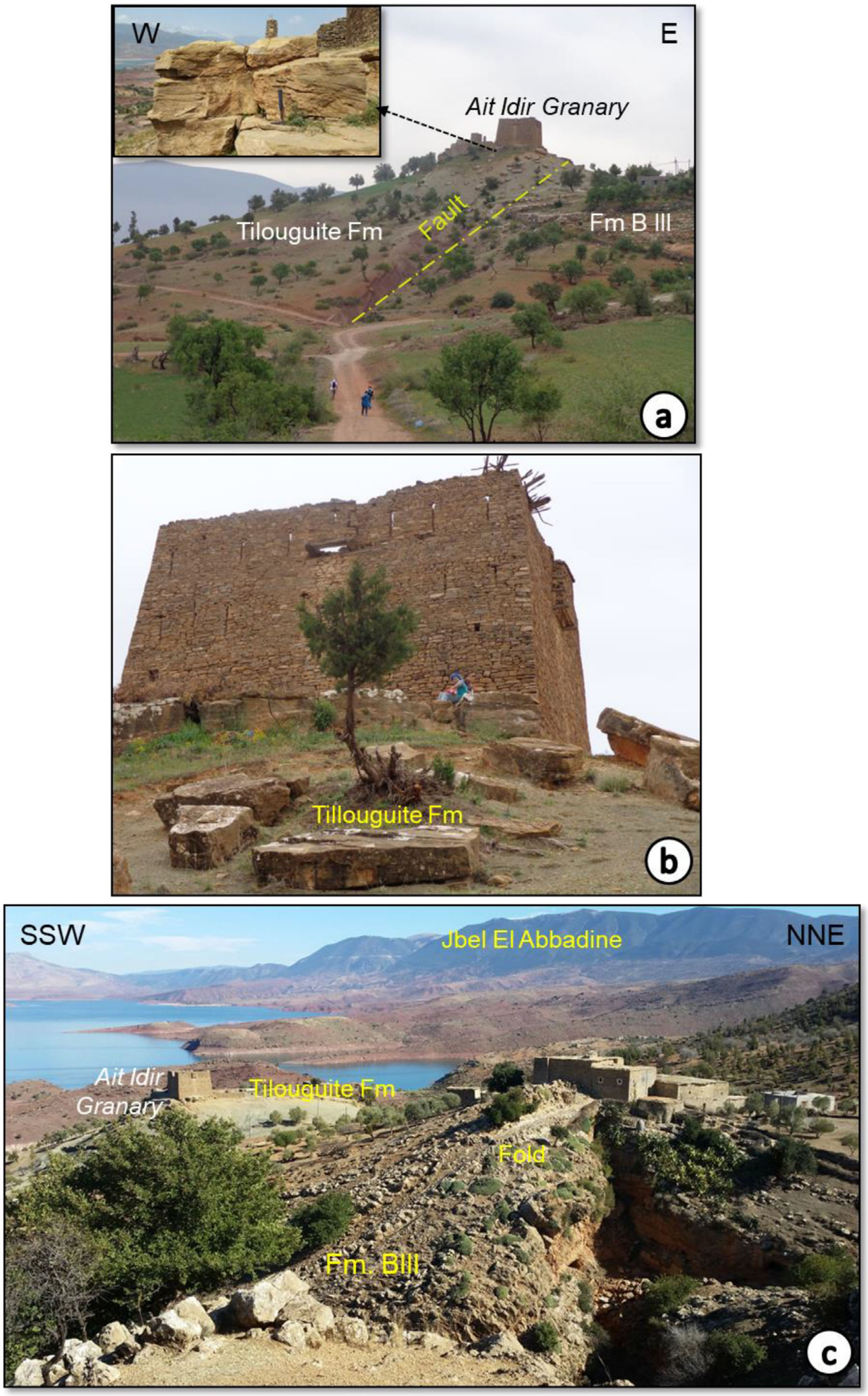

Fig. 11. Stop 8: panoramic view of the Ait Idir granary and of the Tilouguite Fm and Fm BIII faulted contact (a), the Ait Idir granary showing the relationship between the Tilouguite Fm and the stone used in its construction (b), and panoramic view of the lake and the fold affecting the Fm BIII (c).

The scientific and aesthetic value of the Bine El Ouidane dam region is combined with architectural interest. Indeed, the typical Berber douars (Ait Halouane, Ait El Bakour, and Ait Mazigh) are scattered almost everywhere at the bottom of the valleys or perched on limestone slopes and hills. Thirty granaries (Tighremt in berber) and Ksar have been identified around the dam (Fig. 12), and witness a remarkable and highly developed architecture. The Berber douars (Ait Halouane, Ait El Bakour, and Ait Mazigh) are often built around collective granaries that are fortified constructions, often large and of diverse forms. Granary or

Fig. 12. Granary (Tighremt) of Douar Ait El Bakour with these 4 towers (a), Stone construction associated with the granary of Ait El Bakour (b), Granary of Ait Idir (c), the roof Granary of Ait Idir (d), Granary and Cayda of Ait Halouane (e) (f); Granaries of Ait Mazigh (g) (h).

Tighremt is a fortified construction (sometimes with towers in the corners) (Fig. 12a and e) generally having a single door and being practically devoid of construction windows which, according to various regional examples, can correspond either to a collective attic or an attic of lineage, or to a former dwelling of a more famous owner (Laoust, 1920; Meunié, 1944). The granary is used by locals to store their crops and precious objects (deeds, money, jewelry, clothes, carpets, food …). During the war or flood alert, the animals and people fell back into the granary-citadel which appears as castles, built on accessible high grounds (hill, cliff) and easy to defend. The interior of these granaries consists of many individual grain chambers (10 to 60 chambers), each of them contains the reserves of a family (Costa & Batista, 2018; CREPEAU & Tamim, 1986; Laoust, 1920; Meunié, 1944).

Around the lake, the architectural diversity observed is the consequence of abiotic, biotic, and cultural diversity. On the NW and SE sides of the lake, each Berber douar (village) (Ait Halouane, Ait El Bakour, and Ait Mazigh) has its own architecture (Fig. 12). The stone blocks used in ancient construction show many times beautiful cross-stratification (Fig. 11a) and of fossils (large oncolites and brachiopods). Several footpaths exist allowing to discover this architectural richness and diversity which is in harmony with the geological formations described above (Fig. 3).

Projects aimed at developing the tourist sector in mountain areas of the region do not take this heritage into account, which is certainly an asset and a tourist product typical of mountainous areas and its upgrading is a necessity for the development of the entire region. Endangered due to its degradation, its substitution by the use of new materials such as concrete, and by inappropriate maintenance or rehabilitation practices, the region is losing its ancestral identity and its harmony with its environment.

3.2. Evaluation of inventoried sites

The identification of geosites and the knowledge of their geomorphological context, the understanding of their importance, and the highlighting of some cultural components (archaeological, historical, and architectural) constitute determining factors that can contribute to their economic and tourist valuation and, consequently, to their conservation, wherever the territory concerned (Al Bani et al. 2020, Garcia et al. 2019).

Based on our scientific knowledge on the subject, and on the scientific data previously published on inventoried geosites, the scientific interest (SI) of the different sites (eight stops) along the two proposed itineraries has been assessed (Table 1). Other criteria, namely representativeness, rarity, and relevance, have also been used to quantitatively evaluate the scientific interest (SI) of the stations of interest. A quantitative evaluation of contextual interest (CI) was conducted based on cultural potential, floristic, educational, landscapes, hiking, historic and architectural uses. Each station interest was rated using 0, 1, 2, or 4 stars according to the importance of each criterion. The scoring of each criterion for the SI and CI quantification, the SI evaluation, and the SI degree of the eighteen occurrences identified are summarized in Table 2.

The identification and characterization of sites are decisive steps in any geoconservation strategy (Brilha 2005; Henriques et al. 2011) revealed that the study area offers variability and diversity of interest, namely sedimentological, stratigraphic,

Table 1
The geotope types, characteristics and valorization.

	Geotope type	Characteristics	Valorization: perspectives and directions
Stop 1	Hydrology, Hydrogeology	Water stream, river, lake, dam	Water resources management
Stop 2	Structural	Fold, fault	Development of the site for: - geoconserving and promoting of endangered rare paleosites (explanatory dinosaur-footprint mode panel dinosaur); - reconstructing the original environment: sandstone, current wrinkles, desiccation polygons, fossilized cross stratification that is witnesses of a detoxified river (from about 140 m.y. ago).
	Stratigraphy	Site illustrating the relative dating of layers or strata and the use of stratigraphic principles.	
	Sedimentological	Site showing the transition from a platform marine environment to a continental fluvio-delta environment	
	Paleontological	Site containing fossils witnessing life in the marine and continental environment	
Stop 3	Sedimentological and stratigraphic	Cretaceous marine transgression	Explanatory panel of the geodynamics and cretaceous transgression of Ouaouizaght synclinal
Stop 4	Stratigraphy	Site explaining the relative dating of strata and the use of stratigraphic	Planning for enhancing magmatic bodies (explanatory panel for setting up basalt casting)
	Sedimentological	Site illustrating ancient fluvio-deltaic, sebkha and actual fluvial environments	
	Magmatic	Site illustrating the implementation of basaltic lava flow under a transtensive regime.	
	Hydromorphological	Site allowing the hydromorphological study of Oued el Abid river	Explanatory panel for the hydromorphology of Oued el Abid river
Stop 5	Sedimentological	Site illustrating the mode of erosion and transport and the formation of badlands	Establishment of educational sites for reading and analyzing the landscape
	Geomorphological	Relief processes and forms testifying to the evolution of the Earth's surface (Badlands, cuesta).	
Stop 6	Hydrological	Oued Ahansal river	Explanatory panel of transgression-regression phenomena in a tectonically unstable environment
	Stratigraphic	Site illustrating well the phenomenon of unconformity and sedimentary gap as well as some principles of stratigraphy	
	Sedimentological	Ancient marine and continental environments and current fluvial deposits	
Stop 7	Karstic	Lapiez; ruiniform landscape; cavity and cave	Development for valorization and speleology (explanatory panels of karstification)
	Sedimentological	Marine environment of ancient platform and current fluviatile	
	Architectural and built heritage		Promotion of the architectural heritage along hiking trails
Stop 8	Structural	Reverse fault, anticline fold and joint	- Improvement for promotion to a large audience: educational relative dating (explanatory panel on relative dating, sedimentation, folding and relative dating by principle of overlap, - Installation of a room for lovers of landscape paintings
	Sedimentological	Marine and continental Sedimentary figures (bedding and intersecting stratification)	
	Stratigraphy	Principle of stratigraphy: relative dating between sedimentation and tectonics (fold and fault)	
	Paleontological	Fossils reflecting marine-platform and continental environments	

Table 2
Quantitative evaluation of scientific and contextual interests.

	Stop 1		Stop 2		Stop 3		Stop 4		Stop 5		Stop 6		Stop7		Stop 8		
Scientific interest (SI)	**SI**	**CI**	**SI**	**CI**	**SI**	**CI**	**SI**	**CI**	**SI**	**CI**	**SI**	**CI**	**SI**	**CI**	**SI**	**CI**	**Contextual interest (CI)**
Sedimentology		**	***		**		****		***		***		****		***		Cultural
Stratigraphy			***	***	**		****	****	***		****			****	***		Floristic
Paleontology		**	****	***		***		***	**	***		***	***	****	**	****	Educational
Magmatism		**		****		***	***	****	***	*****		****	****			****	Landscapes
Structural	**		**	***		***		***		****		***	**	***	***	***	Hiking
Geomorphology		***					***										Historic
hydrogeology	***			**		****	***			****	****	***	**	****		****	Architectural
Karstification													****				
Geotourism	***		***		***		***		***		*****		***		****		
SI evaluation																	
Rare			*				*				*		*				
Model	*		*														
Representativeness			**		*		*		*		*		*		*		
SI degree																	
Local																	
Regional	*		*														
National	*		*		*		*		*		*		*		*		
International	*		*		*		*				*		*		*		

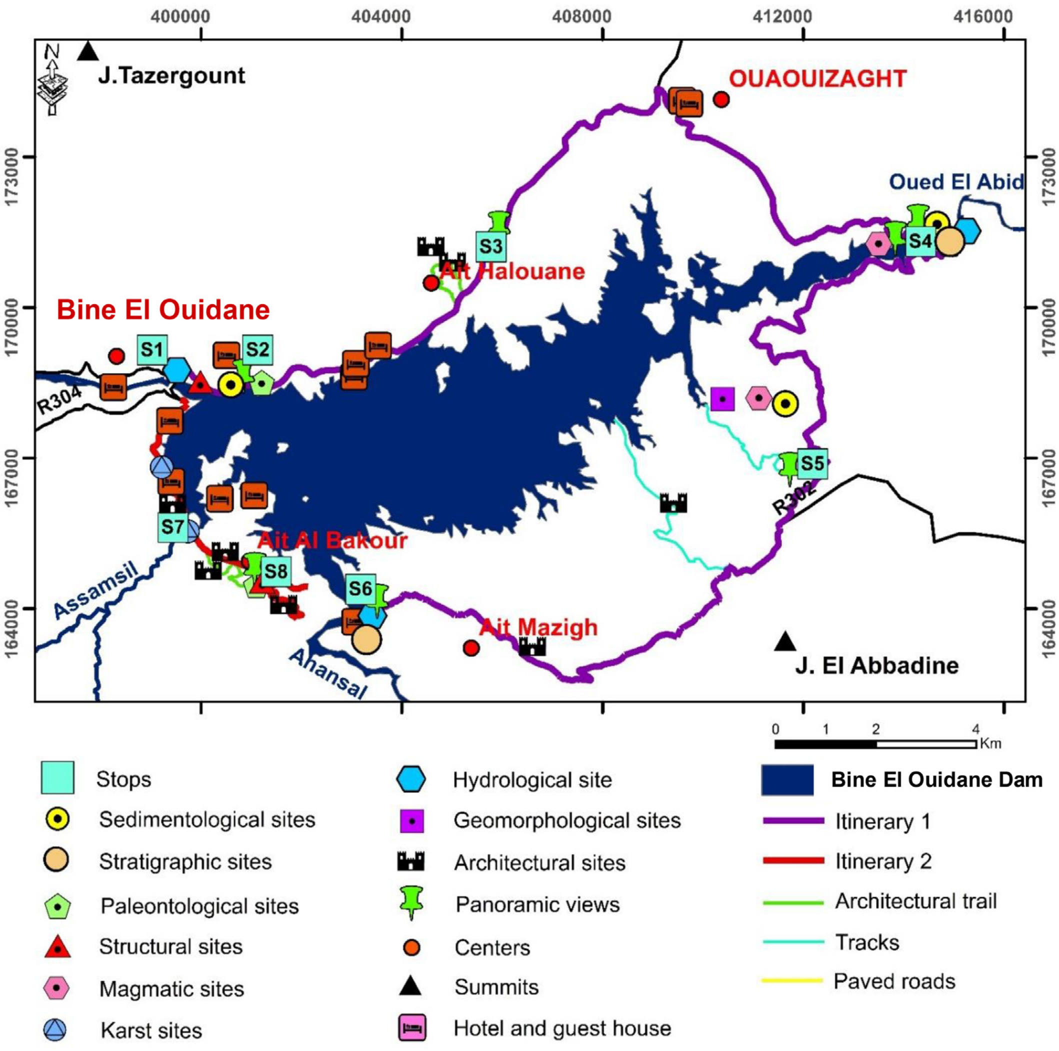

Fig. 13. Geotouristic map of the nearby area of Bine El Ouidane dam.

paleontological, magmatic, structural, geomorphological, hydrogeological, and karstic, so that each station has more than three different interests (Table 1 and Table 2, Fig. 13). These geological topics conferring main interests for the inventoried geosites, reflected the geological nature of the area, composed mainly of sedimentary rocks related to alpine tectonics affecting the calcareous High Atlas (Michard, 1976; Laville, 1981; Souhel, 1996; Henriques et al. 2011; Missenard et al., 2007; Charrière & Haddoumi, 2016; Guezal et al., 2013, 2015; Guezal et al., 2011). In terms of scientific evaluation and degree, nearly all of the selected occurrences are representative, and are national and international importance (Table 2). Magnificent landscapes and outstanding outcrops, which characteristics are sometimes unique and rare, should be dedicated to educational field trips. The significant scientific interest of the identified occurrences makes the study area an excellent working platform and field stage in the fields of geosciences, education, and geotourism. So, all the stations in Bine El Ouidane dam at the area nearby are considered more suitable for geo-educational circuits. It should be noted that some sections of the circuit have long served to pedagogical field activities for the Béni Mellal university students (Morocco). In addition to the scientific and pedagogic interests, the inventoried sites present great landscape, floristic, historical, cultural, and architectural interests.

All of these scientific ad contextual interests of the identified geosites helped to exalt the tourist interest of the selected occurrences. Their good conditions for observation and places with good accessibility also constitute an attractive tool to encourage visitors. However, this would require investments and targeted interventions to promote and protect them. The tourist potential of the Bine El Ouidane Dam area still lacks tools for mediation and geodidactic valuation of geosites allowing boosting their usability and promoting geotourism. That remains to be done is to develop the infrastructure for geotourism purposes by adding explanatory and educational panels for each station and to integrate the Berber population of the douars into the enhancement and protection of the assets that they have. Several types of mediation tools must be developed, namely geodidactic panels, advertising sheets, leaflets, orientation tables, a website, etc., to encourage visitors to discover and explore the region. Geodiversity, biodiversity, and cultural diversity of the Bine El Ouidane dam area.

4. Conclusion

The present work has been conducted with the aim of identifying the geosites valuable for the geotourism in the Bine El Ouidane dam area, and of proposing circuits providing characteristics required by tourists. The choice of the study area was motivated by its privileged geographical location in the center of the country and at the Northern limit of the M'Goun geopark located in the central High Atlas.

Two geoitineraries created based on the accessibility and touristic potential, comprise interesting geosites that were defined based on field works and the current geological knowledge. The identification and characterization of selected sites revealed that the study area offers variability and diversity of interest, namely sedimentological, stratigraphic, paleontological, magmatic, structural, geomorphological, hydrogeological, and karstic, so that each station has more than three different interests. In terms of scientific evaluation and degree, nearly all of the selected occurrences are representative, and are a national and international importance. In addition to the scientific and pedagogic interests, the inventoried sites present great landscape, floristic, historical, cultural, and architectural interests. All of these scientific and contextual interests of the identified geosites helped to exalt the tourist interest of the selected occurrences. However, the geotourist circuits will need infrastructure that will work as hiking paths for the visitors, and allow transportation between the sites. Also, other tools, such as explanatory and educational panels, orientation tables, advertising sheets, flyers, and websites… are missing, while they are necessary to vulgarize and protect the fragile identified and unidentified geosites of the Bine El Ouidane dam area.

Finally, the results of the present study would familiarize and contribute to a better public awareness of geoheritage that remains little known, ignored, or unexploited for sustainable development for the local economy. The results provide information that could help decision-makers for supporting management decisions and land management in the Bine El Ouidane dam area.

Credit author statement

The authors contributed towards the article, read and approved the final manuscript.

Declaration of Competing Interest

No potential conflict of interest was reported by the authors.

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