



# Geo-Heritage and Geo-Tourism Potential of the Saoura Valley: A Field Geology Museum in the Ougarta Range (SW Algeria)

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## Abstract

The geo-heritage of the Saoura Valley in Southwest Algeria is particularly rich and of undeniable scientific value for studying the Palaeozoic, Neogene and Quaternary strata inherited from the Ougarta chain. Although Algeria has always been highly ranked among the most fascinating geodiversity countries, its geological heritage has been seldom described and presented to the African and international community. Subsequently its geodiversity and geo-resources are under-recognized. The Saoura Valley is renowned for its gorgeous geological, oasian and geomorphological landscapes, as well as for its archaeological wealth. In the present paper, we intend to briefly describe the main lithostratigraphic units of the Devonian series exposed in the Saoura Valley and to give an overview of the Quaternary outcrops. Several geo-sites were observed and inventoried, showing a highly significant scientific value and also some remarkable educational and tourism potential as evidenced by their huge historical, archaeological, geological, and cultural heritage. Additionally, the Saoura Valley displays pedagogical geo-sites of cardinal interest for different geological disciplines, among which are stratigraphy, palaeontology, ichnology, geomorphology, geodynamics, structural geology, and ecology, all reflecting the diversified geological record of the area. Besides its aesthetic value, the rich geodiversity of the Saoura Valley displays an obvious scientific and touristic interest. According to the obtained numerical scores using recent quantitative assessment methodology, the Saoura Valley is very promising and can be considered a first-order destination since geo-sites therein score quite a high attraction potential and recreational value for tourism development. These scores ought to be treated with great care by the authorities to effectively promote tourism and to accordingly enhance the local socio-economic development in this remote area. Furthermore, the Saoura Valley area deserves more attention and requires geo-conservation programs and protection strategies right away to make sure that these geo-resources will be preserved for future generations.

**Keywords** Geological Heritage · Geosite · Geodiversity · Saoura Valley · Sahara · Algeria

## Introduction

The geological sites, also known as geo-heritage sites, refer to the valuable geomorphological features of the Earth: they comprise unique geological phenomena both considered worthy of protection, conservation and transmission to the future generations, and regarded very valuable to scientists,

educators and tourists (Reynard et al. 2009; Martin 2014; Gray 2018; Coratza and Hobléa 2018; Abdel Maksoud et al. 2019). Geo-heritage sites include soil and rock formations, fossil assemblages, landforms and landscapes, and the impact of geomorphological processes on their modification (Cresswell and Semeniuk 2018). They may also refer to regionally or globally referenced sections, outcrops or locations that have preserved geological features providing information about Earth's evolution or the history of Earth sciences and that can be used for research, education and also geo-touristic attraction (Reynard and Brilha 2018; Bentivenga et al. 2019; Chauhan et al. 2021). Recognition of geological heritage sites has been accelerating during the last few decades (e.g., Zagorchev and Nakov 1998; Osborne 2000; Moufti and Németh 2013; dos Santos et al. 2016; Reynard and Brilha 2018; Bentivenga et al. 2019; Lahmidi et al.

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2020; Bhosale et al. 2021; Chauhan et al. 2021; Cameron 2022; Chavan et al. 2022; Joshi et al. 2022; Mir et al. 2023; Bhat et al. 2023; Si Mhamdi et al. 2023; Thakkar et al. 2023; among others). Subsequently, there has been a lot of attention paid to the quantitative and qualitative approaches for categorizing and inventorying the diversity of geo-heritage sites because of their widespread use, growing knowledge and international significance (Dowling 2010; Gray 2011; Farsani et al. 2012; Hose and Vasiljevic 2012; Ollier 2012). Considering the sole African continent, since 2006, the scientific community has been paying more attention to and interest in the inventory, protection, classification, and valorization of the African geological heritage (Marok 2023). This interest appeared to the international community in the last decade through several publications from different countries, to name but a few: Morocco (Errami et al. 2013), Angola (Tavares et al. 2015), Egypt (Sallam et al. 2018), Cameroon (Henriques and Neto 2019), Algeria (Marok 2021), and South Africa (Matshusa et al. 2021). As a result, the paradigm of African geo-parks materialized with the creation of the Ngorongoro Lengai National Park in Tanzania and the M'Goun National Park in Morocco, respectively.

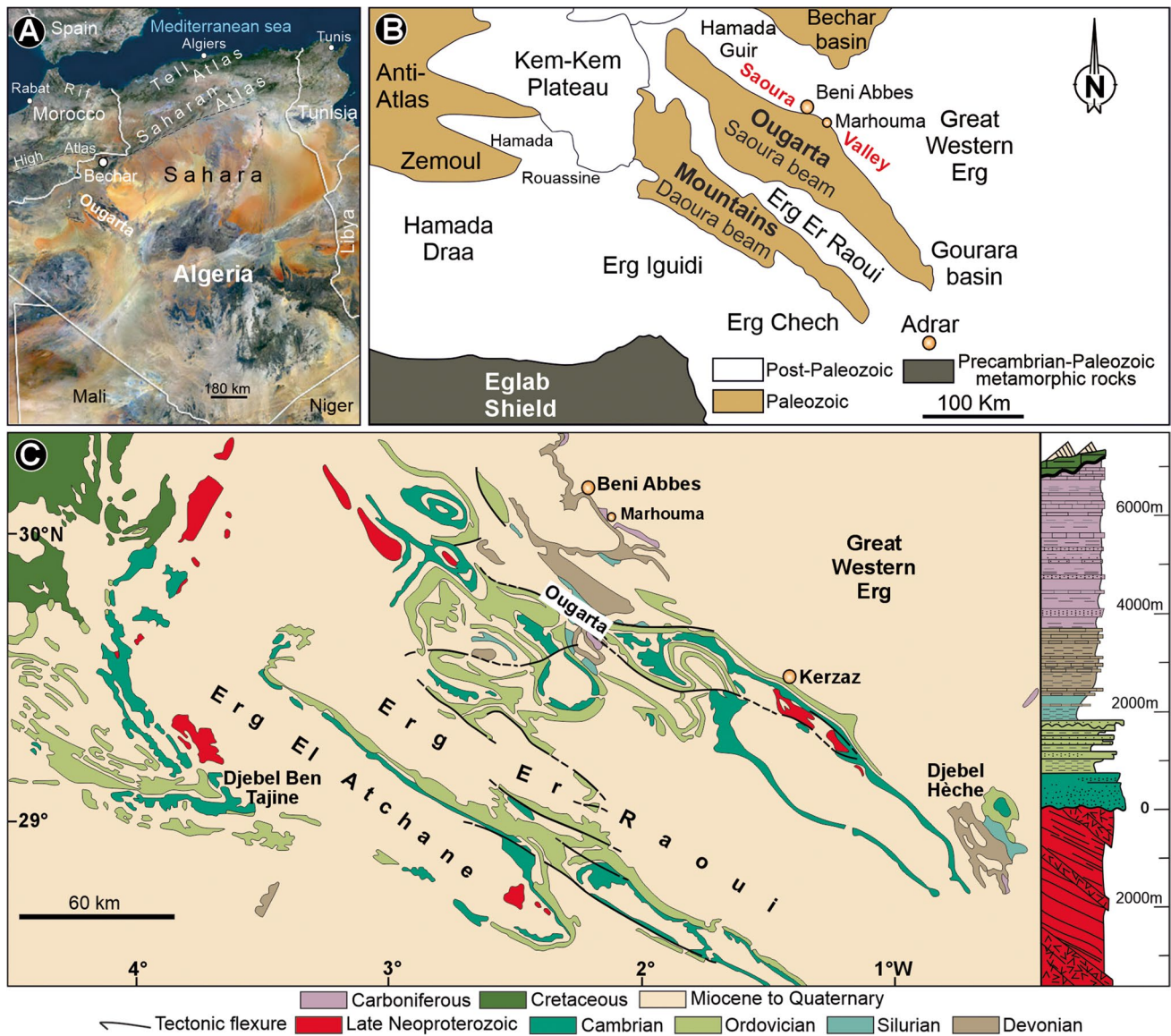
On the other hand, the term “geo-site” refers to a location with significant geological or geomorphological features that should be preserved or are already protected (e.g., Panizza and Piacente 1993; Wimbledon et al. 1995; Wimbledon 1996; Panizza 2001; Reynard 2004). It provides an understanding of both the internal and external geological phenomena prevailing on Earth (Chauhan et al. 2023). According to these authors, investigation of geo-sites is crucial for increasing public understanding of the significance of preserving and enhancing the nation's geological heritage. However, during the early history of geology and palaeontology, conservation of geological sites and materials was rarely an issue for the ‘ever’ developing science, as new areas with “fresh” fossil assemblages were regularly discovered (Page 2018). Both palaeontological and geological sites are now receiving a lot of attention worldwide, especially with the rising use of palaeontological sites in education and tourism, which has focused ever-growing attention in the media (Haste 1993; Torrens 1993). As a result, conservation schemes such as Geoparks and Paleo-parks, have boosted the identification and protection of such sites (Lipps 2009). In contrast, research and studies on the assessment and inventory of geo-heritage sites, particularly palaeontological ones, in Algeria are still scarce compared to those managed in other nations worldwide (e.g., Chabou et al. 2015; Bendaoud et al. 2015; Bessedik et al. 2022; Nedjari 2023; Marok 2023). However, considering Algeria's geological diversity, it is now time and crucial to spot, investigate and evaluate quite a number of geological heritage sites. To date, only a few papers have already highlighted the importance and vulnerability

of some Algerian geo-heritage sites. For instance, Chabou et al. (2015) inventoried several dinosaur track geo-sites, most of which are located in the Saharan Atlas. These authors highlighted the danger and dramatic decay facing this invaluable world's geological heritage and proposed subsequently several geo-conservation measures, including the creation of geo-parks to protect and preserve them.

Located in southwestern Algeria, the Saoura Valley (Ougarta Range) is characterized by high geodiversity and a rich geological heritage. The Devonian and Quaternary outcrops in this region consist in a diverse geological heritage still not well-known to the public, despite several MSc and PhD thesis and published scientific papers about its geology, particularly the palaeontological, ichnological and sedimentological studies (e.g., Ouali Mehadji 2004; Benachour 2011; Bendella 2012; Besseghier 2014; Bouchemla 2021). It does not yet benefit from conservation and valorization strategies or even from a mere assessment of these geo-sites. This paper presents the first multi-disciplinary geo-heritage inventory list of the Ougarta Range (Algerian Sahara), particularly from the Saoura Valley, since the works of Bendaoud et al. (2015) and Nedjari (2023) only focused the famous bioclastic limestone bar, so-called ‘Bar A = Chinese Wall’, well known for their giant *Orthoceras* content in the Marhouma section (Saoura Valley). The paper aims to highlight and assess the scientific, educational, cultural, and touristic values of the Saoura Valley, followed by an assessment of its potential within the scope of geo-tourism and geo-education.

## Geological Setting

The Ougarta Basin is a deep intra-cratonic basin located in southwestern Algeria and considered as part of the north-western margin of the Sahara platform. Its sedimentary infill is about 5,000 m-thick, ranging in age from the Precambrian to the Late Devonian (Strunian), with scarce Cenozoic accumulations (Fabre 2005). The basin is 450 km-long and 200 km-wide, subdivided following a NW-SE direction into two ranges separated by the Erg Er Raoui: the Saoura Range to the NE and the Daoura Range to the SW (Fig. 1B). These ranges display the same morphological trend as that of the Appalachians (Conrad et al. 1970; Ait Kaci 1990). The Ougarta Range, including the Saoura and Daoura Ranges, is bounded by the Guir Hamada to the north, the Great Western Erg (erg = sand sea) to the northeast, the Kem-Kem Plateau to the northwest, and by the Erg Check and the Erg Iguidi to the southwest (Fig. 1B). It is considered as an extension of the Moroccan Anti-Atlas to the northwest and the Touareg shield to the south. The Precambrian is essentially formed by volcanic (rhyolite) and volcano-sedimentary rocks and considered as the basement of a very thick Palaeozoic sedimentary cover (Chikhaoui 1974). This latter ranges from



**Fig. 1** Location of the study area. **A.** Satellite image (from Google Earth) showing the general position of the Ougarta Mountains. **B.** Geological map of the Ougarta Range. **C.** Geological sketch map of

the Ougarta Range and synthetic log of the sedimentary succession. (adapted from Ghienne et al. 2007)

the Cambrian to the Strunian, predominantly composed of terrigenous and carbonate deposits unconformably overlying the Precambrian (Fig. 1C). The Palaeozoic series is affected by the Hercynian orogeny and presents a structural direction N120°E, so-called Ougartian.

In the Saoura Range, the Cambro-Ordovician strata build anticlines, separated by Silurian-Devonian synclines (Menchikoff 1930; Donzeau 1983; Boumendjel et al. 1997; Fabre 2005). The synclines are dominated, however, by 3,000 m-thick Devonian strata (Fabre 2005), largely widespread and exposed through dissymmetric ridges (cuestas), and bounded by fluvial, lacustrine and aeolian deposits of Miocene, Pliocene and Quaternary ages (Bouchemla et al.

2021). The Lower Devonian is predominantly composed of mixed siliciclastic-carbonate deposits where storm-influenced shallow marine conditions prevailed. The Middle Devonian is represented by marl-limestone alternations and corresponds to a transgressive deposition covering vast areas of the Saharan platform during the Middle Devonian (e.g., Bouchemla et al. 2021). The Upper Devonian strata start with carbonate deposits, turn upwards into clay-fine-to medium-grained sandstone alternations, showing several types of soft-sediment deformation structures, especially at the top of the series. The Neogene formations lie on the Palaeozoic series of the Guir Hamada (a stony plateau forming the so called reg) with an angular unconformity.



### Marhouma Section (or “Km 30” Reference Section) ~ 1,500 m

The regionally referenced section of the Devonian outcrops in the Ougarta Basin is located about 30 km southeast of the town of Beni Abbes, by the side of the national road RN°6 connecting Bechar to Adrar, in a well-known sector called “Marhouma section” or “Km 30 section”. In this area, the Devonian, outcropping on both sides of the road, is represented by a famous and remarkable metric limestone bar commonly called “Chinese Wall” (= ‘*Muraille de Chine*’ in the francophonie literature).

The Devonian mixed siliciclastic-carbonate succession overlies the Silurian shales without any apparent lithological discontinuity (Menchikoff 1933). The Silurian–Devonian boundary had been studied in detail by Legrand (1977, 1985), based on graptolites. The presence of *Monograptus uniformis uniformis* characterizes the base of the Devonian.

The Devonian series of the Marhouma section can be subdivided into seven formal lithostratigraphic units (Legrand 1962, 1977; Boumendjel et al. 1997; Fig. 2A), from base to top:

#### Zeimlet Formation (120 m)

It consists of an alternation of sandy clays with micaceous sandstone and bioclastic limestone beds. It is dated as Lower Lochkovian thanks to the appearance of *Monograptus uniformis uniformis* (Legrand 1962). The age was confirmed later by Boumendjel and Paris (1997), based on chitinozoans (*Eisenackitina bohémica* Zone) and trilobites (*Warburgella rugulosa maura* and *Acastella jacquemonti*).

#### Saheb El Djir Formation (220 m)

It is represented by a thick claystone deposit intercalated with a few decimetric, bioclastic limestone beds. The formation is assigned to the Lower-Upper Lochkovian due to the presence of basal Devonian graptolite index taxon *Monograptus uniformis uniformis* and *M. hercynicus* (Legrand 1967, 1977), brachiopods (*Lanceomyonia borealiformis*; Brice 1997), trilobites (*Acastella levis*; Morzadec 1997), and chitinozoans (*Eisenackitina bohémica*; Boumendjel and Paris 1997).

#### Dkhissa Formation (320 m)

This formation is characterized by an alternation of clay and sandstone with occasional lenticular, bioclastic limestone intercalations (Fig. 2B). It is subdivided into three informal members: the first two units being attributed to the Upper Lochkovian (Legrand 1967), whereas the last one is dated to the Pragian (Le Maître 1952). The age assignment of this formation is based on chitinozoans (Boumendjel and Paris 1997), brachiopods (e.g., *Lanceomyonia occidentalis*;

Brice 1997), trilobites (e.g., *Protacanthina robusticostata*; Morzadec 1997), and tabulate corals (*Cleistopora geometrica*; Plusquellec 1997).

#### Teferguenite Formation (250 m)

It ranges from the base of the so-called limestone bar “A” to the base of the ‘coralligenous level’ (Le Maître 1952), also known as the bed with a diversified benthonic fauna (DBF, = “FBV”) (Ouali Mehadji 2004). The Teferguenite Formation is subdivided into two members:

- The lower member (Lower Emsian; Le Maître 1952; Legrand 1967; Fabre 1976) consists of three blueish to greyish, metric, bioclastic limestone beds rich in *Orthoceras* (so-called bars A, B and C, respectively) of pluri-kilometric lateral extent (Fig. 2C), intercalated with two greenish, clay-dominated depressions several tens of metres thick.
- The upper member (Upper Emsian; Boumendjel et al. 1997) is characterized by an alternation of greenish clays with fine-grained, silty limestone beds. Sandstone beds display several sedimentary structures and diverse bioturbations.

#### Chefar El Ahmar Formation (155 m)

This carbonate-dominated stratigraphic unit starts at the base of the upper Emsian coralligenous level (Le Maître 1952; Göddertz 1987) and ends up with ‘griotte’ limestone facies assigned to the Frasnian Ia-Ib (Petter 1959, 1960; Casier 1982; Boumendjel et al. 1997). It can be subdivided into three informal members (Bouchemla et al. 2021):

The lower member corresponds to an irregular alternation of greenish clays and greyish-to-blueish, bioclastic to clayey limestone beds yielding rich benthonic fauna (Table 1) of late Emsian age (Le Maître 1952; Göddertz 1987);

The middle member consists of an alternation of greenish to dark grey marls and centimetric to decimetric limestone beds interrupted by some silt- and sandstone levels. The member is capped by a dark grey, 50 m-thick, marl deposit. It is assigned to the Eifelian–Lower Frasnian (Göddertz 1987; Maillet et al. 2013);

The upper member consists of a slumped alternation of greenish or reddish, laminated marl, and red, nodular to pseudo-nodular, strongly bioturbated, ammonoid-rich, calcareous beds. The deposits are referred to the griotte limestone facies assigned to the Frasnian Ia-Ib (Petter 1959, 1960; Casier 1982; Boumendjel et al. 1997).

#### Marhouma Claystone Formation (370 m)

This formation is divided into three members (Abbache et al. 2019): The lower clayey member (Famennian II) corresponds to 115 m-thick clays interbedded with

**Table 1** Summary table of the main features of the devonian lithostratigraphic units, Saoura Valley

Age	Formation	Thickness (m)	Lithology	Ichnofacies	Faunas	
Upper Devonian	Upper Famennian (zone VI)	Ouarourout Sandstone	120	Clay, sandstone	-	Goniatites
	Famennian II-VI	Marhouma Claystone	370	Clay, silt, griotte limestone, sandstone	<i>Nereites</i> ichnofacies	Goniatites, orthoceras, brachiopods, conodonts.
Lower–Upper Devonian	Upper Emsian–Frasnian Ib	Chefar El Ahmar	155	Marl, clay, limestone, griotte limestone, sandstone	<i>Zoophycos</i> and distal <i>Cruziana</i> ichnofacies	Goniatites, orthoceras, bryozoans, crinoids, corals, brachiopods, trilobites, bivalves, gastropods, ostracodes, conodonts.
Lower Devonian	Pragian pro parte–Emsian	Teferguenite	250	Clay, limestone, sandstone	Archetypal <i>Cruziana</i> ichnofacies	Orthoceras, bryozoans, brachiopods, trilobites.
	Upper Lochkovian pro-part	Dkhissa	320	Clay, sandstone, limestone	-	Chitinozoans, corals, trilobites, brachiopods.
	Lower to Upper Lochkovian	Saheb El Djir	220	Clay, sandstone, limestone	-	Orthoceras, chitinozoans, brachiopods, trilobites.
	Lower Lochkovian	Zeimlet	120	Clay, sandstone	-	Orthoceras, chitinozoans, trilobites.

decimetric calcareous spheroids yielding brachiopods (Mottequin et al. 2015) and small pyritic ammonoids (Allaire et al. 2016; unpublished data). The middle limestone member (Famennian III, IV, V, and base of VI) consists of 70 m-thick, griotte limestone beds (Fig. 2D). The upper clayey-sandstone member (Famennian VI, Strunian) corresponds to an irregular alternation of about 185 m-thick between greenish clays and centimetric to decimetric, fine- to medium-grained sandstone beds (Fig. 2E). The age of this member is dated as late Famennian and is inferred to correlate with Zone II with *Cheiloceras* to Zone VI with *Wocklumeria* (Abbache et al. 2019).

**Ouarourout Sandstone Formation (120 m)**

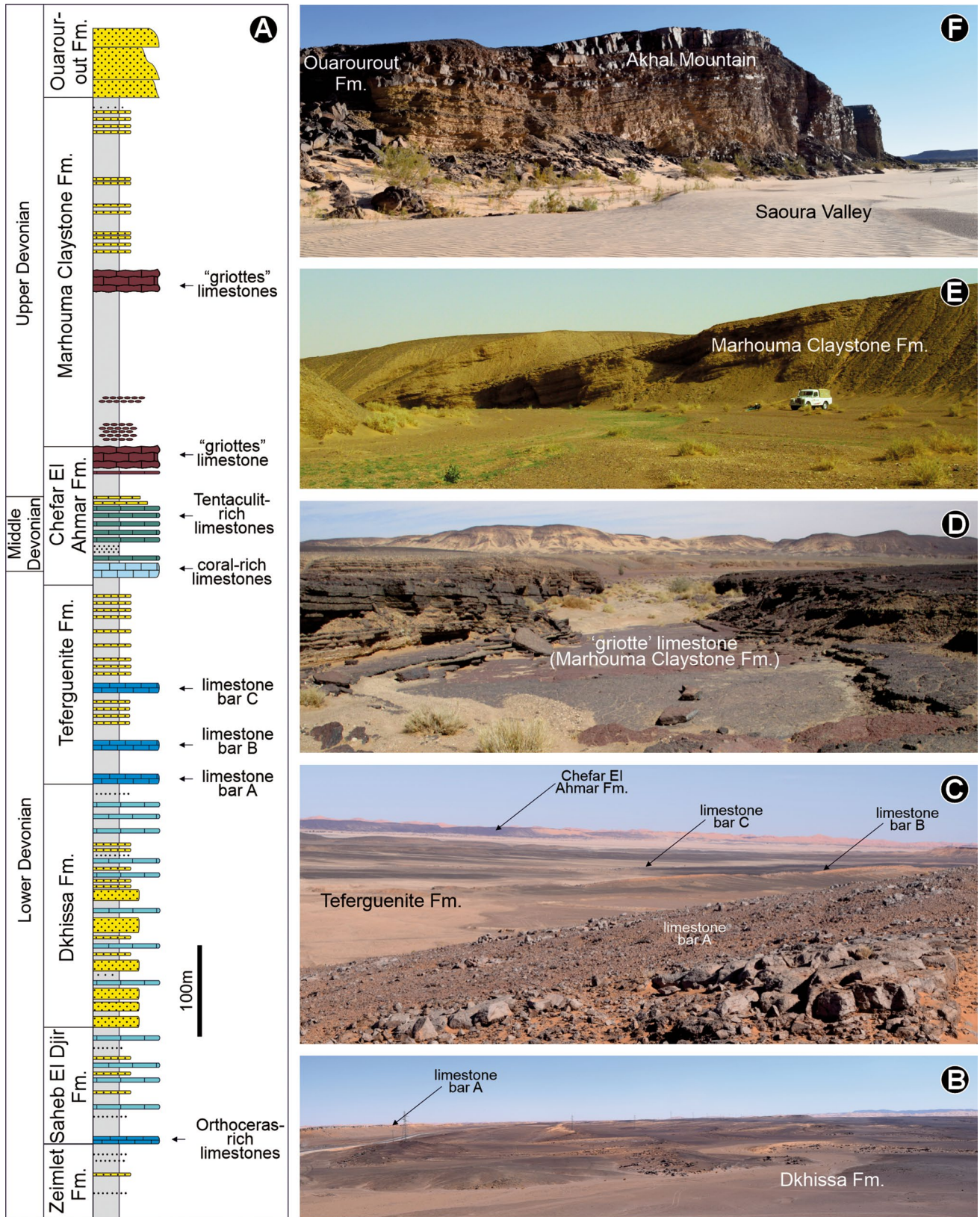
This formation builds the whole relief of the Akhal Mountain and is mostly represented by massive sandstones and thin clayey interbeds (Fig. 2F). The Ouarourout Sandstone Formation is subdivided into two members (Ouali Mehadji et al. 2012): a basal member consisting of turbidites marred by catastrophic event indices, and a second, upper member represented by sandstones with channels and cross-bedding displaying Liesegang rings at the top. This formation is attributed to the late Famennian (Zone VI), which is confirmed by the presence of the ammonoid *Wocklumeria* at the base of the formation in its type locality (Petter 1959, 1960; Malti 2012).

**The Quaternary of the Saoura Valley**

The Quaternary stratigraphy of the Saoura Valley is dominated by fluvial sequences in an arid desert environment. The Algerian Sahara is characterized by several fossil valleys of Quaternary age. Among them, the Saoura Valley is the one that has preserved life as best as possible and was once described as a fossil ‘River Nile’ (Gautier and Larnaude 1921). During the Quaternary, the Saoura Valley had brought a large quantity of sediments and strongly eroded the overflowed outcropping exposures outcrops (Capot-Rey 1965) from the Igli oasis over a distance exceeding 400 km into the Sahara up to the Timmoudi Sebkh, known as its main mouth (Fig. 3). The Saoura Valley flows straight through, in a deep and clean itinerary, from the Igli oasis to the Foug El Kheneg area, close to some successive agglomerations and oases (i.e., Ouarourout, Beni Abbes, Marhouma, Bechri, Temtert, Idigh, Anfal, Agdal, etc.), located on its left bank and the western edge of the Great Western Erg. Water in these oases is heavily dependent on the Saoura Valley and subsequently constitutes both a genuine lifeline of oases and a watershed (Fig. 4A).

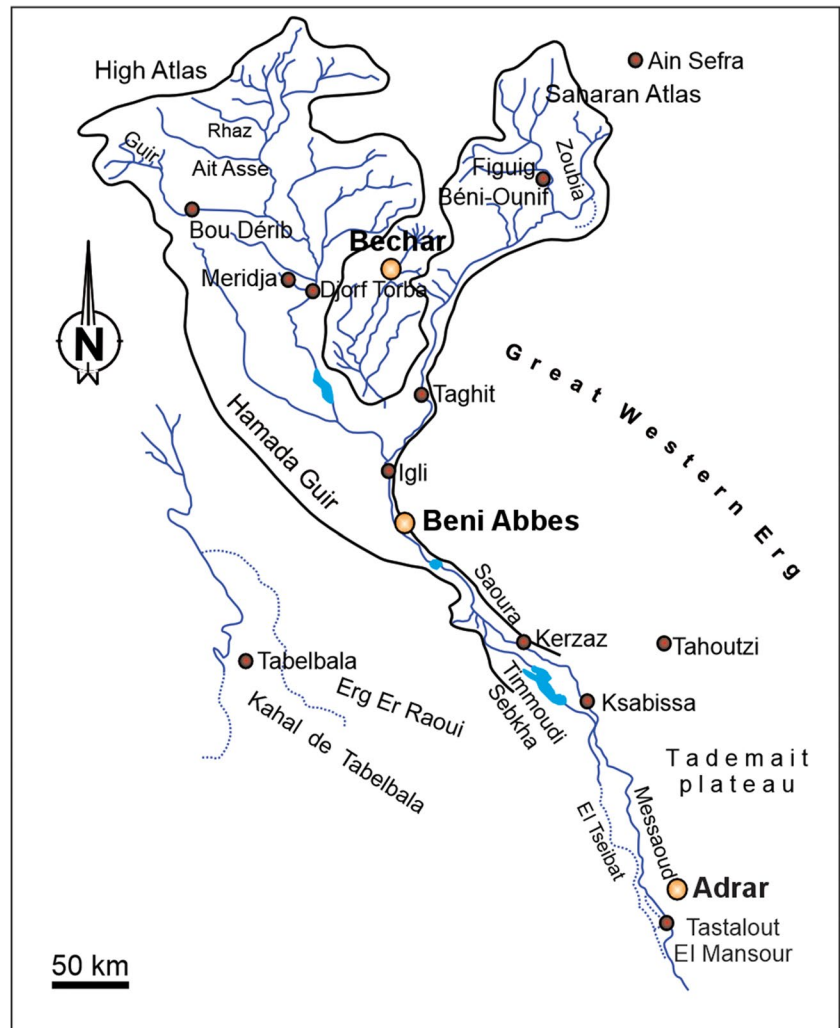
During the drought period, the Saoura Valley reveals various interesting sedimentary structures generated by the high hydrodynamics of the recorded flooding season. Erosional wind action on sedimentary bodies has revealed noteworthy exposures and nice outcrops, thus facilitating





**Fig. 2** A. Synthetic lithostratigraphic log of the Devonian outcrops from the Ougarta Range (Saoura Valley). **B-F**. Field panoramic photographs of the Devonian formations (Saoura Valley)

**Fig. 3** Map of the Saoura Valley watershed



direct observation of several structures, including ripple marks (symmetrical and asymmetrical ripples), obstacle marks, climbing ripples, horizontal- and cross-laminations, rill- and crescent marks, as well as evidence of subaerial emergence (raindrop impressions and mud cracks) (Fig. 4B-E). Moreover, some other structures such as sole marks, convolute lamination, imbricated clasts, and graded bedding (normally and/or reversely graded), could also be observed.

Moreover, modern traces are quite abundant across the valley, mainly observed on the top surface of mud deposits, generally located near standing water reservoirs (Nemra 2013). Bioturbation is roughly represented by root structures and repichnial traces produced mainly by terrestrial organisms (e.g., birds, reptiles, sand foxes, and beetles). These observed traces are usually associated with subaerial emergence structures (i.e., desiccation cracks and raindrop impressions). Other traces and tracks produced by the same animals are observed on dune sands (Fig. 5), scattered all over the valley as well as the Marhouma area. However, their preservation is nearly impossible since they quickly fade

from the constant movement of sand dunes by wind, which is the main agent of sand movement in this dry climate.

The association of both biogenic and sedimentary structures recorded in the Saoura Valley could be easily observed in the sedimentary record (i.e., old geologic series) and, consequently, should be considered of great use to geologists seeking to identify the fluvial depositional environment.

**Methodology**

The Saoura Valley has been the subject of several geological fieldwork projects in the last decades by different universities and researchers, mostly within the scope of research and educational purposes. The site is well-known for its geodiversity and wealth of geo-resources, reflecting its scientific, geo-educational and geo-touristic worth. Unfortunately, this site is left unrepresented to the national, African and international communities as a geo-heritage, despite the numerous international research papers revealing its scientific importance. Thus, only geodiversity elements with scientific value





**Fig. 4** A. Panoramic view of the Saoura Valley during the flooding season. B-E. Representative field photograph of the main sedimentary structures of the Saoura Valley; B1. Horizontal lamination.

B2. Sinusoidal lamination. B3. Cross lamination. C. Mud crack. D. Climbing ripple. E. Giant obstacle mark





**Fig. 5** Modern vertebrate tracks on sand dune from the Saoura Valley

recognized by the national and/or international scientific communities will be considered as geo-heritage (Brilha 2016). The term geo-site is used for an in situ geo-heritage element. The present study aims to present and extol further on the importance of the Saoura Valley as a genuine geo-heritage issue, regarding its scientific value as well as its potential use in both education and tourism.

In the present work, the selected Saoura Valley site is evaluated using the quantitative method proposed by Brilha (2016). The purpose of such a method is to assess the scientific value (SV) of the geo-site, followed by an assessment of its potential to be used in geo-education (PEU) and/or geo-tourism (PTU). First, the scientific value is evaluated using seven criteria to distinguish the geo-site with the highest scientific value, drawn up in maximum 28 points, each criterion being given a score of 0, 1, 2, or 4. Depending on the achieved score, each criterion is weighted in percentage. The final scientific value is the weighted average of the seven criteria. On the other hand, the second quantitative evaluation method is used to evaluate the potential educational use (PEU) and the touristic use (PTU) of the site. The first one is assessed according to 12 criteria, whereas the second one is evaluated according to 13 criteria (Brilha 2016). Both the PEU and the PTU share 10 common criteria, while each one display only

a couple of specific criteria. In this way, the didactic potential and geological diversity are reserved for the PEU, whereas the interpretative potential, economic level and proximity of recreational areas are specific to the PTU. Similarly, each criterion is assessed from 0 to 4 points and weighted in percentage accordingly. The assessment of the educational and touristic values is the weighted average of these scores. The risk of degradation is related to the vulnerability and fragility of the site, as well as to other factors such as the accessibility of the site and its proximity to human activities (Fuertes-Gutiérrez and Fernández-Martínez 2012; Brilha 2016).

## Scientific Interest of the Saoura Valley

### Palaeontological Interest

The Devonian deposits of the Saoura Valley (e.g., Marhouma (Km 30) reference section, Ougarta Range) have revealed an outstanding scientific value since they have been the subject of several first-order stratigraphic and palaeontological studies, especially those of Menchikoff (1930, 1933, 1936), Le Maître (1952), Alimen et al. (1952), Petter (1959), Casier (1985), Göddertz (1987), Fabre (1976, 2005), Boumendjel et al. (1997), and Paris et al. (1997). In this area, the lower member (Upper Praguian to Lower Emsian) of the Teferguenite Formation consists of three bioclastic calcareous beds (namely bars “A”, “B” and “C”) of pluri-kilometric lateral extent, rich in giant orthoceratids (Fig. 2C). The beds are considered as an important stratigraphic landmark in the Saharan platform and are currently protected (Nedjari 2023). Above, the Upper Emsian-Frasnian Ib strata of the Chefar El Ahmar Formation have been the subject of several palaeontological and biostratigraphic studies, most of which focused on the highly fossiliferous basal part of this formation, which was named “*banc coralligène*” (= ‘coralligenous bed’) by Le Maître (1952) and more recently redefined as a major level with a diversified benthonic fauna (DBF, = “FBV”) by Ouali Mehadji et al. (2004). Since the discovery of this highly fossiliferous deposit, the respective fossil groups (crinoidal stems, corals, brachiopods, trilobites, bryozoans, bivalves, gastropods, orthoceratids, and goniatites) (Figs. 6 and 7) have led to numerous studies over the last decade (e.g., Ouali Mehadji et al. 2004; Besseghier 2014; Khaldi et al. 2015; and many others in progress). Above this deposit, the Eifelian-Givetian strata have also been studied in detail thanks to diversified ostracod and conodont assemblages (Maillet et al. 2013; Tandjaoui-Arif 2014). The succession is characterized by a moderate diversity of trace fossils with several tentaculite-bearing beds, considered as index levels in the Marhouma section (Fig. 7H). Moreover, red nodular limestones (i.e., ‘griotte’ facies) characterize the Upper Devonian (Famennian) Marhouma Claystone Formation and are rich in ammonoids (Allaire et al. 2020), constituting an

**Fig. 6** Diverse fossil groups from the Saoura Valley. **A-B.** Goniatites. **C.** Trilobite. **D-E.** Brachiopods. **F.** Nautiloid. **G-H.** Corals. **I.** Orthoceratids. Scale bar: 1 cm



important part of the Devonian marine macro-invertebrates in North Africa. The availability of palaeontological data from the Devonian succession in the Marhouma section provides an insight into the palaeo-biological and palaeo-ambiental features of the Devonian palaeo-ecosystem, and helps researchers make comparison with other Devonian localities from the Gondwana supercontinent. Consequently, such a synergistic partnership enhances our general understanding of the palaeo-biogeography of this area within the northern Gondwana passive margin. Thus, it attracted researchers from different countries interested in studying Devonian fossiliferous deposits, thus greatly enhancing its scientific value, especially from a palaeontological point of view.

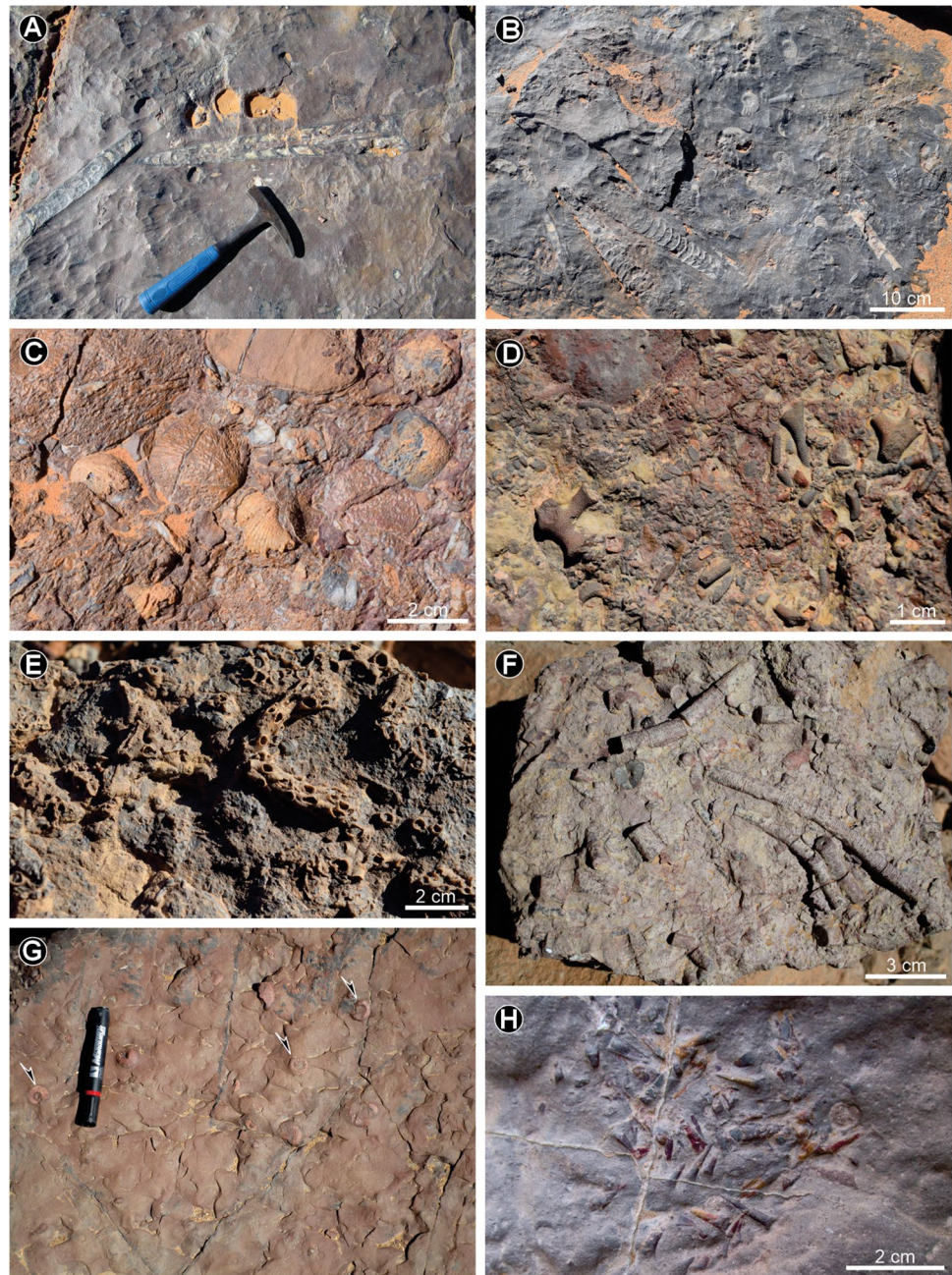
### Stratigraphical Interest

The Devonian succession of the Marhouma section is characterized by almost continuous outcrops exposed over the whole site through hills, domes, rivers, and road cuts.

Consequently, the section is considered a great site for applying the principles of stratigraphy (e.g., the principle of lateral continuity and correlation) for educational purposes due to stratal arrangement (with or without any stratigraphic and sedimentary discontinuities). Moreover, regarding the high occurrence of sedimentary figures and structures in the recent sediments of the Saoura Valley, the principle of uniformitarianism can be easily applied and helps teachers passing on knowledge to geology students since the Marhouma section is a great pedagogical site to teach different disciplines of sedimentary geology. On the other hand, the well-preserved index fossils (micro- and macrofauna) in these deposits, greatly help researchers to define with certainty the stratigraphic boundaries between the respective formations and the Devonian stages. Therefore, the Marhouma reference section for the Devonian outcrops should be considered a strategic milestone for stratigraphic geo-sites of both scientific and educational relevance based on its worth, accessibility and representativeness.



**Fig. 7** Fossil records from the Saoura Valley. **A-B.** Orthoceratid-rich limestone from the Chinese wall (= “*Muraille de Chine*”). **C.** Brachiopod-rich limestone. **D.** Bryozoan-rich limestone. **E.** Coral-rich limestone. **F.** Crinoid-rich limestone. **G.** Goniatite-rich red limestone (griotte facies). **H.** Tentaculite-rich limestone



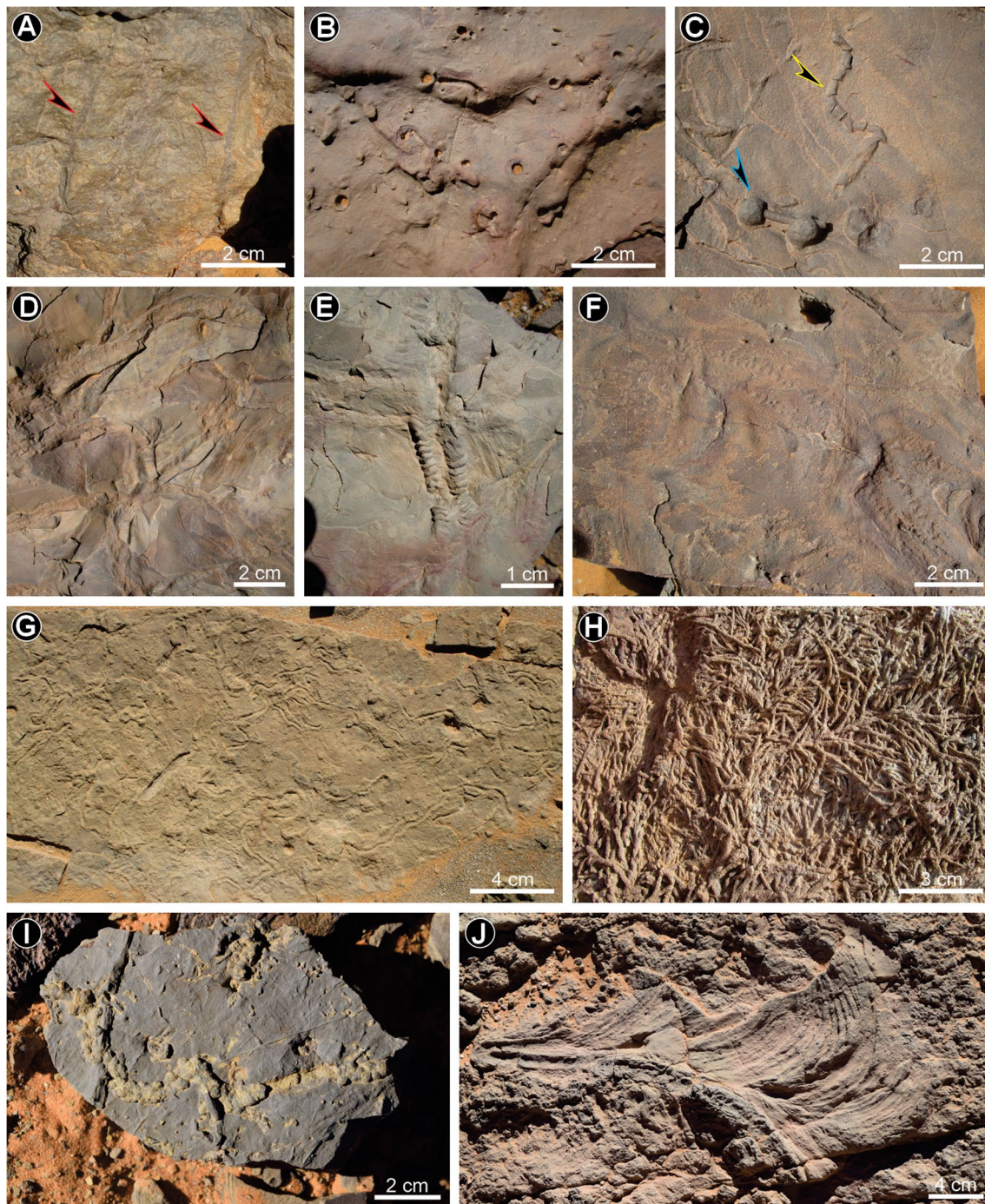
### Ichnological Interest

Current research identified the Marhouma (Km 30) section (Saoura Valley) as an important ichno-site in the whole Ougarta Range, given the extreme abundance of trace fossils within the Devonian strata, especially from the Praguian upwards. Trace fossils are indeed very common in the Phanerozoic of Algeria and the number of descriptive studies from numerous continental and marine settings has steadily increased over the last decade, especially the very last couple of years (e.g., Mekki et al. 2023; Benyoucef and Bouchemla 2023; Bouchemla et al. 2020, 2023). Nevertheless, only a

few studies have been dedicated to Devonian ichnofossils so far (Bendella and Ouali Mehadji 2015; Bouchemla et al. 2021; Bendella et al. 2022).

The present ichno-site is easily accessible from the national road RN°6. The sediments include a moderate to high diversity of trace fossils preserved in fine- to medium-grained sandstone and limestone deposits through five formations (i.e., the Dkhissa, Teferguenite, Chefar El Ahmar, Marhouma Claystone, and the Ouarourout Sandstone, respectively). Ichnological analysis of these formations indicates a deepening trend from foreshore (Dkhissa Formation) to mid-deep-sea-fan settings (Marhouma Claystone Formation),





**Fig. 8** Shallow marine invertebrate trace fossils from the Saoura Valley. **A.** *Skolithos linearis*. **B.** *Arenicolites* isp. **C.** *Hormosiroidea* isp. (blue arrow), and *Rhabdoglyphus* (yellow arrow). **D-E.** *Cruziana* isp.

**F.** *Diplichnites gouldi*. **G.** *Nereites* cf. *missouriensis*. **H.** *Arthropycus* isp. **I.** *Neonereites biserialis*. **J.** *Zoophycos* isp

whereas the Ouarourout Sandstone Formation corresponds to a regressive trend (Bendella and Ouali Mehadji 2015). Apart from the Dkhissa Formation, whose ichnological study is still in progress, the other formations are now studied in detail. The ichnological data of the Teferguenite Formation evidence a moderate to high diversity of trace fossils

(Fig. 8). In contrast, the Upper Emsian to Frasnian Ib strata of the Chefar El Ahmar Formation display low to moderate diversity of trace fossil assemblages, among which *Zoophycos* specimens are the most common elements (Bouchemla et al. 2021). The upper Famennian deposits consist of the two uppermost formations of the Marhouma section, i.e., the



Marhouma Claystone Formation and the overlying Ouarourout Sandstone Formation. The former is characterized by a wide variety of deep-sea trace fossils (Fig. 9).

In the considered area, the abundance of trace fossils led researchers to use several ichnological concepts (e.g., the concept of ichnofabric) and to better understand the close interaction between organisms and substrates, subsequently leading to the paradigm of bioturbated textures (see Bouchemla et al.

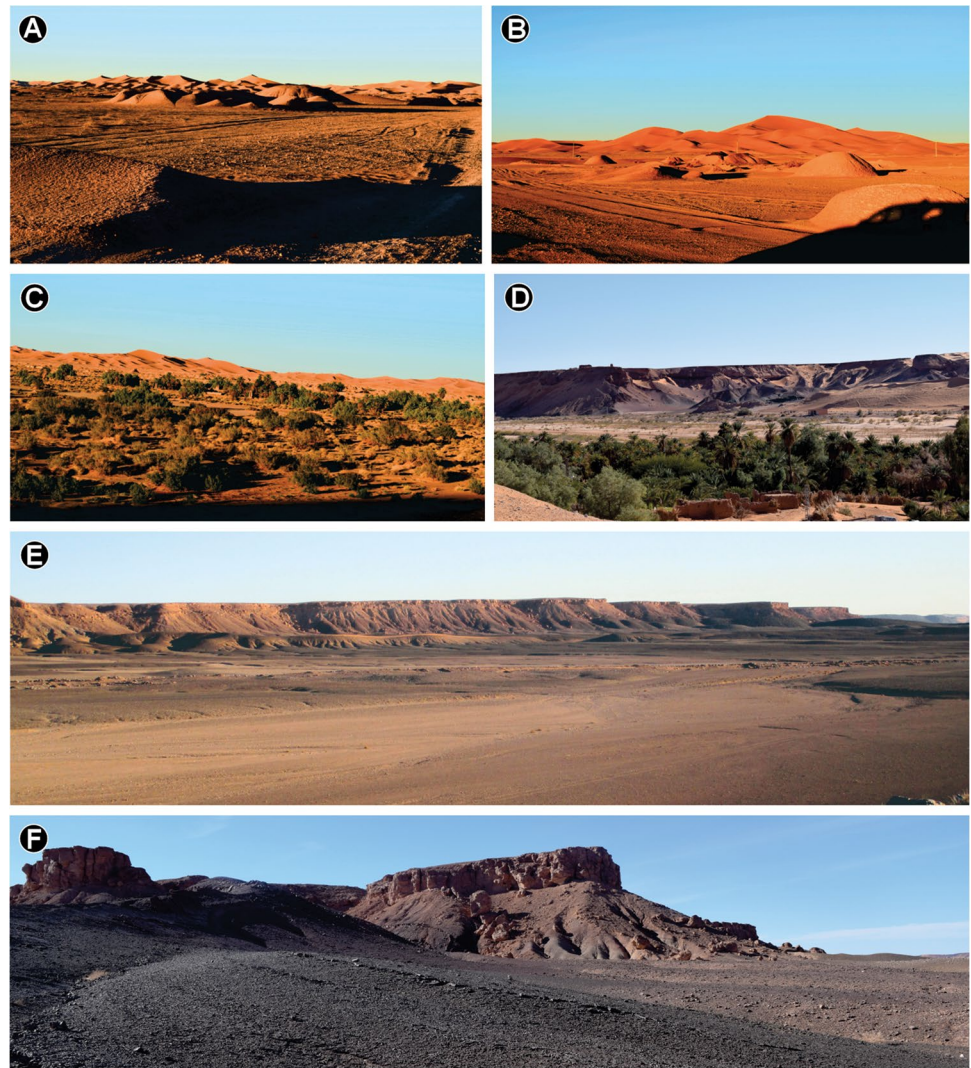
2021). Furthermore, trace fossil records disclose the respective behaviours and ecological conditions of their producers, their individual and group activities, and their evolutionary trends and taphonomic windows, all these contribute to our understanding of the evolution of life and Earth's history (Chauhan and Desai 2023). Moreover, the availability of neo-ichnological data through the Saoura Valley contribute to help researchers in identifying the possible trace makers in



**Fig. 9** Deep-sea invertebrate trace fossils from the Saoura Valley. **A-B.** *Protopaleodictyon submontanum*. **C.** *Nereites jacksoni*. **D.** *Megagraption submontanum*. **E.** *Torrowangea* isp. **F.** *Nereites irregularis*



**Fig. 10** Main geomorphological features of the Saoura Valley. **A–B.** Sand dunes of the Great Western Erg. **C–D.** Plain displaying oasis along the Saoura Valley. **E–F.** Stony plateaus (Reg or Hamada) of the so-called Guir Hamada



the recent fluvial system and in applying knowledge acquired from current trace makers (sometimes obtained from ichnological experiments), to fossil records, using the uniformitarian issues for both scientific and educational purposes.

### Geomorphological Interest

The geomorphological value of the Saoura Valley is linked to the desert landforms visible in this area, including sand dunes, plains holding oases and stony plateaus (reg and hamada) reflecting the dry climate of the region (Fig. 10). Likewise, many desert sites (e.g., Lahmidi et al. 2020) and sceneries in the Saoura Valley display a gloomy appearance from the desert patina. Furthermore, it is considered a great field laboratory to test and document all the wind processes from the aeolian transport, through wind erosion and finally to sandy creeping. However, the process of sandy creeping is a real issue for site conservation: it requires prompt actions to protect the area, especially around the town of Beni Abbes,

built just next to the giant sand dunes. Furthermore, these giant sand dunes jeopardize the self-sufficient agriculture of the local population established along the course of the Saoura flowing next to these giant sand dunes. However, the sand dunes are one of the main landforms in the area. They belong to the Great Western Erg (spanning over an area of 80,000 km<sup>2</sup>), and form a true sandy sea where the dune height ranges from a few dozen metres to over 300 m (Bendaoud et al. 2015). In the last decades, these dunes have become a popular touristic destination for camping and sand skiing, turning this area into a first-order spot for tourism but also for studying geomorphological processes and other environmental phenomena.

### Archaeological Interest

The Beni Abbes province yields many Neolithic prehistoric heritage sites such as Zghamra, Tlya, Anfidh, Taghit, Ougarta, and Marhouma, where rock engraving sites are



**Fig. 11 A-D.** Rock engravings from the Saoura Valley (Marhouma prehistoric site). Note that the figures are entirely dotted and mainly displaying ostriches



evidence of a human dwelling several thousand years old. The rock engraving site of Marhouma is located on the banks of the Saoura Valley, some 18 km southeast of the town of Beni Abbes, at the gateway to the Great Western Erg. It was discovered in 1951 by Captain Villalonga (a French military officer). According to Alimen (1954), the rupestrian engravings are reported to three phases: (1) naturalistic, with punctuated lines presenting mainly bovids in absolute profile; (2) dotted entirely with ostrich dominance, but orants are the most frequent; and (3) in a faint line showing mainly caballins. They would be associated with hunting and fertility rites (Seddiki 2013). The Marhouma prehistoric site is relatively rich in human figures and does not include any engravings with heavily incised lines like the Taghit site (Fig. 11). Among the dotted figures, Alimen (1954) recorded a total of 20 engravings, including 11 men, 3 women and 6 enigmatic figures, suggesting as much a woman as an ostrich. In the Beni Abbes province, the Marhouma prehistoric site, among others, displays the evolution of the lithic industry and the lifestyle of Neolithic men occupying southwestern

Algeria during the third phase of the Quaternary, as the last prehistoric period (Seddiki 2013). The diversity and large number of Neolithic evidence are direct testimonials of the large number of people who had been living on the banks of valleys and lakes that are now dry.

The Neolithic of the Sahara constitutes a very interesting and impressive issue for researchers in prehistory, contributing to understanding the human prehistory in Algeria and worldwide through the numerous foundations for civilization, such as advanced industry, agriculture, animal husbandry, pottery, construction, engravings, art, and means of transport, except for the use of metals, writing and the constitution of the state (Alimen et al. 1952; Seddiki 2013).

#### Geo-Heritage Significance and Geo-Touristic Aspect of the Saoura Valley Geo-Sites

The Devonian outcrops of the Saoura Valley are of great value compared to other areas within the Ougarta Basin or any other basins. This value is even greater since the

**Table 2** Touristic geo-sites and their main features in the Saoura Valley

Geo-site	Coordinates	Type	Features	Main illustrated theme
Marhouma (Km 30)	30°07'51,97"N 2°09'57,28"W	section	Lower to Middle Devonian strata; Chinese Wall with giant orthoceras; Neogene deposit; Sedimentary structures; FBV (bryozoans, crinoids, corals, brachiopods, goniatites, trilobites, bivalves, orthoceras, gastropods, etc.); Trace fossils; Strate succession; Angular unconformity between the Neogene and Devonian deposits; Stony plateaus (reg and hamada).	Stratigraphical Palaeontological Ichnological Sedimentological Geomorphological Geological
Ougarta road	29°48'32,77"N 2°14'47,02"W	section	Lower Devonian strata; Strate succession; Sedimentary structures; Faults and Folds; Macrofossils (orthoceras, brachiopods, bryozoans, corals, etc.)	Stratigraphical Palaeontological Sedimentological Structural geology
Akhal Mountain	29°58'49,45"N 2°01'58,31"W	point	Upper Devonian strata; Soft sediment deformation structures; Trace fossils; Strate succession; Angular unconformity between Neogene and Devonian deposits; Actual sedimentary structures in the Saoura Valley.	Sedimentological Geomorphological Ichnological Geological
Marhouma prehistoric site	29°59'50,39"N 2°04'20,43"W	point	The rupestrian engravings; The sand dunes of the great Western Erg; The palm groves; Upper Devonian strata; The channel of the Saoura Valley.	Geoarchaeological Geomorphological
Beni Abbes	30°07'51,97"N 2°09'57,28"W	area	The sand dunes of the great Western Erg; Ancient Ksars (e.g., Ksar Beni-Abbes); Former inmate of l'Ougarta; Crafts (e.g., pottery, sewing, brassware); The palm groves; Water source of Sidi Othman Gharib; Folklore; The Church of Charles de Foucauld; Gastronomy (e.g., Couscous, El Rkik bread); Stony plateaus (reg and hamada); The scientific heritage museum; Annual festivals (e.g., El Mawlid Ennabaoui); Zaouia of Sidi Othman; The channel of the Saoura Valley.	Geomorphological Archaeological Historical Cultural Geological Scenic views

outcrops of the respective exposed lithostratigraphic units (without any major discontinuities or gaps) are continuous and the quality of fossil preservation is good. In contrast to other areas, the site accessibility and its proximity to a civilized place (town of Beni Abbes) make it a favourite destination for scientists and geology students, as well as for amateurs and tourists. Moreover, one of the original site specificities making it unique, is the availability of actual fluvial deposits along the Saoura Valley. These deposits are rich in modern traces and show diverse sedimentary structures at different scales, which can be easily compared to the fossil ones visible in the Devonian outcrops.

As many touristic sites, the Saoura Valley area is served by several roads, facilitating the entry and exit of people from all around Algeria or even from abroad (especially with the opening of an airfield in the town of Beni Abbes). Besides enhancing freight and passenger transport in the area, this new transportation facility is designed as an additional asset for the development of tourist activities in a region with such an invaluable world-renowned touristic potential. Geo-tourism promotion often combines good quality of infrastructures and interactive interpretation as the appropriate forms of local economic development through community involvement (Farsani et al. 2011; Margiotta and Sansò 2014).



**Table 3** Quantitative assessment of the scientific value (SV) of the Saoura Valley geo-sites from the Ougarta Range (after Brilha 2016)

Scientific Value (SV)		Parameters (points)	Weight (%)
Criteria/indicators			
A. Representativeness	The geo-site is the best example in the study area to illustrate elements or processes, related with the geological framework under consideration	4	30
B. Key locality	The geo-site is used by international science, directly related with the geological framework under consideration	2	10
C. Scientific knowledge	There are papers in international scientific journals about this geo-site, directly related with the geological framework under consideration	4	5
D. Integrity	The main geological elements (related with the geological framework under consideration, when applicable) are very well preserved	4	15
E. Geological diversity	Geo-site with more than three types of distinct geological features with scientific relevance	4	5
F. Rarity	In the study area, there are two to three examples of similar geo-sites (representing the geological framework under consideration, when applicable)	2	8
G. Use limitations	The geo-site has no limitations (legal permissions, physical barriers, etc.) for sampling or fieldwork	4	10
Total		24/28 points	83/100%

Across the Saoura Valley, several geo-sites with high touristic attractions can be observed; their locations, coordinates and features as touristic sites are summarized in Table 2. These geo-sites will surely provide a gorgeous destination for the tourists' sake and any other recreational activities (e.g., sand skiing and camping). These sites are especially noteworthy for their geo-diversity and archaeological heritage, as shown by their great historical, archaeological, geological, and cultural heritage. Moreover, these geo-sites are located in safe areas (i.e., no risky outcrops), served by good-quality itineraries and trails with low traffic, allowing rapid transfers between them. These spots can be developed very easily for geo-educational enhancement and holiday destinations, since these sites are already quite popular. Additionally, the surrounding areas display many diverse scenic beauties in a clean, fresh and healthy environment like many other spectacular places along the Saoura Valley (e.g., oases and palm groves) that can be easily accessed either within walking distance or by means of transport.

## Discussion

### Scientific Value Assessment

The assessment results show that the studied geo-sites indicate a high scientific value, with a score up to 80% (Table 3). The high scientific value directly reflects the diverse and numerous geological characteristics of these geo-sites and one of the most important evidences of the Devonian biodiversity as a major element for understanding the rise and evolution of marine life during this period of Earth's history. For instance, the Marhouma (Km 30) geo-site displays several *Zoophycos*-bearing levels occurring in the Middle Devonian deposits (Bouchemla

et al. 2021). Therefore, these Devonian *Zoophycos* have been considered as the first bloom of this trace maker during the Palaeozoic and a key to understanding its environmental and morphological evolutionary trend through the Phanerozoic. Actually, several aspects contribute significantly to the scientific value of a given geo-site, including their meaning in growing geoscience knowledge and enhancing site preservation for future research. In such a context, the Saoura Valley is highly representative and constitutes a key locality serving as a first-order international reference in various fields of geosciences, namely palaeo-environment and sequence stratigraphy, palaeontology (fossils and trace fossils), biostratigraphy, and palaeo-geography. All these features support the general scientific value of the geo-site described herein and the international relevance of the reference Marhouma (or Km 30) section (Saoura Valley) with its geological features or geological framework, such as the micro- and macrofossil diversity and abundance. Additionally, the geo-sites display several well-preserved geological features of scientific relevance, easily available for future research. Similarly, the geomorphological significance of the Saoura Valley lies within the diversity of its many desert landform elements, mainly dealing with the geomorphological processes occurring in such an arid environment. Although the Palaeolithic site was not evaluated using the quantitative method used herein, the bibliography emphasizing its national scientific worth clearly evidenced that this is a genuine portion of the Saoura Valley heritage.

### Geo-Education and Geo-Tourism Potential

The quantitative assessment of the educational potential use of the Saoura Valley shows a high geo-educational potential since the site is renowned for its ease-of-use

**Table 4** Quantitative assessment of the educational and tourism potential use of the Saoura Valley geo-sites from the Ougarta range (after Brillha 2016)

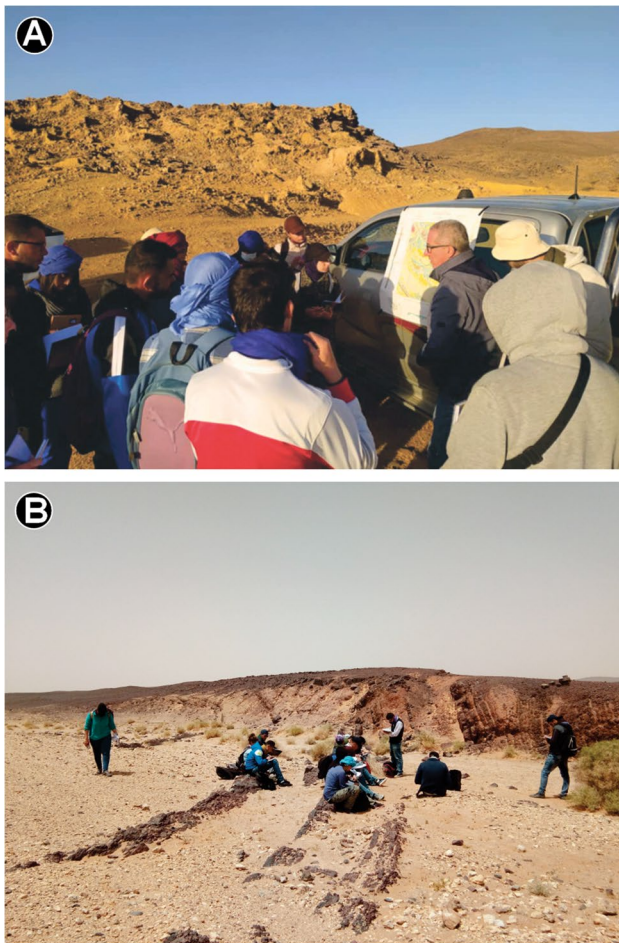
Potential Educational and Touristic Uses of the Saoura Valley geo-sites					
Potential Educational Use (PEU) and Touristic Use (PTU) Criteria/indicators		PEU		PTU	
		Parameters (Points)	Weight (%)	Parameters (Points)	Weight (%)
A. Vulnerability	There is the possibility of deterioration of secondary geological elements by anthropic activity	3	8.5	3	8.5
B. Accessibility	Site located less than 100 m from a paved road and with bus parking	4	10	4	10
C. Use limitations	The site has no limitations to be used by students and tourists	4	5	4	5
D. Safety	Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services	2	5	2	5
E. Logistics	Lodging and restaurants for groups of 50 persons less than 50 km away from the site	3	4	3	4
F. Density of population	Site located in a municipality with less than 100 inhabitants/km <sup>2</sup>	1	1.5	1	1.5
G. Association with other values	Occurrence of several ecological and cultural values less than 10 km away from the site	3	5	3	5
H. Scenery	Site currently used as a tourism destination in national campaigns	4	5	4	15
I. Uniqueness	The site shows unique and uncommon features in the country	3	4	3	8
J. Observation conditions	All geological elements are observed in good conditions	4	10	4	5
K. Didactic potential	The site presents geological elements that are taught in all teaching levels	4	20	-	-
L. Geological diversity	More than 3 types of geodiversity elements occur in the site	4	10	-	-
K. Interpretative potential	The site presents geological elements in a very clear and expressive way to all types of public	-	-	4	10
L. Economic level	The site is located in a municipality with a household income similar to the national average	-	-	2	2.5
M. Proximity of recreational areas	Site located less than 10 km from a recreational area or tourist attraction	-	-	3	3.5
Total		39/48 points	88/100%	40/52 points	83/100%

and national uniqueness (Table 4). Furthermore, the selected geo-sites such as the Marhouma (Km 30) section, can also be easily reached by means of transportation and provide safe conditions to prevent people from dangerous behaviour. This site is also characterized by its geodiversity easily observed by students of all school levels. In this sense, the geological diversity and accessibility of the outcrops exposing the continuous Devonian formations, provide a place where school pupils and university students can challenge their scientific knowledge in situ. The studied geo-site has been indeed used for several years as a pedagogical site (geo-didactic)

to teach palaeontology, stratigraphy, sedimentology, geodynamics, and even fossilization processes to geology students from several universities, depending on their academic levels (Fig. 12). All these criteria raise the PEU higher.

On the other hand, the assessment of the potential touristic use (PTU) of the Saoura Valley shows a rather high potential since it is close to recreational areas with touristic attractions, especially around the town of Beni Abbes holding the sole accommodation (e.g., Hotel Rym) in the region and not very far from others geo-sites, including the Marhouma (Km 30) section. Generally





**Fig. 12** A-B. Example of pedagogical activity (geo-didactic) to teach the geodynamics of the Ougarta Basin to the geology students from the Saoura Valley

speaking, as a common practice worldwide, people visit natural sites with fascinating sceneries. According to Hose et al. (2011), geographically and geologically significant landscapes play an important role in tourism development and attraction, aptly called geo-tourism. Thus, geo-tourism is a type of tourism enabling the public to learn about the geological and geomorphological processes of a specific location (Hose 1996). It can also be used in geo-education for its geodiversity, constitutes a new form of scientific popularization of geology, and serves as a valuable economic resource for communities near geo-sites. In this context, the Saoura Valley site, including the town of Beni Abbes, offers a beautiful perspective and provides opportunities for a variety of touristic activities, such as hiking and camping in the sand dunes to experience nomadic life, sand skiing, visiting the oasis and talking to local people to learn more about their culture and traditions, and climbing the giant sand dunes to take a more authentic look at this sand sea (Fig. 13). In this

arid area, the sand dunes are considered an important component of the desert in several aspects, including the ecological, technical, symbolic, social, and aesthetic issues of several human groups (Varichon and Roccella 2006; Boulay and Gélard 2013; Lahmidi et al. 2020). Additionally, they are regarded as a natural resource, demonstrating the complexities of scientific, socio-economic and environmental concerns (Welland 2009), therefore considered as a specific resource and cultural tourism of the region.

Furthermore, the town of Beni Abbes has several monuments and touristic areas (Fig. 14) that attract tourists every year, among which are the palm groves of the oasis, the church and the history of its presence in the region (the rite of Father Charles de Foucauld), and the scientific heritage museum in the region of El Ouahat. This latter facility consists in a research centre on dry areas and belongs to the “*Unité de Recherche sur les Zones Arides (URZA)*” created in 1942. The centre is also considered a huge conservation repository for hundreds of different stuffed birds recorded with both their scientific and local names. The municipalities of the county include numerous ksars (a local term for palace), some of which are still inhabited, notably Ksar Beni Abbes (Fig. 14E), as the largest and most important in terms of tourism. The town also uses to organize several festivals all yearlong to celebrate religious holidays (e.g., El Mawlid Ennabaoui), keeping the city in permanent operations during several days to promote customs and traditions (Fig. 14F). All these touristic potentials and characteristics have led the officials to adopt a strategy for tourism promotion and to turn the region into the preferred touristic destination, thus contributing to the protection of these heritages and generating sustainable income for their preservation.

### Risk of Degradation

Due to the lithological nature of the Saoura Valley outcrops (such as clay-rich siltstones and shales), mostly exposed to atmospheric conditions, they have already been impacted by deterioration. It had actually taken millions of years for geological processes to develop any geological feature but, in turn, this latter can be easily tampered by anthropogenic interventions. Therefore, various conservation measures are inevitable to manage and safeguard any geo-heritage site (Hose 2000; Crofts and Gordon 2015). The studied geo-sites are located in a municipality with less than 100 inhabitants per km<sup>2</sup>, thus minimizing anthropic interventions. However, the risk of degradation, especially around the Marhouma (Km 30) section, is related to its lack of control over access and its service by a paved road. Any future development of the road (RN°6) between Bechar and Adrar would have

**Fig. 13** Some touristic activities from the Saoura Valley. **A.** Camel ride in the dunes. **B.** Hiking in the oasis and giant dunes. **C.** Sand skiing. **D.** Trying some traditional clothing and watching the local pottery



direct consequences for the destruction, especially of the famous and remarkable metric limestone bar rich in *Orthoceras* (also called the Chinese Wall = “*Muraille de Chine*”). As a consequence, the geo-resource strata and well-preserved fossils (e.g., FBV), should be protected, especially when considering the easy transportation from the *in-situ* to the *ex-situ* position, resulting in a possible permanent loss of geological material of international importance. Therefore, the materials collected by geology students or researchers must be reasonable and subsequently housed in a geological laboratory or museum as a common repository for the scientific community. Overall, the Saoura Valley geo-sites currently show no sign of major degradation. However, we propose to create a geo-park in the Saoura Valley in order to manage the preservation of its significant geo-resources and to prevent these sites from any future degradation. Furthermore, the archaeological site ought to be also included since it started showing signs of degradation due to modern human writings and, on the other hand, it has been the subject of promotion in education and tourism as well. This proposal will contribute to educate the public, to

generate awareness about the importance of geosciences and to upraise sustainable economics of rural regions through geo-tourism (Kelley et al. 2019).

## Conclusion

The Palaeozoic deposits of the Saoura Valley (Ougarta Range) have been known for more than a century and present the most complete Devonian stratigraphic sequence in southwestern Algeria. The Marhouma reference section is the best place to observe a continuous Devonian exposure within the Ougarta Range. Therefore, this succession has been studied by many researchers of different geological disciplines, given its wealth of geological material of international significance, resulting in many research papers on miscellaneous topics, mostly dealing with stratigraphy and palaeontology. However, despite its geological diversity, it has never been considered or assessed as a geo-heritage deserving more attention, geo-conservation and promotion, not only for the sake of scientific research but also for geo-education and geo-tourism activities. In this context, the



**Fig. 14** Some touristic attraction sites within the Saoura Valley. **A.** Giant panel introducing some touristic locations and activities in the surroundings of the town of Beni Abbes. **B, D.** Accommodation in Hotel Rym. **C.** Visiting the palm grove of the town of Beni Abbes. **E.** Internal view of the ancient Ksar of the town of Beni Abbes. **F.** Festival schedules to celebrating some religious holidays



Saoura Valley geo-sites meet all conditions to be a first-order destination for visitors of all ages and backgrounds, either for touristic or geo-educational purposes. Thus, we invite the decision makers and the administrative authorities to take measures for the protection and conservation of the geo-sites regarded in this study as geo-sites of international interest in order to make them a popular tourist destination in this area and preserve them for future generations. This will have an extra socio-economic influence in the area, besides characterizing their scientific, educational and tourism attractions. Hence, geo-heritage is highly significant for several reasons. In this way, the proximity of the studied geo-sites to the town of Beni Abbes, (which is actually considered as the preferred tourist destination in the area, particularly

during holiday periods) since it already encompasses all the touristic qualifications (e.g., accommodation, oasars, ksars, sand dunes, etc.) and encourages tourist agencies to propose the studied geo-sites as an endearing destination by proposing several geo-trails within the area, especially for those enthusiasts of nature contemplation. Therefore, such a decision will enhance local socio-economic development by creating jobs in the sectors of tourism, valorization and conservation, as well as promoting local products and creating sustainable small businesses in this remote area. Consequently, we propose to create a geo-park as one of the most appropriate tools to achieve and realize these goals and, on the other hand, we will be able to promote scientific education for sustainable development.

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**Author Contributions** **Imad Bouchemla** conceived and designed the study, collected and analyzed data, and wrote the original draft. **Madani Benyoucef** supervised and performed both the experiment and the field job. All authors read and approved the final manuscript.

## Declarations

**Competing Interests** The authors declare that they have no competing interests.

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