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ORIGINAL ARTICLE

The Geoheritage of Northwestern Central Morocco Area: Inventory and Quantitative Assessment of Geosites for Geoconservation, Geotourism, Geopark Purpose and the Support of Sustainable Development

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Abstract

Throughout the course of the last years, geoconservation is increasingly becoming on the A-list of topics holding more and more attention, given its importance on geoheritage regarding several scales: conservation, geotourism, geoeducation, and local development. Central Moroccan massif is one of the Variscan massifs that amass a number of geosites (sedimentological, basin genesis, petrographical, paleoclimate …) allowing the understanding of the relevant period of the Earth's evolution and the geodynamics of the area, as well as, it contains geosites from the Ediacarian to Quaternary. In this perspective, the current work aimed to identify priority sites for geoconservation actions, geoeducation, and geotourism. All geological sites were inventoried and evaluated by a quantitative assessment relying on the scientific value, the degradation risk, the educational and touristic potential uses regarding both the protection priorities and the use management. The inventory of geosites and their quantitative assessment were performed by the method of Brilha (Geoheritage 8:119–134, 2016). The takeaways of this work may help improve the sustainable development of the area through the establishment of geopark, the implement of a geoconservation strategy and the geotourism action plan. In addition, it could be the path to achieve a global target of the sustainable goals in the Central Morocco area.

Keywords Central Morocco · Geosites · Inventory · Quantitative assessment of geosites · Geoconservation · Geotourism · Geopark

Introduction

Recently, the awareness about geoconservation has strongly been increased, this is translated by the number of studies published in this same vein (e.g., Wimbledon 2011, Wimbledon et al. 1995, 1999; Gray 2008; Carcavilla et al. 2008; Lima et al. 2010; Ruban 2010; Henriques et al. 2011; Prosser et al. 2011; Thomas 2012; Pereira et al. 2013; Silva et al. 2013, 2015; Bradbury 2014; Brilha 2016; Reynard et al. 2016; Brazier et al. 2017; Świerkosz et al. 2017; Gordon et al. 2018; Brown et al. 2018; Gray 2018; Reynard and Brilha 2018; Bétard and Peulvast 2019; Gordon et al. 2019; Brocx and Semeniuk 2019;

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Semeniuk 2019). Geoconservation is implemented on geodiversity elements with a high scientific value (geosites) which may also have an educational, touristic, and cultural value (Brilha 2016).

The inventory is the first and important step in any geoconservation strategy. A solid inventory leads to the establishment of conservation, management and interpretation actions, and determines a specific management that should be applied only for important geosites (Brilha 2018).

The development of methodologies focused on geosites and geomorphosites assessment is one of the important topics in geoconservation, which aims at protection, valuation and promotion. The definition of a guideline and the proposition of a methodology for assessment of geosites and geomorphosites, taking into account their specificities have been done by several researches (Wimbledon 1996, 2011, Wimbledon et al. 1995; Grandgirard 1995, 1996, 1999; Cendrero 1996a, b; Alexandrowicz and Kozlowski 1999; Wimbledon et al. 2000; Panizza 2001; Bruschi and Cendrero 2005, 2009; Coratza and Giusti 2005; Pralong 2005; Pralong and Reynard 2005; Serrano and González-Trueba 2005; Zouros 2005; De Wever et al. 2006; Pereira et al. 2007; Reynard et al. 2007; Zouros 2007; Panizza and Piacente 2008; Reynard 2009; García-Cortéz and Carcavilla 2009; Erhartič 2010; Fuertes-Gutiérrez and Fernández-Martínez (2010); Lima et al. 2010; Pereira and Pereira 2010, 2012; Ruban 2010; Pereira and Brilha 2010; Baca and Schuster 2011; Poirier and Daigneault 2011; Bruschi et al. 2011; Feuillet and Sourp 2011; Bruschi et al. 2011; Vujičić et al. 2011; Bollati et al. 2012, 2013, 2016; Fassoulas et al. 2012; Brilha 2016, 2018; Sellier 2016). However, the development of a universal guideline is not possible due to the differences of the geoconservation goals and the geological setting.

While researches highlighted above think to develop methodologies for inventorying geosites and their quantitative assessments, others are awarded for geotourism and geoparks (Hose 2000, 2006, 2008, 2012; Dowling and Newsome 2006; Hose et al. 2011; Newsome and Dowling 2010; Grant 2010; Dowling 2011; Megerle and Beuter 2011; De Wever et al. 2017; Štrba 2018; Štrba et al. 2018), and educational use of geoheritage (Cayla et al. 2010; Bollati et al. 2011). Making inventory, quantitative assessment, geotourism, educational uses… all those approaches deal to protect and use the geoheritage one way or another; however, any use should take into account the value of this geoheritage and help always on its conservation.

The geoconservation could be an opportunity to protect the geoheritage but at the same time it could be an encouragement to exploit it differently for the scientific, educational and geotourism purposes. According to Dowling (2011) "Geotourism is sustainable tourism with a primary focus on experiencing the earth's geological features in a way that fosters environmental and cultural understanding, appreciation and conservation, and is locally beneficial." Application of a geotourism action plan is a way to use the geoheritage as benefit for society in which geological element (Form and process) together with tourism components (for instance: attractions, planning and management, activities, tours…) contribute to increase the sustainable development." In addition, geotourism could be an opportunity to increase the learning, appreciation and awareness about geology for both tourists and local community.

The growth of sustainable development through the use of geoheritage could require the establishment of geopark. The concept of geopark is very developed in Europe comparing with Morocco. Geopark is a strategy for development of a territory with a relevant geological heritage that should be conserved (Henriques et al. 2011), it aims for the promotion of economic sustainable development of local communities (Patzak and Eder 1998; Eder 1999; Eder and Patzak 2004; Zouros 2004; McKeever et al. 2010) across the promotion of geotourism and education (Henriques and Brilha 2017).

The establishment of a geopark and creating a geotourism action plan are considered as a good initiative which help to achieve the rural economy (Farsani et al. 2011) and sustainable development goals such as enhancing job opportunities and foster economic benefits for people living the geopark. While geoparks consider as a management tool aims on sustainable development across the use of geoheritage combining with other types of heritage, protected areas (Natural parks, National parks, natural reserves, natural monuments, etc.) aims on the long-term conservation of natural heritage including the geoheritage using the law determined by the authorities. The co-existing of protected areas and geoparks totally or partially in the same territory is possible.

Moroccan territory contains geodiversity with exceptional scientific value at the scale of the region, the country and the globe, this geodiversity allow understanding the regional, national, and international geological history. The elaboration of a good geoconservation strategy constitutes the greatest tools for conserving this geoheritage. For this reason, Moroccan researches start working on geoheritage recently and trying to make an inventory of geosites in different regions (Malaki 2006; De Waele et al. 2009; El Wartiti et al. 2009, 2017; Beraaouz et al. 2010; Tahiri et al. 2010a; El Hadi et al. 2011, 2012, 2015; Nahraoui et al. 2011, 2016; Enniouar et al. 2013, 2015; Errami et al. 2013, 2015a, b; Bourchich et al. 2015; Druguet et al. 2015; Noubhani 2015; Saddiqi et al. 2015; Bouzekraoui et al. 2017; Arrad et al. 2018; Bouzekraoui et al. 2018; El Hassani et al. 2017; Khoukhouchi et al. 2018; Aoulad-Sidi-Mhend et al. 2019; Beraaouz et al. 2019; Berred et al. 2019; Oukassou et al. 2019, Kaid Rassou et al. 2019; Mehdioui et al. 2020; Baadi et al. 2020; Lahmidi et al. 2020; Mirari and Benmlih 2020; Mirari et al. 2020; Salhi et al. 2020). However, the geoheritage efforts remain limited, beginner and random. The works done in the purpose of geoheritage show some weaknesses, which come from several reasons:

– Unclear inventory aims

The aim of the inventory should be identified in order to develop the goal needed through the identification of the action that should be implemented.

– The misunderstanding of the concept of geoheritage

This point has affected the inventory made in several areas. Generally, the inventories are based on the point of view of the researcher, choosing only geosites that the researcher know or visited previously while others that have a scientific value are ignored; consequently, they will be ignored too during the legal protection process. The inventory should be systematic and include all geosites of the area.

Another idea must be stressed, there is an understanding gap on how to apply the geoconservation strategies especially during the application process of geosites assessment methodologies; thus, the results will be affected (may a geosite be removed from the potential list or a geodiversity site be included).

– The use of different methods

A different approach is used in order to identify geosites and their assessment. Hence, Moroccan territory has a really huge number of geosites with high scientific relevance from Precambrian to Quaternary that should be assessed by methods that take into account this advantage; it is preferable to use a method that is recognized by the international geoscientist community in which all important scientific value criteria that summarize the maximum of geological information should be included.

– The lack of national project or at least a regional project

The current state of geoheritage in Morocco together with geological heritage that comprise with degradation risk or potential educative and touristic use require an urgent national project that unified the efforts and the methods to avoid the dispersed personal initiative, in which all Moroccan geoscientists community work on the same goals and on the same approach.

Despite those weaknesses, Morocco try to set up a legal protection of geoheritage by publishing the first law for the protection of the Moroccan geoheritage (BO 6807, August 2019). This law could constitute an important change in the current deficient situation of the national geoheritage.

The Central Massif area, which is the focus of this work, contains numerous outcrops and landscapes which are described and studied by researches using different methods and techniques (Field trips, collection of samples, analyses…) and for different purposes (Petrography, geochemistry, sedimentology, stratigraphy, structural…). Those outcrops represent different geological events through the geological time scale; some of them are unique and universal with a high scientific relevance while others make the difference between the area and the other regions.

The area provides a large number of geodiversity sites with a high scientific value, educational and touristic uses. Despite the few works of geoheritage done in the central massif (Tahiri et al. 2010a; Nahraoui 2016), the systematic inventory and the quantitative assessment of geosites have never been done. The present work consists to fill this gap. The establishment of geoparks and the development of geotourism action plan require a solid geoconservation strategy; this latter is based on the inventory and quantitative assessment (Henriques and Brilha 2017). For this reason, this paper's aim is to make the inventory of geosites that represent the geological history of the area, quantitative assessment of geosites, proposition of georoads, assessment of georoads and to set the background for the future geoconservation actions, management use and geotourism. Likewise, the platform of the national inventory "Lithothèque du Maroc" has been elaborated by the Scientific Institute of Rabat (http://www.israbat.ac.ma/Lithotheque-du-Maroc/) under the supervising of Professor Tahiri. This initiative is the first and the only one in Morocco; however, it has been made by isolated effort, which should be congregated. It starts by the Rabat region meanwhile the inventory of the other regions be finished. The results of the inventory of the area will be included in the platform. This web platform contributes to enhance the geoscience culture of the society, a science that is being far away from the general public. Now, it is available to the general public and scholar population.

The aims of the paper have the same direction of the seventeen United Nation Sustainable Development Goals 2016–2030 (UN 2015) as international goals. It could be a scientific support regarding the sustainable development of the local people through the elaboration of the geosites inventory of the region Rabat-Sale-Kenitra.

Geological Setting

From a geological point of view, The Central Massif occupies the Northwestern part of the Meseta (Figs. 1 and 2); it is one of the Paleozoic massifs of the Moroccan Meseta affected by Variscan deformations (Tahiri 1991).

In the Occidental Meseta, at the Late Upper Devonian, the subsidence basins are opened followed by essentially a basic magmatism (alkaline to Tholeiitic) (Piqué 1979; Fadli 1990; Tahiri 1991; Kharbouch 1994). After that, at the Westphalo-Stephanian, this outcrop folded under the Variscan

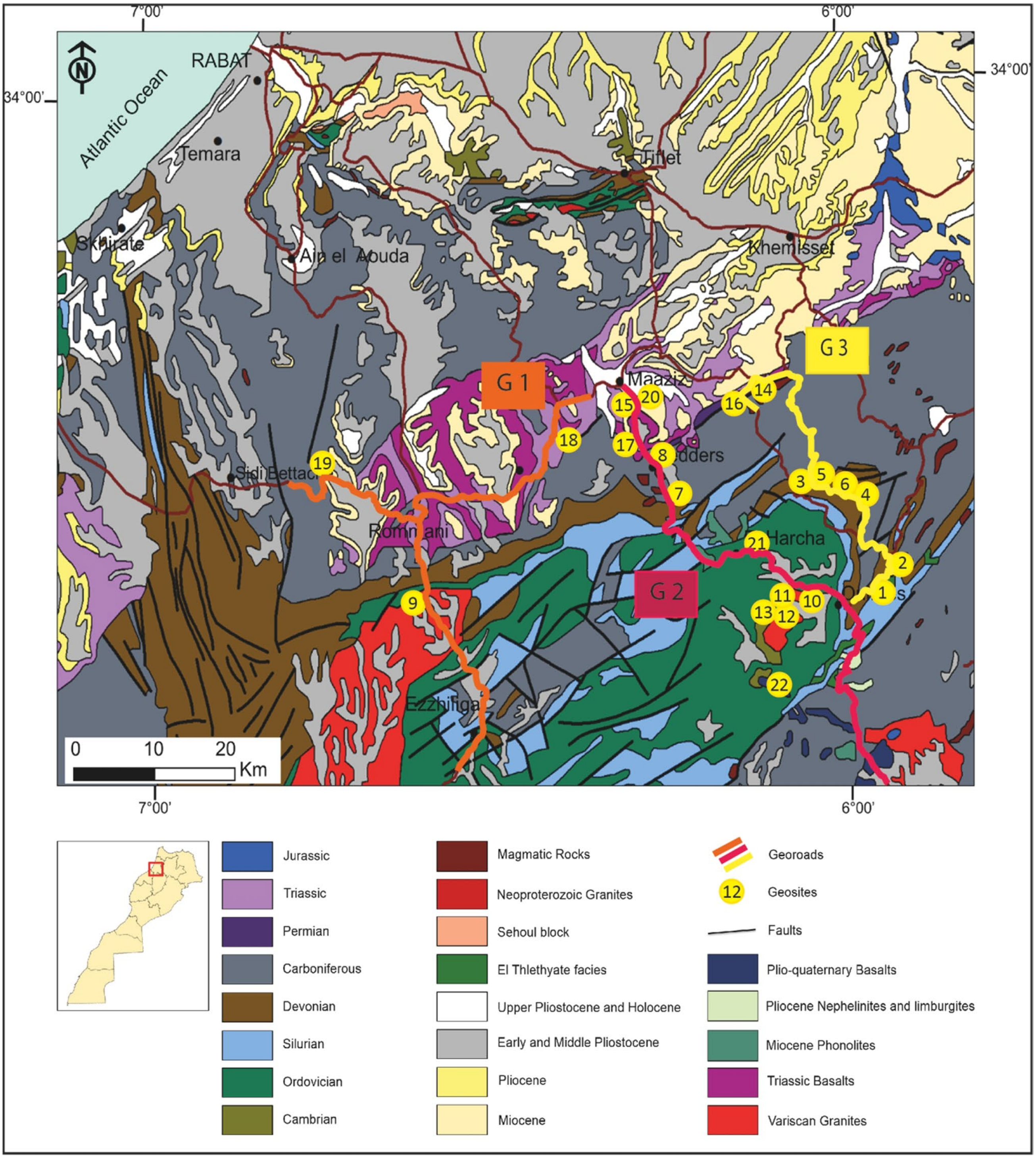


Fig. 1 Geological map of Central Morocco area with geosites position and georoads (From the geological map of Morocco 1/1000000)

compression (Tahiri 1991) accompanied by an epi-mesozonal regional metamorphism (Distene in Rehamna; Michard 1968) with an age ranging from 289 to 290 Ma (Oulmes area; Huon 1985). This compression generates Variscan granites in the shear zones with the maximum of deformation, from the syntectonic phase to the late (Autunian) britle tectonic deformation phase (Diot 1989; Tahiri 1991).

Above the Ediacarian substratum which only appears locally in the Tiflet area (Tahiri et al. 2010b) and eastward in Aguelmous area (Ouabid et al. 2017), the Paleozoic

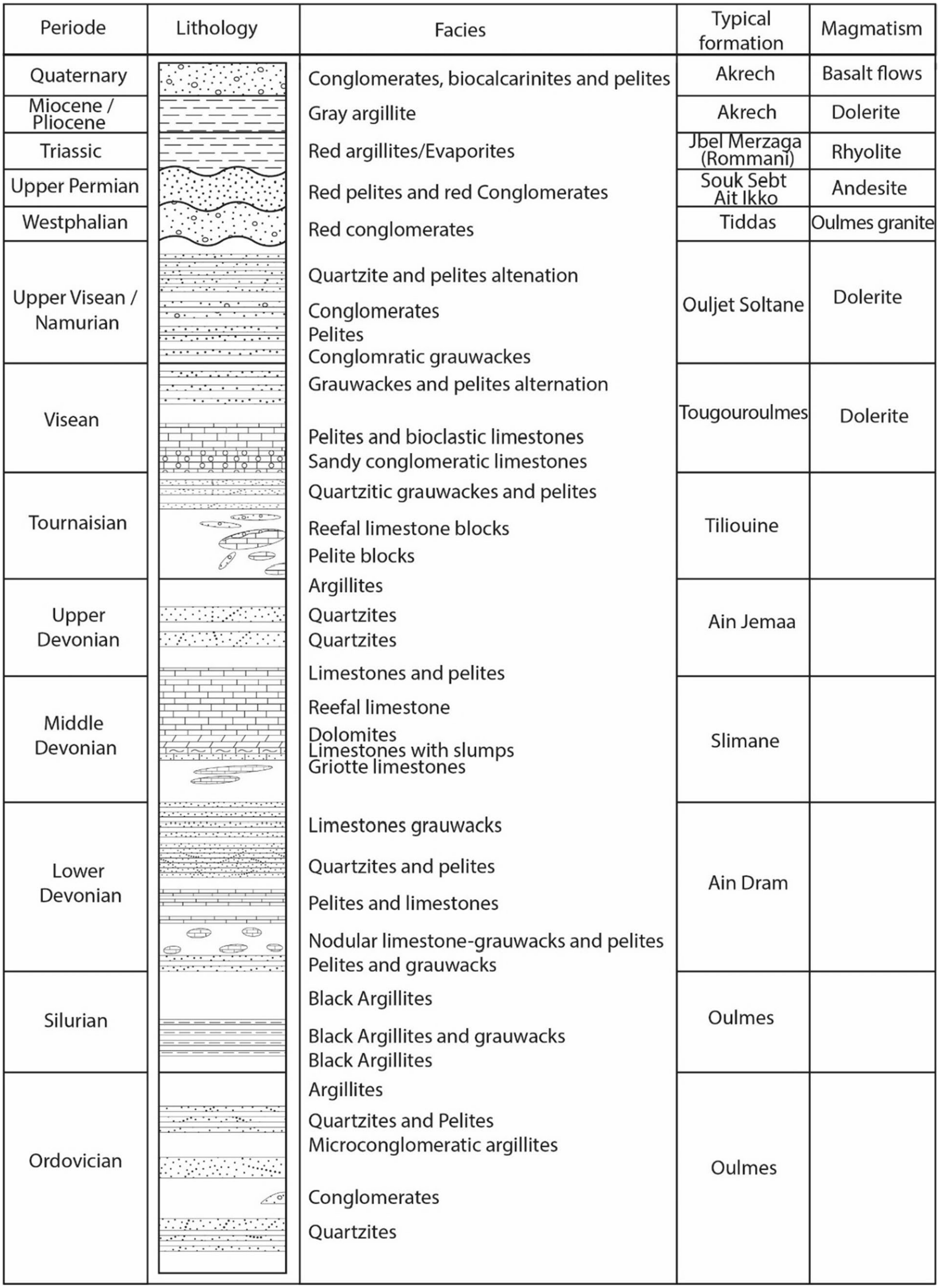


Fig. 2 Synthetic stratigraphic log of the Central Morocco zone (From Tahiri 1991; simplified) (Scale not respected)

stratigraphic series in the Central Massif showed quasi-continuity from the Middle Cambrian (?) to Westphalian (Hoepffener et al. 2005; Michard et al. 2008).

The Lower Paleozoic was characterized by an epicontinental platform sedimentation (Hoepffener et al. 2005; Michard et al. 2008). A distension occurred in this part; it causes the NE-SW graben of the coastwise Meseta during the middle Cambrian with a basaltic magmatism (Bernardin et al. 1988; Ouali et al. 2000; El Hadi et al. 2006), while a paleogeography with a deep domain in the East and with a talus domain and coastwise in the West was developing during the upper Ordovician under the orientation of the NE-SW faults (Tahiri 1991). Despite that the important distension exists in this area; there is no index of the basalts (Tahiri 1991). The Lower Ordovician calc-alkaline basalts of the Sehoul Block are due to the crustal thinning (El Hassani 1990; El Hadi et al. 2014). The Upper Silurian is well known in this area by gaps (Middle Ordovician to Middle Silurian) which are the result of the Caledonian movements in the nearby area (Rabat-Tiflet axis; El Hassani 1990), such movements exist just in this part in the whole Morocco (El Hassani 1990, Hoepffener et al. 2005; Tahiri 1991; Tahiri et al. 2010b).

Since the Devonian, the sedimentation begins to be inhomogeneous. Two domains are differentiating one on the west (Tiliouine region) and the second on the east (Moulay El Hassan) which are separated by a shear zone of Oulmes with a direction of NE-SW (Tahiri 1991). From the Lochkovian to the Famennian, the sedimentation evolved from a detrital sediment into deltaic environment at the Famennian passing by a carbonated platform sediment of the middle Devonian (Tahiri 1991). It stills no index of the magmatism in the area (Tahiri 1991). However, in the Upper Devonian begins the creation of the basins nearby the sub-EW faults (Tahiri 1991) which are gone with the calc-alkaline magmatism (Kharbouch 1982).

The Central Massif characterized by weakness zones like the one of Oulmes, which causes the generation of the Paleozoic basins (Sidi Bettache, Tiliouine, Fourhal…) (Tahiri 1991; Piqué 1994). On the late Paleozoic, those faults change from the extension faults to the ductile shear faults (Tahiri 1991).

At the Ante-Visean phases (Famenno-tournaisian priode), the Mesetian platform dislocated into several continental blocs that surround by strike slip (and or normal) fault zones where the future basins (Sidi Bettache and Tiliouine basins) were created (Tahiri 1991, Hoepffener et al. 2005). During the Visean and the Namurian, the magmatism related to the crustal thinning (Tahiri 1991) was calc-alkaline (Kharbouch 1982).

During the major Westphalo-Stephanian age deformation (Michard et al. 2008, 2010), the shear faults zone between the Tiliouine basin and the Fourhal basin (Oulmes zone) reach the maximum of deformation which causes the maximum of metamorphism (Tahiri 1991).

The Westphalian-Stephanian deformation is characterized by two episodes of syncleaved folding and the ductile shears. A NW–SE compressive tectonic regime replaced the Lower Paleozoic extensional tectonic regime, leading to remobilization of the faults in shears, which generate the syntectonic granites: Oulmes, Zaer, Oued Zem, Moulay Bou Azza-Aouam and El Hammam (Boushaba et al. 1987; Tahiri 1991; Rahou 1996), those granites are the result of the crustal melting (Diot 1989; Tahiri et al. 2007). The tectonic and metamorphism were maximal (Mesozonal) at this episode in the shears zone of Oulmes (Ait Omar 1985; Tahiri et al. 2007). The second episode was characterized by a coaxial folding that exists just in Oulmes shear zone (Ait Omar 1985; Tahiri et al. 2007).

At the Lower Permian (Autunian; Broutin et al. 1987), small intramountain basins are generated after the remobilization of the faults in shears due to the same compressive tectonic regime (Saidi et al. 2002), associated with rhyolitic volcanism (Gonord et al. 1980; Youbi 1990; El Hadi et al. 2006).

Methodology

The inventory and quantitative assessment of geosites are the first steps of geoconservation strategy, it is an important tool to identify and select geosites, which represent the geological history of the region in order to protect it, because it is impossible to protect all the geodiversity elements of the earth.

Making geosites inventory require the answer to four main points: the topic, the value, the scale and the use (Lima et al. 2010). This work focused on the identification, selection, and assessment of geological heritage (topic), with international, national, and local scientific relevance (value), outcropping in the Central Massif (scope) in order to support future proposals for the protection, management and promotion of this geoheritage by the regional authority (use).

An inventory aimed on the scientific value requires the strong involvement of the geoscientific community, including researchers and experts from different institutions with a very solid scientific knowledge (Garcia et al. 2017).

While the inventory deals to make a solid list of geosites in order to conserve it, the quantitative assessment aims to make the priority in order to identify the geosites that should be conserved first, taking into account their Scientific value, Educational and touristic potential uses, and degradation risk (Brilha 2018). The results of the quantitative assessment considered as a consistent tool in order to delineate geoconservation strategies, proper geosites management (Prosser et al. 2018) or their uses like geotourism development (Newsome and Dowling 2018). It should be highlighted that while geosites with high degradation risk require an urgent geoconservation action plan, those with high educational and touristic uses should have a higher priority in the management planning (Brilha 2018).

In spite of the few works done in the study area (El Wartiti et al. 2017; Tahiri et al. 2010a; Nahraoui 2016), no systematic

Table 1 Criteria, indicators, and numeric parameter to quantify the scientific, educational, and touristic values, together with the degradation risk of the Rabat-Tiflet geosites (Brilha 2016)

Scientific value	
Representativeness (SVW = 30; EVW = 0; TVW = 0; DRW = 0)	Points
The geosite is the best example in the study area	4
The geosite is a good example in the study area	2
The geosite is a reasonable example in the study area	1
Key locality (SVW = 20; EVW = 0; TVW = 0; DRW = 0)	
The geosite is recognized as a GSSP or ASSP by the IUGS or is an IMA reference site	4
The geosite is used by international science	2
The geosite is used by national science	1
Scientific knowledge (SVW = 5; EVW = 0; TVW = 0; DRW = 0)	
There are papers in international scientific journals about this geosite	4
There are papers in national scientific publications about this geosite	2
There are abstracts presented in international scientific events about this geosite	1
Integrity (SVW = 15; EVW = 0; TVW = 0; DRW = 0)	
The main geological elements are very well preserved	4
Geosite not so well preserved, but the main geological elements are still preserved	2
Geosite with preservation problems and with the main geological elements quite altered or modified	1
Geological diversity (SVW = 5; EVW = 0; TVW = 0; DRW = 0)	
Geosite with more than three types of distinct geological features with scientific relevance	4
Geosite with three types of distinct geological features with scientific relevance	2
Geosite with two types of distinct geological features with scientific relevance	1
Rarity (SVW = 15; EVW = 0; TVW = 0; DRW = 0)	
The geosite is the only occurrence of this type in the study area	4
In the study area, there are two to three examples of similar geosites	2
In the study area, there are four to five examples of similar geosites	1
In the study area, there are over than five examples of similar geosites	0
Use limitations (SVW = 10; EVW = 0; TVW = 0; DRW = 0)	
The geosite has no limitations (legal permissions, physical barriers…) for sampling or fieldwork	4
It is possible to collect samples and do fieldwork after overcoming the limitations	2
Sampling and fieldwork are very hard to be accomplished due to limitations difficult to overcome (legal permissions, physical barriers…)	1
Educational and touristic value (Common criteria)	
Vulnerability (SVW = 0; EVW = 10; TVW = 10; DRW = 0)	
The geological elements of the geosite present no possible deterioration by anthropic activity	4
There is the possibility of deterioration of secondary geological elements by anthropic activity	3
There is the possibility of deterioration of main geological elements by anthropic activity	2
There is the possibility of deterioration of main geological elements by anthropic activity	1
Accessibility (SVW = 0; EVW = 10; TVW = 10; DRW = 0)	
Site located less than 100 m from a paved road	4
Site located less than 500 m from a paved road	3
Site accessible by bus but through a gravel road	2
Site with no direct access by road but located less than 1 km from a road accessible by bus	1

Table 1 (continued)

Use limitations (SVW = 0; EVW = 5; TVW = 5; DRW = 0)	
The site has no limitations to be used by students and tourists	4
The site can be used by students and tourists but only occasionally	3
The site can be used by students and tourists but only after overcoming limitations (legal, permissions, physical, tides, floods…)	2
The use by students and tourists is very hard to be accomplished due to limitations difficult to overcome (legal, permissions, physical, tides, floods, …)	1
Safety (SVW = 0; EVW = 10; TVW = 10; DRW = 0)	
Site with safety facilities (fences, stairs, handrails, etc.), mobile phone coverage and located less than 5 km from emergency services	4
Site with safety facilities (fences, stairs, handrails, etc.), mobile phone coverage and located less than 25 km from emergency services	3
Site with no safety facilities but with mobile phone coverage and located less than 50 km from emergency services	2
Site with no safety facilities, no mobile phone coverage and located more than 50 km from emergency services	1
Logistics (SVW = 0; EVW = 5; TVW = 5; DRW = 0)	
Lodging and restaurants for groups of 50 persons less than 15 km away from the site	4
Lodging and restaurants for groups of 50 persons less than 50 km away from the site	3
Lodging and restaurants for groups of 50 persons less than 100 km away from the site	2
Lodging and restaurants for groups less than 25 persons and less than 50 km away from the site	1
Density of population (SVW = 0; EVW = 5; TVW = 5; DRW = 0)	
Site located in a region with more than 1000 inhabitants/km^2	4
Site located in a region with 250–1000 inhabitants/km^2	3
Site located in a region with 100–250 inhabitants/km^2	2
Site located in a region with less than 100 inhabitants/km^2	1
Association with other values (SVW = 0; EVW = 5; TVW = 5; DRW = 0)	
Occurrence of several ecological and cultural values less than 5 km away from the site	4
Occurrence of several ecological and cultural values less than 10 km away from the site	3
Occurrence of one ecological value and one cultural value less than 10 km away from the site	2
Occurrence of one ecological or cultural value less than 10 km away from the site	1
Scenery (SVW = 0; EVW = 5; TVW = 15; DRW = 0)	
Site currently used as a tourism destination in national campaigns	4
Site occasionally used as a tourism destination in national campaigns	3
Site currently used as a tourism destination in local campaigns	2
Site occasionally used as a tourism destination in local campaigns	1
Site has no use as a tourism destination	0
Uniqueness (SVW = 0; EVW = 5; TVW = 10; DRW = 0)	
The site shows unique and uncommon features considering this and neighboring countries	4
The site shows unique and uncommon features in the country	3
The site shows common features in this region but they are uncommon in other regions of the country	2
The site shows features rather common in the whole country	1
Observation conditions (SVW = 0; EVW = 10; TVW = 5; DRW = 0)	
All geological elements are observed in good conditions	4
There are some obstacles that make difficult the observation of some geological elements	3
There are some obstacles that make difficult the observation of the main geological elements	2
There are some obstacles that almost obstruct the observation of the main geological elements	1

Table 1 (continued)

Educational value	
Didactic potential (SVW = 0; EVW = 20; TVW = 0; DRW = 0)	
The site presents geological elements that are taught in all teaching levels	4
The site presents geological elements that are taught in elementary schools	3
The site presents geological elements that are taught in secondary schools	2
The site presents geological elements that are taught in the university	1
Geological diversity (SVW = 0; EVW = 10; TVW = 0; DRW = 0)	
More than 3 types of geodiversity elements occur in the site (mineralogical, paleontological, geomorphological, etc.)	4
There are 3 types of geodiversity elements in the site	3
There are 2 types of geodiversity elements in the site	2
There is only 1 type of geodiversity element in the site	1
Touristic value	
Interpretative potential (SVW = 0; EVW = 0; TVW = 10; DRW = 0)	
The site presents geological elements in a very clear and expressive way to all types of public	4
The public needs to have some geological background to understand the geological elements of the site	3
The public needs to have solid geological background to understand the geological elements of the site	2
The site presents geological elements only understandable to geological experts	1
Economic level (SVW = 0; EVW = 0; TVW = 5; DRW = 0)	
The site is located in a municipality with a household income at least the double of the national average	4
The site is located in a municipality with a household income higher than the national average	3
The site is located in a municipality with a household income similar to the national average	2
The site is located in a municipality with a household income lower than the national average	1
Proximity of recreational areas (SVW = 0; EVW = 0; TVW = 5; DRW = 0)	
Site located less than 5 km from a recreational area or tourist attraction	4
Site located less than 10 km from a recreational area or tourist attraction	3
Site located less than 15 km from a recreational area or tourist attraction	2
Site located less than 20 km from a recreational area or tourist attraction	1
Degradation risk	
Deterioration of geological elements (SVW = 0; EVW = 0; TVW = 0; DRW = 35)	
Possibility of deterioration of all geological elements	4
Possibility of deterioration of the main geological elements	3
Possibility of deterioration of secondary geological elements	2
Minor possibility of deterioration of secondary geological elements	1
Proximity to areas/activities with potential to cause degradation (SVW = 0; EVW = 0; TVW = 0; DRW = 20)	
Site located less than 50 m of a potential degrading area/activity	4
Site located less than 200 m of a potential degrading area/activity	3
Site located less than 500 m of a potential degrading area/activity	2
Site located less than 1 km of a potential degrading area/activity	1
Legal protection (SVW = 0; EVW = 0; TVW = 0; DRW = 20)	

Table 1 (continued)

Site located in an area with no legal protection and no control of access	4
Site located in an area with no legal protection but with control of access	3
Site located in an area with legal protection but no control of access	2
Site located in an area with legal protection and control of access	1
Accessibility (SVW = 0; EVW = 0; TVW = 0; DRW = 15)	
Site located less than 100 m from a paved road	4
Site located less than 500 m from a paved road	3
Site accessible by bus through a gravel road	2
Site with no direct access by road but located less than 1 km from a road accessible by bus	1
Density of population (SVW = 0; EVW = 0; TVW = 0; DRW = 10)	
Site located in a region with more than 1000 inhabitants/km^2	4
Site located in a region with 250–1000 inhabitants/km^2	3
Site located in a region with 100–250 inhabitants/km^2	2
Site located in a region with less than 100 inhabitants/km^2	1

inventory of geosites was ever made in the whole area of the Central Massif. The selection of geosites was done based on the literature review, field trip and discussing with expert, followed by the use of the qualitative criteria: representativeness, integrity, rarity and scientific knowledge (Brilha 2016), then the quantitative assessment of the scientific value, educational and touristic use, and the degradation risk (Brilha 2016). 26 criteria were used, with numerical scores ranging from 1 to 4, according to the below-referred method (Brilha 2016) (Table 1). The region's specificities require some indicator adaptations namely: accessibility, scenery.

A good inventory requires the decrease of the subjectivity during the process of the selection; it means that the selection should not base on the point of view of the researcher (Brilha 2018). This is the reason of the application of the quantitative assessment for the Central Morocco area, which leads to a proper site conservation and management. The inventory should include only geosites that contribute to the understanding of the geological history of the study area. This goal is achieved when the applied methodology takes into account the prioritizing of the geodiversity sites with a scientific value (geosites) separately of the educational and touristic value and their uses. Evenly, the quantitative assessment leads to creation of a solid list of geosites. Those are the reason of the choice of the methodology of Brilha 2016, in order to select and assess the geosites of the Central Massif. In addition, this method is based on the assembling of the best practices in the world and the author rich experience.

The type of geosites is elaborated by the Fuertes-Gutiérrez and Fernández-Martínez (2010) method.

Proposition of georoads and their assessment are performed using the methodology of Bolatti et al. (2013, 2017), which consists of calculating the average of the values of all geosites along each georoads.

Results

Inventory of Geosites

Twenty-two geosites were selected representing the geological history of the region (Fig. 1). The type of geosites was determined according to the method proposed by Fuertes-Gutiérrez and Fernández-Martínez (2010) (Table 2).

A number of outcrops represent the geological history of the western central massif where different events are documented. Before the Hercynian orogeny, a platform was developed in the western Central Massif at the lower Paleozoic, the sedimentation was characterized by a shallow deposit (Tahiri 1991). During the Ashgilian, a synsedimentary instability is represented by unique and relevant sedimentary feature: the Upper Ordovician Quartzite Slump balls (Tahiri 1991; Chakiri 1991; Tahiri et al. 2010b) (Geosites 1; Fig. 3). The limit Sillurian/Devonian is characterized by limestone bed with *Schyphocrinites* (Walliser et al. 1995) and the Lower Devonian carbonate nodule (Tahiri 1991; Zahraoui 1994). The Devonian age is well documented in this area, the limestone deposits of the Lower Devonian testify the platform environment (Tahiri 1991; Pique 1983; Piqué et al. 1983, Hoepffner 1987) which are developed to a reef deposits on the middle Devonian (Tahiri 1991; Cattanéo et al. 1993), those reef deposits contain a relevant outcrop of reef organisms such as *Stromatoporas* with

Table 2 Brief characterization of 22 geosites of the Central Morocco

Geosites	Geographical Coordinates	Main features	Relevance	Main threats	Type of geosite*	Notes	Sizes
Geosite (1): Upper Ordovician Quartzite slump balls	33°35′56.56″N 6°06′36.94″W	Synsedimentary movements related with the Caledonian orogeny that took place in the nearby region	International	Road	Point	Legal protection is necessary	Decametric
Geosite (2): Givetian reefal limestones *Stromatoporas*	33°32′44.71″N 6°00′26.43″W	The witness of Devonian reefal sedimentation	International	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (3):Givetian reefal limestones Algal laminitis	33°33′24.41 ″ N 6°2′21.78 ″ W		International	Road	Point	Urgent conservation measures are necessary	Metric
Geosite (4): Givetian reefal limestones Slump balls	33°32′54.82 ″ N 6°01′48.62 ″ W	Synsedimentary movements of Devonian reefal sedimentation	International	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (5): Famenno-Tournaisian calcareous (Mid Devonian reef limestones) rocks falls of Tiliouine	33°32′45 ″ N 6°00′27 ″ W	Example of the deconstruction of Devonian platform	National	Road	Point	Potential educational use due to the rarity of the feature	Decametric
Geosite (6): Middle Devonian reefal limestone olistoliths within the Tournisian turbidites West of Tiliouine	33°33′12 ″ N 6°04′13 ″ W		National	Road	Point	Potential educational use due to the rarity of the feature	Hectometric
Geosite (7): Tournaisian reefal limestones Olistoliths of Tiddas	33°31′42 ″ N 6°15′06 ″ W		National	Road	Point	Potential educational use due to the rarity of the feature	
Geosite (8): Westphalian red conglomerates	33°31′26 ″ N 6°15′23 ″ W	Show the continental sedimentation during the Westphalian	National	Road	Section	Legal protection is necessary	Decametric
Geosite (9): Granite of Zaer	33°23′39.07 ″ N 6°34′50.84 ″ W	Witness of the Variscan orogeny	International	Road	Area	Legal protection is necessary, Potential educational use due to the rarity of the feature	Decametric
Geosite (10): Variscan synorogenic Granite of Oulmes	33°26′28 ″ N 6°03′09 ″ W		International	Road	Area	Legal protection is necessary, Potential educational use due to the rarity of the feature	Hectometric
Geosite (11): Oulmes Granite and metamorphism aureole contact	33°26′28 ″ N 6°03′09 ″ W	Show clearly the contact between granite and metamorphism aureole	National	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (12): The El Karit mine: fillonien complex with the Tin and tungsten	33°25′05 ″ N 6°06′09 ″ W	Best outcrop that for showing Tin and tungsten ores	National	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (13): The El Karit mine: giant andalusite	N33°25′21 ″ W6°06′07 ″	Show an exceptional size of andalusite	National	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (14): Autunian fluviatile channels volcano-detritic Red serie of Souk Sebt	33°38′40.72 ″ N 6°08′37.89 ″ W	Show the Permian sedimentation	National	Road	Section	Urgent conservation measures are necessary	Hectometric

Table 2 (continued)

Geosites	Geographical Coordinates	Main features	Relevance	Main threats	Type of geosite*	Notes	Sizes
Geosite (15): Autunian Trachy-andesite of Tiddas	33°34′ 44 N 6°16′ 15 W	Witness of the opening of the Atlantic Ocean	International	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (16): Permian Rhyolite of Souk Sebt	33°38′31.87 ″ N 6°08′8.98 ″ W		International	Road	Point	Urgent conservation measures are necessary	Hectometric
Geosite (17): Triassic Basalts of Jbel Merzaga-Maaziz	33°41′9.71 ″ N 6°26′36.50 ″ W		International	Road	Point	Urgent conservation measures are necessary	Decametric
Geosite (18): Upper Triassic evaporate (gypsum) of Khemisset	33° 37′ 19 ″ N 6° 25′ 00 ″ W	Example of Triassic evaporate	International	Road	Section	Legal protection is necessary, Potential educational use due to the rarity of the feature	Decametric
Geosite (19): Visean-Miocene unconformity	33°33′54.78 ″ N 6°44′58.71 ″ W	Show the gap between Visean and Miocene	National	Road	Section	Potential educational use due to the rarity of the feature	Decametric
Geosite (20): Triassic-Miocene unconformity of Maaziz	33° 36′ 37 N 6° 24′ 18 W	Show the gap between Triassic and Miocene	National	Road	Viewpoint	Potential educational use due to the rarity of the feature	Hectometric
Geosite (21): Quaternary Basaltic flow of El Harcha	33°29′09 ″ N 6°09′30′′W	Example of lava flow of quaternary	National	Road	Point	Potential educational use due to the rarity of the feature	Hectometric
Geosite (22): Quaternary Basaltic flow of Oued Boulahmayl lavas	33°19′44.45 ″ N 6°59′48.11 ″ W	Example of basaltic flow of quaternary	International	Road, River	Point	Urgent conservation measures are necessary	Hectometric

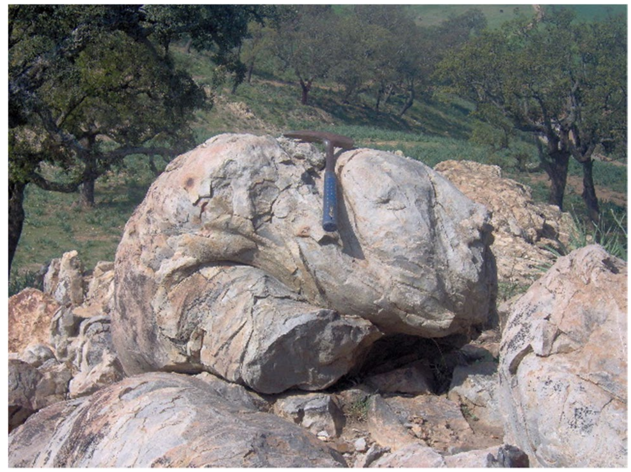


Fig. 3 Upper Ordovician quartzite Slump balls (geosite1)

Fig. 4 Givetian reefal limestones at Souk Jemaa with Stromatoporas (geosite2)

Fig. 5 Givetian reefal limestones with Algal laminitis (geosite3)

Fig. 6 Givetian reefal limestones with Slump balls (geosite4)

Fig. 7 Famenno-Tournaisian calcareous (Mid-Devonian reef limestones) rocks falls of Tiliouine (geosite5)

life position (Geosite 2; Fig. 4), *Thamnoporas*, *Amphiporas*, Algal laminitis and red algae (Geosite 3; Fig. 5) (Termier 1936; Cogney 1967; Gendrot 1973; Tahiri 1991; Cattanéo et al. 1993). The diversity, abundance, and distribution of those organisms testify the different reefal environment (Tahiri 1991; Cattanéo et al. 1993). This period also is characterized by synsedimentary movements, which are translated by the Givetian reefal limestones Slump balls (Geosite 4; Fig. 6). The Central Massif is very known by numerous basins that start the generation at the Upper Devonian, which is meaning the destruction of the platform, under the control of the pre-Hercynian compression. This event is documented by several outcrops: Famenno-Tournaisian calcareous rock falls formed mainly by Mid-Devonian reefal limestones of Tiliouine (Geosite 5; Fig. 7), Middle Devonian

Fig. 8 Middle Devonian reefal limestone olistoliths within the Tournisian turbidites west of Tiliouine (geosite6)

Fig. 9 Tournaisian reefal limestones Olistholithes of Tiddas (geosite7)

Fig. 10 Westphalian red conglomerates (geosite8)

Fig. 11 Granite of Zaer (geosite9)

Fig. 12 Variscan synorogenic Granite of Oulmes (geosite10)

Fig. 13 Oulmes Granite and metamorphism aureole contact (geosite11)

Fig. 14 The El Karit mine: fillonien complex with the Tin and tungsten (geosite12)

reefal limestone olistoliths within the Tournisian turbidites West of Tiliouine (Geosite 6; Fig. 8), Tournaisian Olistholithes of Tiddas composed by Lower and Middle reefal limestones (Geosite 7; Fig. 9), the Westphalian red molasse of Tiddas (Geosite 8; Fig. 10) which are known by the “Sidi Kacem facies.” The emplacement of Variscan granitoids is related to the Hercynian compression as well. Granite of Zaer (Geosite 9; Fig. 11) and Granite of Oulmes (Geosite 10; Fig. 12) are the geosites that represent this event, they are peraluminous (El Hadi et al 2006 and references therein) and their emplacement was during the Late Hercynian orogenic phases (Diot 1989; Boushaba et al. 1987; Tahiri 1991). The relevance of those two geosites comes from the fact that the granite of Oulmes does not have enclaves and the granite of Zaer is the large one of the Variscan granites. The granites of Oulmes show a very special outcrop where the contact of granite-shale “cornéenne” is visible (Geosite 11; Fig. 13). The abandoned mine El Karit shows dykes of quartz and pegmatite (Geosite 12; Fig. 14). The shale of the metamorphic aureole contains a giant andalusite that can be seen macroscopically (Geosite 13; Fig. 15), this mine was exploited due to the tin and tungsten metals, it stills a quantity of those metals that necessity of protection is required.

Fig. 15 The El Karit mine: Micashichts with giant andalusite (geosite13)

Fig. 16 Autunian fluviatile channels volcano-detritic Red serie of Souk Sebt (geosite14)

Fig. 17 Autunian Trachyandesite of Tiddas (geosite15)

Fig. 18 Permian Rhyolite of Souk Sebt (geosite16)

Fig. 19 Triassic Basalts of Jbel Merzaga-Maaziz (geosite17)

Fig. 20 Triassic evaporate (gypsum) of Khemisset (geosite18)

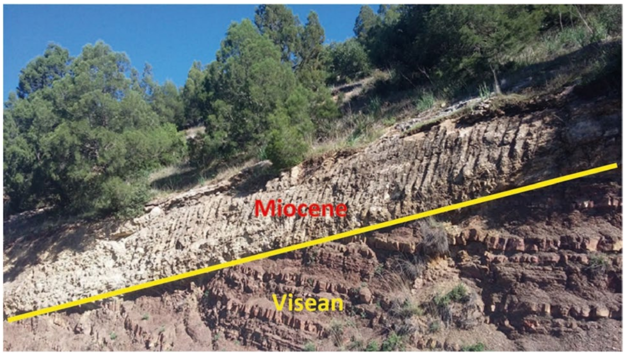


Fig. 21 Visean-Miocene unconformity (geosite19)

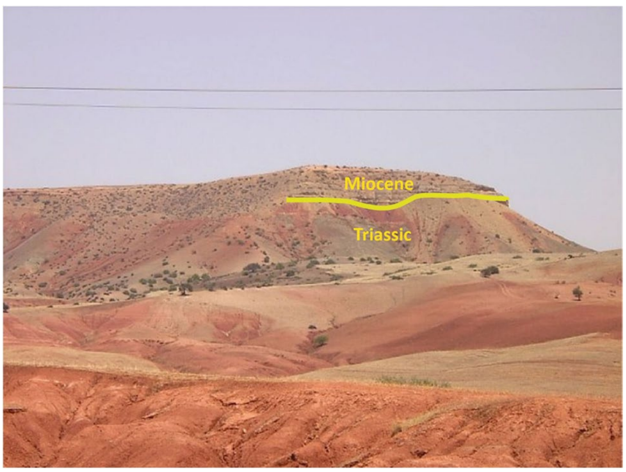


Fig. 22 Triassic (red)-Miocene (gray/yellow) unconformity of Maaziz (geosite20)

The Autunian basin filled by fluvial deposits such as: the Autunian Fluvial channels of Souk Sebt (Geosite 14; Fig. 16), and it crossed by filions Permian Trachyandesite of Tiddas (Geosite 15; Fig. 17), and Permian Rhyolite of Souk Sebt (Geosite 16; Fig. 18).

Since the Triassic, a huge rifting is known in several regions, this rifting is related to the opening of the Atlantic Ocean (especially with the Central Atlantic magmatic province (CAMP); Marzoli et al. 2019), and it is documented by: Triassic Basalts of Jbel Merzaga-Maaziz (Geosite 17; Fig. 19). In addition, the Triassic is characterized by the deposit of evaporate (gypsum) of Khemisset (Geosite 18; Fig. 20).

The tectonic movements and the Neogenic transgression in the study area cause several unconformities: Miocene/Visean unconformity (Geosite 19; Fig. 21), Miocene-Triassic unconformity of Maaziz (Geosite 20; Fig. 22). The quaternary age is very famous by the magmatism activity, which is responsible for the emplacement of quaternary basalts. Two geosites occurred in the study area representing this event: Lavas flows of El Harcha (Between 2.8 Ma à 0.31 Ma, and 1.07 Ma à 0.5 Ma; K/Ar Total rock; Rachdi 1995; Baudin et al. 2001) (Geosite 21; Fig. 23); it is an alkaline phonolite, and the basalt columns of Oued Boulahmayl (2.8–0.64 Ma; Rachdi 1983; Baudin et al. 2001) (Geosite 22; Fig. 24) which are divided on two unite; the bottom unite is formed by the Melanephelinite and the top unite (the new unite) is a tephrite (Baudin et al. 2001).

Quantitative Assessment of Geosites

The quantitative assessment of the 22 geosites is presented in Tables 3, 4, 5, and 6, and Fig. 25. The results show that 50% of geosites have a high scientific value in which "Granite of

Fig. 23 Quaternary Basaltic flow of El Harcha (geosite21)

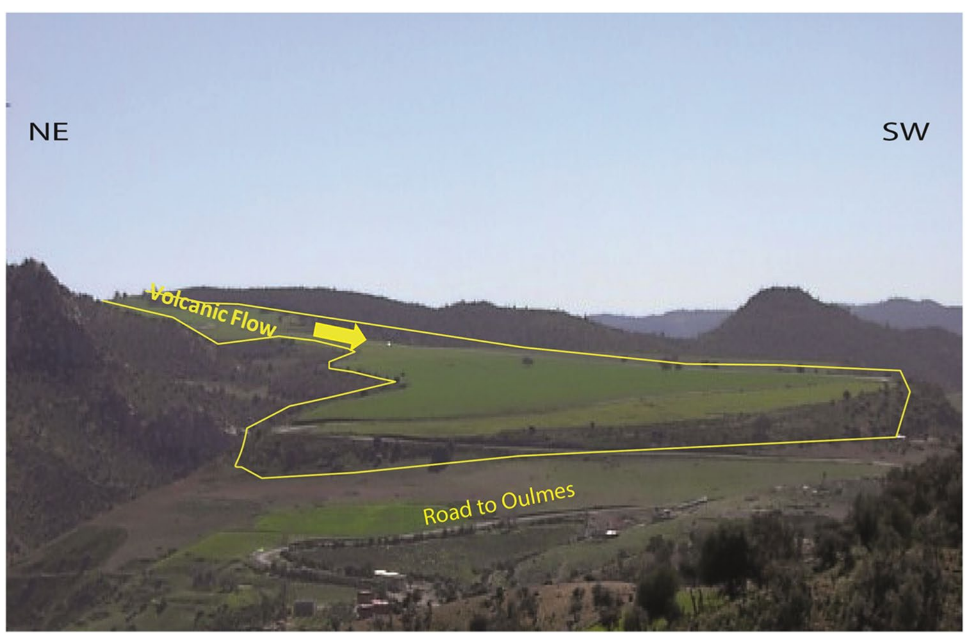


Fig. 24 Quaternary Basaltic flow of Oued Boulahmayl lavas (geosite22)

Zaer" and "Variscan synorogenic Granite of Oulmes" are the most important in the study area, both are scored 360. The rest of geosites have a moderate scientific value, which scored between 200 and 300. The described geosites present a diverse and a rich geodiversity that allow the understanding of geological history of the study area especially during the major events. The global scientific value is testified by the high scores of some criterions for the majority of geosites, namely, representativeness, geological diversity, use limitation, and scientific knowledge.

Regarding the educational value, 13 geosites have a high educational value while the rest of geosites have a moderate educational value. The "Variscan synorogenic Granite of Oulmes" is the most important in term of educational value with a score of 355. These results are justified by the fact that the geosites are already used as educational localities for the university students. The area includes pedagogical examples for all teaching levels in addition to their accessibility.

For the touristic value, all geosites have a moderate value. The "Variscan synorogenic Granite of Oulmes" and "The El Karit mine: fillonien complex with the Tin and tungsten" have the highest value "295". This is explained by the fact that globally, geosites are accessible but at the same time, there is a lack of some facilities and logistics.

Concerning the risk of degradation, 16 geosites have a high risk of degradation, 4 geosites have a moderate risk of degradation and 2 have a low risk of degradation. Among those that have a high degradation risk, 7 of them are in the top of the scientific value which means they require an urgent geoconservation and management actions. Geosites are threatened mainly by the proximity of roads, and anthropic activities.

Table 3 Quantitative assessment of the geosites scientific value

Criteria	Representativeness	Key locality	Scientific knowledge	Integrity	Geological diversity	Rarity	Use limitations
Geosite (1)	4	1	4	2	4	2	4
Geosite (2)	4	1	4	2	4	2	4
Geosite (3)	4	1	4	2	4	2	4
Geosite (4)	4	1	4	2	4	2	4
Geosite (5)	4	1	2	4	4	2	4
Geosite (6)	4	1	0	2	4	4	4
Geosite (7)	4	1	4	2	4	4	4
Geosite (8)	4	1	2	4	4	2	4
Geosite (9)	4	2	4	4	4	4	4
Geosite (10)	4	2	4	4	4	4	4
Geosite (11)	4	1	4	2	4	4	4
Geosite (12)	4	1	4	2	4	4	4
Geosite (13)	4	1	4	2	4	4	4
Geosite (14)	4	1	0	2	4	4	4
Geosite (15)	4	1	4	2	4	2	4
Geosite (16)	4	1	4	2	4	2	4
Geosite (17)	4	2	4	2	4	2	4
Geosite (18)	4	1	4	4	4	2	4
Geosite (19)	4	1	0	4	4	2	4
Geosite (20)	4	1	0	4	4	2	4
Geosite (21)	2	1	2	4	4	1	4
Geosite (22)	4	1	2	2	4	4	4

Table 4 Quantitative assessment of the geosites educational value

Criteria	Vulnerability	Accessibility	Use limitations	Safety	Logistics	Density of population	Association with other values	Scenery	Uniqueness	Observation conditions	Didactic potential	Geological diversity
Geosite (1)	3	4	4	2	3	4	4	0	4	4	1	4
Geosite (2)	3	4	4	2	4	4	4	0	1	4	1	4
Geosite (3)	3	4	4	2	4	4	4	0	1	4	1	4
Geosite (4)	3	3	4	2	4	4	4	0	4	4	1	4
Geosite (5)	2	2	4	2	3	4	4	0	4	4	3	4
Geosite (6)	3	4	4	2	3	4	4	0	4	4	1	4
Geosite (7)	2	4	4	2	3	4	4	0	3	4	3	4
Geosite (8)	3	4	4	2	3	4	3	0	2	4	4	4
Geosite (9)	4	4	4	2	3	4	4	0	3	4	4	4
Geosite (10)	4	4	4	2	4	4	4	0	3	4	4	4
Geosite (11)	2	4	4	2	4	4	4	0	4	4	2	4
Geosite (12)	3	4	4	2	4	4	4	0	4	4	4	4
Geosite (13)	3	4	4	2	4	4	4	0	4	4	2	4
Geosite (14)	1	4	4	2	3	4	4	0	2	4	3	4
Geosite (15)	2	4	4	2	3	4	4	0	3	4	4	4
Geosite (16)	3	4	4	2	3	4	4	0	3	4	4	4
Geosite (17)	3	3	4	2	3	4	4	0	2	4	4	4
Geosite (18)	3	4	4	2	2	4	4	0	3	4	4	4
Geosite (19)	3	4	4	2	2	4	4	0	3	4	1	4
Geosite (20)	4	1	4	2	3	4	4	0	2	4	1	4
Geosite (21)	4	1	4	2	4	4	4	0	2	4	4	4
Geosite (22)	3	4	4	2	4	4	4	0	4	4	4	4

Table 5 Quantitative assessment of the geosites touristic value

Criteria	Vulnerability	Accessibility	Use limita-tions	Safety	Logistics	Density of population	Association with other values	Scenery	Uniqueness	Observation conditions	Inter-pretative potential	Eco-nomic level	Proximity of recreational areas
Geosite (1)	3	4	4	2	3	4	4	0	4	4	2	1	0
Geosite (2)	3	4	4	2	4	4	4	0	1	4	2	1	0
Geosite (3)	3	4	4	2	4	4	4	0	1	4	2	1	0
Geosite (4)	3	3	4	2	4	4	4	0	4	4	2	1	0
Geosite (5)	2	2	4	2	3	4	4	0	4	4	2	1	0
Geosite (6)	3	4	4	2	3	4	4	0	4	4	2	1	0
Geosite (7)	2	4	4	2	3	4	4	0	3	4	2	1	0
Geosite (8)	3	4	4	2	3	4	3	0	2	4	4	1	0
Geosite (9)	4	4	4	2	3	4	4	0	3	4	4	1	0
Geosite (10)	4	4	4	2	4	4	4	0	3	4	4	1	4
Geosite (11)	2	4	4	2	4	4	4	0	4	4	3	1	3
Geosite (12)	3	4	4	2	4	4	4	0	4	4	4	1	4
Geosite (13)	3	4	4	2	4	4	4	0	4	4	3	1	4
Geosite (14)	1	4	4	2	3	4	4	0	2	4	3	1	2
Geosite (15)	2	4	4	2	3	4	4	0	3	4	4	1	1
Geosite (16)	3	4	4	2	3	4	4	0	3	4	4	1	1
Geosite (17)	3	3	4	2	3	4	4	0	2	4	4	1	1
Geosite (18)	3	4	4	2	2	4	4	0	3	4	4	1	0
Geosite (19)	3	4	4	2	2	4	4	0	3	4	2	1	0
Geosite (20)	4	1	4	2	3	4	4	0	2	4	2	1	0
Geosite (21)	4	1	4	2	4	4	4	0	2	4	4	1	1
Geosite (22)	3	4	4	2	4	4	4	0	4	4	4	1	1

Table 6 Quantitative assessment of the geosites degradation risk

Criteria	Deterioration of geological elements	Proximity to areas/activities with potential to cause degradation	Legal protection	Accessibility	Density of population
Geosite (1)	3	3	4	4	4
Geosite (2)	2	3	4	4	4
Geosite (3)	2	3	4	4	4
Geosite (4)	3	3	4	3	4
Geosite (5)	3	2	4	2	4
Geosite (6)	3	3	4	4	4
Geosite (7)	4	4	4	4	4
Geosite (8)	4	4	4	4	4
Geosite (9)	1	1	4	4	4
Geosite (10)	1	1	4	4	4
Geosite (11)	3	4	4	3	4
Geosite (12)	3	2	4	3	4
Geosite (13)	3	2	4	3	4
Geosite (14)	4	4	4	4	4
Geosite (15)	3	4	4	4	4
Geosite (16)	2	3	4	4	4
Geosite (17)	2	3	4	3	4
Geosite (18)	2	3	4	4	4
Geosite (19)	3	4	4	4	4
Geosite (20)	1	1	4	1	4
Geosite (21)	1	1	4	1	4
Geosite (22)	3	4	4	4	4

Georoads Proposal and their Evaluations

The twenty-two geosites are organized into three georoads that allow their accessibility (Fig. 1). The georoad 1 is named "Rommani georoad" and it includes 3 geosites (geosite 9, geosite 18, and geosite 19), the second georoad is called "Oulmes-Tiddas-El Harcha," it comprises 11 geosites (geosite 7, geosite 8, geosite 10, geosite 11, geosite 12, geosite 13, geosite15, geosite 17, geosite 20, geosite 21, and geosite 22), "Oulmes-Souk Sebt-Tiliouine" is referred to the georoad 3 which integrates 8 geosites (geosite 1, geosite 2, geosite 3, geosite 4, geosite 5, geosite 6, geosite 14, and geosite 16).

The proposed georoads have been assessed using the Bollati et al. (2013, 2017) methodology. The results are presented in the Fig. 26. The georoad 1 is the most important in term of the scientific value (320), the combination of high scientific value and high degradation risk (303) means that this georoad requires an urgent action in order to protect the geosites. This georoad has a high educational value and a moderate touristic value. The georoads 2 and 3 will be classified on the second place in term of priority after the georoad 1 because they present scores lower regarding scientific value except degradation risk of georoad 3. Both georoads 2 and 3 have more and less the same scores of educational and touristic value.

Discussion

As mentioned before, the inventory of geosites and their quantitative assessment could provide an adequate protection of geoheritage through the application of geoconservation strategy. It also constitutes as the base for making priority, which geosites should receive the protection firstly.

The representativeness, geological diversity, and use limitation are considered the important criteria that enhance the scientific value of the majority of geosites while the other criteria are quite represented comparing with the first ones. This explains the obtained results (high scientific value for 50% of geosites and moderate value for the others). In addition, this work and results guide the decision-makers to apply the adequate actions regarding geoconservation and/or management since it helps to know the needs of each geosite.

Concerning the educational value, the majority of geosites scored higher than 300, which is explained by the use of the area as educational destination for students, since it contains representative outcrops explaining the major events.

The Central Morocco area is not used as a touristic destination. However, geotourism could be an opportunity to increase the sustainable development and economical level of the local people. This work proves that accessibility,

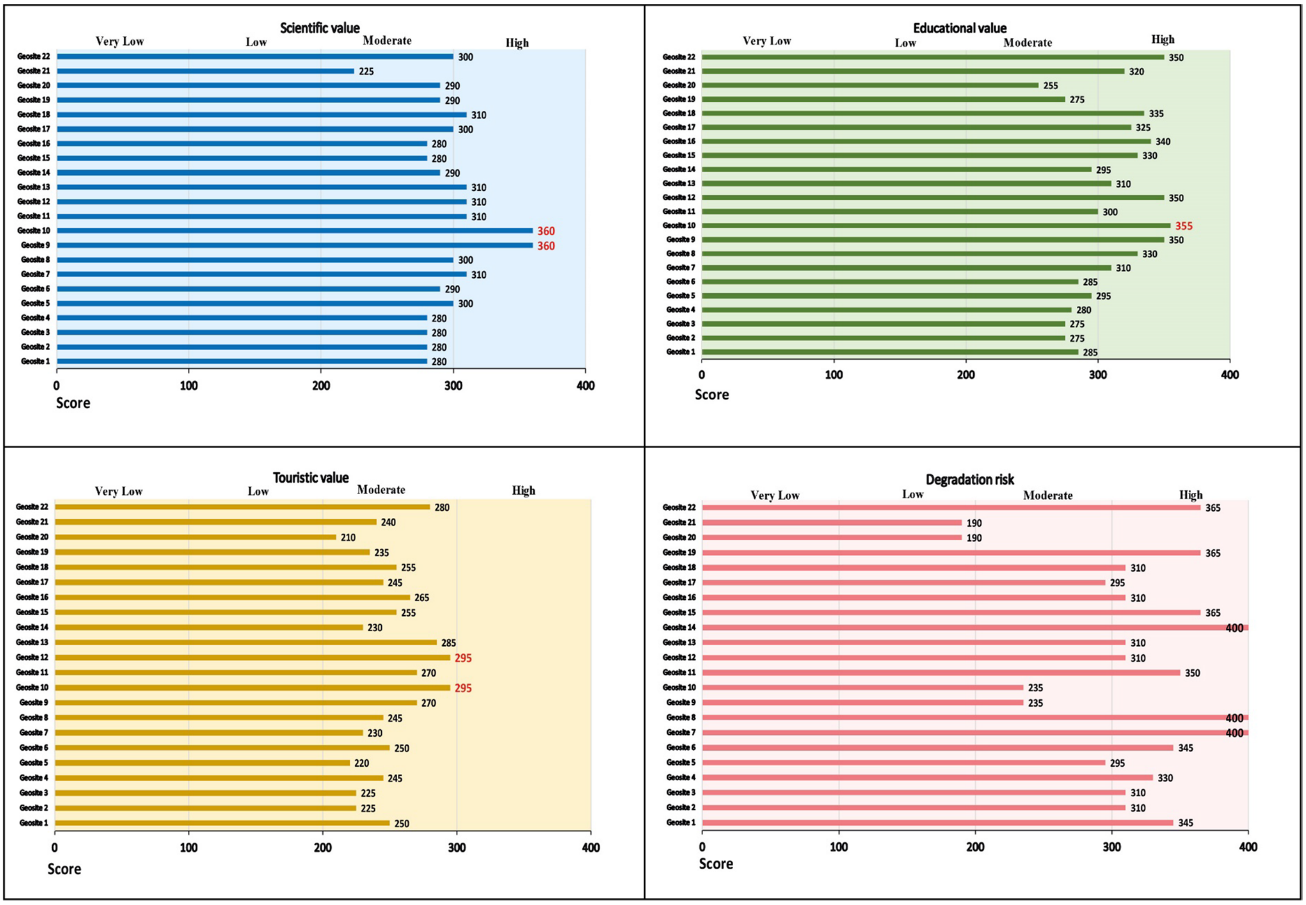
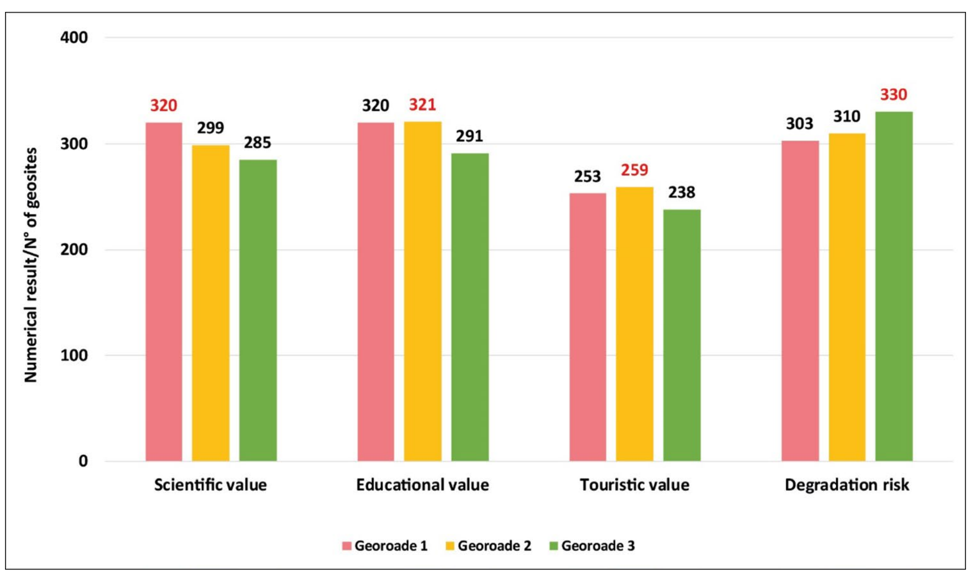


Fig. 25 Final score of geosites

Fig. 26 Georoads assessment



geological diversity, and the use limitation are the criteria that make the area a good geotouristic destination.

It should be mentioned that the high degradation risk of the majority of geosites is related mainly to the closest position from the road, lake of legal protection and its application and the mining activity.

Conclusion

This work started with the identification of geosites followed by their quantitative assessment. The results allow to have a clear view about the scientific, educational and touristic value, and their degradation risk, and to deal with geosites case by case independently of each other, in order to know which action should be applied to a given geosite. The majority of geosites have a high scientific and educational value as well as the degradation risk, while they have moderate touristic value. The most important geosites are the "Granite of Zaer" and "Variscan synorogenic Granite of Oulmes" with an international relevance. The obtained results prove the potential to support a future geopark project in Central Morocco area.

Implementation of geoconservation strategy, geoeducation, and geotourism could be a good opportunity to enhance sustainable development and economical level of the area by creating new jobs, but it should also work on the rise of awareness about geoheritage targeting people for all educational level and using defense methodologies, which depend on the type of public.

On the way to achieve the goals, some suggestions are recommended: promoting the conservation of geological heritage to future generations, combination between the protection of scientific information and the adequate use of the geosites, and inclusion of geosites in spatial planning actions.

Declarations

Conflict of Interest The authors declare no competing interests.

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