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A quantitative approach to geosites assessment of the Talassemtane National Park (NW of Morocco)

Un enfoque cuantitativo para la evaluación de geositios del Parque Nacional de Talassemtane (NO de Marruecos)

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ABSTRACT

The Talassemtane National Park (TNP), registered in the tentative list of Morocco for a future nomination as World Heritage by the UNESCO, is characterized by its great biodiversity and integration in the Intercontinental Biosphere Reserve of the Mediterranean (UNESCO). Although authorities are very concerned about valorization and protection of biodiversity (flora and fauna), the interest in geological heritage is still much lower. Therefore, this paper intends to expose and provide value to the best sites of geologic interest (Geosites) recognizable in the area. We propose 34 Geosites as the most suitable to be considered representatives of the geological diversity of the National Park, displaying a great variety of geological typologies such as: structural geoloy, stratigraphy, sedimentology and paleontological sites, geomaterials and petrography, landforms and hydrogeology-hydraulic features. In order to classify and rank the Geosites while avoiding subjectivity, a numerical methodology based on two modules has been applied. The two modules consist of the Scientific Value (SV) and Additional Value (AV) each one being composed, in turn, by an important number of criteria. In addition, the Degradation Risk (DR) of the Geosites has also been valorized on the basis of several criteria. Some actions, following the criteria of the Global Geoparks Network by UNESCO, have been proposed for better conservation of the Geosites, as well as to contribute to education and to promote tourism. These actions would also stimulate economic activity and sustainable development in the area by attracting increasing numbers of visitors.

Keywords: NW Morocco; Talassemtane National Park; Geosite assesment; UNESCO Global Geoparks.

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RESUMEN

El Parque Nacional de Talassemtane (TNP), recogido en la lista tentativa de Marruecos para su nominación como Patrimonio de la Humanidad por la UNESCO, se caracteriza por su gran biodiversidad y está integrado en la Reserva de la Biosfera Intercontinental del Mediterráneo. Aunque las autoridades están muy interesadas en la puesta en valor y protección de la biodiversidad (flora y fauna), su interés en el patrimonio geológico es mucho menor. Así, este trabajo trata de dar a conocer y poner en valor los excelentes lugares de interés geológico (Geositios) reconocibles en el área. Se proponen 34 Geositios que deberían ser considerados parte del patrimonio geológico y que despliegan una gran variedad de tipologías geológicas como geología estructural, estratigrafía, sedimentología, paleontología, geomateriales, petrología, geomorfología e hidrogeología-hidráulica. Para clasificar y ordenar los Geositios, evitando la subjetividad, se ha empleado una metodología numérica basada en dos módulos. Dichos módulos consisten en el Valor Científico (SV) y el Valor Adicional (AV) estando cada uno compuesto, a su vez, por un importante número de criterios. Además, el Riesgo de Degradación (DR) de los Geositios se ha valorado sobre la base de diversos criterios. Para una mejor conservación de los Geositios, pero también para contribuir a la educación y promoción del turismo, se han propuesto algunas acciones siguiendo los criterios de la Red Global de Geoparques de la UNESCO. Esas acciones podrían estimular también la actividad económica y el desarrollo sostenido de la región atrayendo un número creciente de visitantes.

Palabras clave: NW de Marruecos; Parque Nacional de Talassemtane; Evaluación de Geositios; Geoparques Mundiales de la UNESCO.

Introduction

The project aims to protect natural and cultural assets and tries to provide more visibility to geotourism, as well as education, following the works developed by the European Geopark Network and other individual geoparks in the the world, the UNESCO defined the Global Geoparks in 2015 (although started to work with Geoparks in 2001) as a tool to promote sustainable growth of zones with geological heritage (McKeever *et al*., 2010). Geoparks are well-delimited regions with a growth program, which seek to integrate the geoconservation of areas of geological interest with the conservation of cultural roots of the peoples and nations (Eder & Patzak, 2004; Zouros, 2004; McKeever *et al.,* 2010). To achieve the conservation of a sector with a certain number of suitable geosites, the measures of conservation, education and sustainability recommended by UNESCO in the Global Network of National Geoparks must be followed, because the parks of this network are forced to introduce standard facilities and services of high quality. UNESCO promotes sharing of best practices and similar strategies for growth and preservation of geotourism, providing support to areas with geosites, which leads to exchange of knowledge in the entire world.

The inventory and quantitative approach of geological heritage assessment in the conservation of geoheritage must be the first step, continued by the preservation, study, advancement, and surveillance of sites of geological interest (Brilha, 2016). In relation to the sites of geological interest in recent years a few concepts have come out, but the term used for designating sites with geologic and scientific value is “geosite”.

The Talassemtane National Park (TNP), situated in NW Morocco, was designed by UNESCO (October, 2006) as a part of the Mediterranean Intercontinental Biosphere Reserve (El Merzguioui, 2006). The park is situated south of Tetouan and its geographic coordinates are 35°13’31” N / 5°08’26” W (Fig. 1A). Chaouen, Talambote, Akchour, Oued Laou, Bab Taza, Chrafate, Ametrasse and Khmis M’diq are the most renowned towns and cities inside the TNP (Fig. 1B). The communication roads more important are the P4111 and P4105 (provincial roads), the R412 (regional) and the N2 (national road). The main rivers and valleys are the Oued Laou, Oued Tassikeste, Oued Talambote, Oued Farda, Oued El Kelaa and Oued Kanar (Fig. 1B). The main mountains are the Jbel Kelti (1926 m), Jbel Tazaoute (1725 m), Jbel El Kelaa (1616m), Jbel Tissouka (2122m), Jbel Lakraa (2159m) and the Jbel Taloussisse (2005m). It covers an area of about 60.000 hectares being a natural area with a very important biodiversity and geodiversity at Moroccan and Mediterranean scale.

The TNP shows hot-dry summers and warm (sometimes cold) winters. The average annual temperature varies from 14°C to 20°C. January shows lowest temperatures and August the highest. The rainfalls are abundant (some years exceed 1000 mm, and sometimes 1800 mm in the higher area) in the TNP area (Agence du Bassin Hydraulique

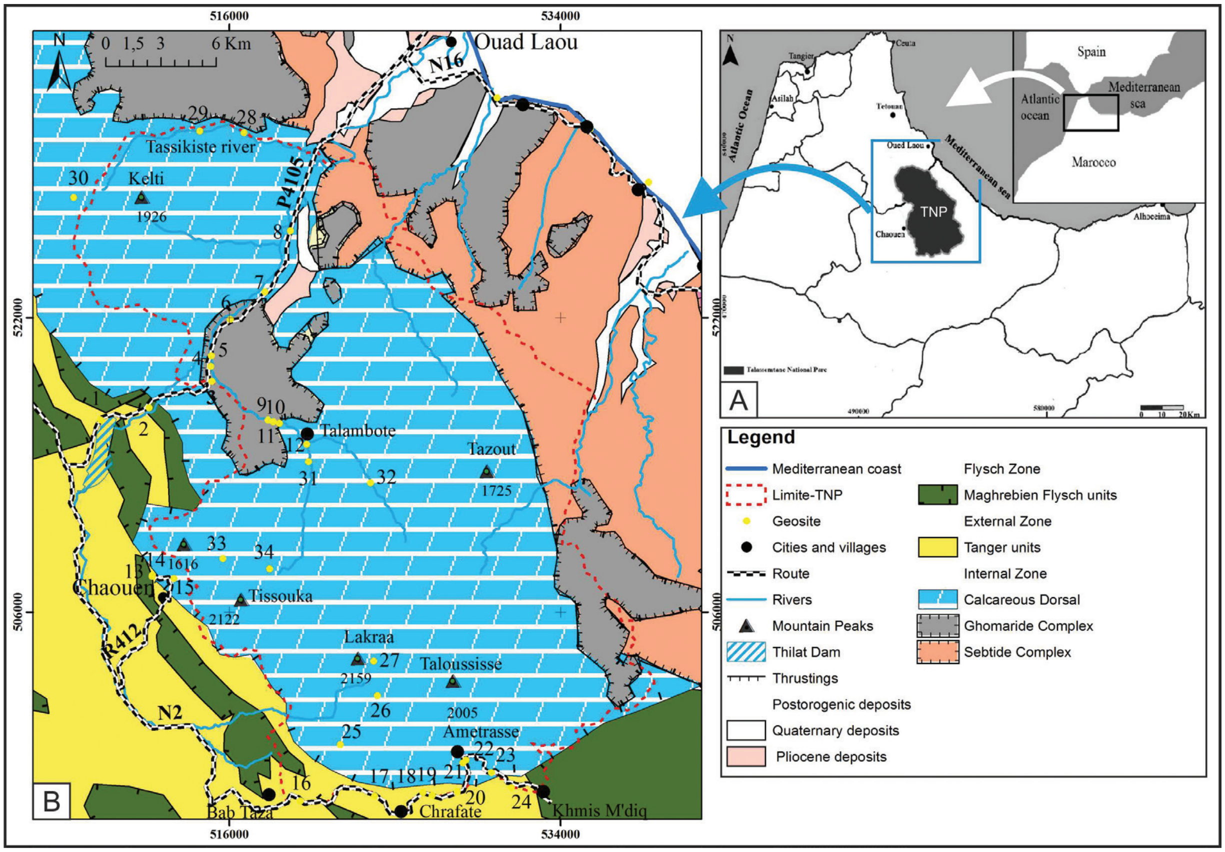

Figure 1.—A) Sketch map of location of the TNP. B) Geological map of the area of the TNP with location of the Geosites.

du Loukkos -ABHL-, 2006). There is a shocking change between the very rainy mountain areas (1939 mm) and the dry bottom ones of the TNP (464 mm in the Talambote weather station). In the high mountains, the rain is measured in a weather station of the Fir plantation. This station is situated between 1250 and 2050 m in the forest of the TNP (2000 ha) and between 1050 and 1893 m in that of Tazaout (1000 ha). This variation is explained by the fact that the humid winds come from the Mediterranean (east) causing precipitations in the steep eastern zone. In the case of the bottom areas of the coast, precipitations increase from S to N (361 mm in Jebha, 464 mm in Oued Laou).

An important contrast between the white and red rock walls (without vegetal cover) and the great variety of greenish colors in the hollow valleys is evident. In the high mountains around Chaouen (usually over calcareous rocks) the endemic tree of Morocco can be found: firs (*Abies maroccana* and *A. tazaotana*), wild olive trees, cork oaks and green oaks (Aafi *et al.,* 1997). Traditional agriculture is developed in terraces on the slopes as fruit trees: pear, olive, pomegranate, fig, walnut, etc. (Bayed & Ater, 2008). Birds of prey such as the golden eagle can also be found (Gensbol, 1984). In some cases, in the upper areas, families of maggot monkeys, gazelles and mountain goats can be spotted (Mehlman & Parkhill, 1988).

The park is a mountain chain from a landscaping point of view. The TNP is mainly made of a calcareous massif where karstic typologies and phenomena are very developed and diffuse (El Gharbaoui, 1980). The more characteristics are the caves, gorges and natural bridges (El Gharbaoui, 1980). Some of these sites have been inventoried as Geosites in this work.

The geoheritage of the TNP has never been addressed by the authorities of the park, despite its great importance. Moreover, the park is a naturally very rich in sites of geological interest (Geosites), several of which are of national relevance (Aoulad-Sidi-Mhend *et al*., 2019). The above mentioned Geosites could be considered, in a near future, as main part of the touristic, educational and economic offer of the TNP. The geological heritage presented in the park is, in a great part, the response to the climate, as well as the geological evolution from the Primary Era to the present day (including the Variscan and Alpine orogenic phases).

Therefore, the main goal is to preserve this geodiversity that is threatened by anthropic activities. In order to achieve this goal, concrete measures for conservation must be approved by local and regional authorities based on accurate knowledge of this topic. This paper tries to evidence and highlight the importance and variety of the sites of geological interest located in this park. In addition, this work intends to go further beyond the classical vision perceived about the geological heritage as an inanimate entity in which the human activities take place without care on preservation. The best way to ensure adequate protection measures for significant geological features in the TNP is to adhere to the measures for sustainable development, education and conservation dictated by UNESCO in the Global Net of Geoparks. For that reason, the aim of this paper is to consider the Geosites of the TNP with the aim of promoting the bases for tourism, preservation and education in a sustainable management plan, following the UNESCO basis from the Global Geopark Network.

Geological setting of the TNP

The TNP is situated in the Moroccan Rif (Fig. 1A) which makes part of the western portion of the Peri-Mediterranean Chain (Guerrera & Martín-Martín, 2014). This chain is the response to the plate evolution, subductions and collisions during the Miocene of the Mesomediterranean Microplate that was located in the westernmost Tethys from Jurassic times on (Guerrera *et al*., 2005 and 2012). In the Moroccan Rif three main tectonic complexes of units are classically defined (Fig. 1B): Internal Zones, Maghrebian Flyschs and External Zones (Guerrera & Martín-Martín, 2014). The Internal Zones show a Variscan paleozoic succession, affected by a nappe tectonic and, in most of the cases, by Alpine metamorphism. These units also show Mesozoic-Tertiary successions, overinposed to the Maghrebian Flyschs Units. The Internal Zones in the Moroccan Rif (Fig. 1B) consist of the Sebtide Complex, in lower position, the Ghomaride Complex, in upper position and, some authors also mentioned the "Dorsal", in uppermost position and frontal tectonic position over the Maghrebian Flyschs Units (Chalouan, 1986; Maate, 1996).

The TNP is located on the "Dorsal" of the Internal Zone (Fig. 1B). In this area this unit is made of thrusting tectonic sheets SW oriented. The successions of the "Dorsal" are made of calcareous and pelitic rocks (Middle Triassic to Lower Miocene in age), being the Late Triassic-Early Liassic calcareous successions the more characteristic (Nold *et al*., 1981; El Kadiri, 1991; Maaté, 1996; Hlila, 2005). With minor representation, terrains assignable to the Ghomaride Complex appear, usually interpreted as klippes over the "Dorsal" (as it is the case of Talambote area). The upper Ghomaride complex in a great part consist of Silurian to Devonian slates, inmature sandstones and limestone (Chalouan, 1986). Paleogene sediments can be also found in a few of cases. Those consists of limestones with larger foraminifera (alveolines and nummulites) according to Hlila *et al*. (2007). Also, minor outcroppings of Sebtide klippes can be found in tectonic contact over the "Dorsal". These klippes are made of shales and pelites (Permian to Triassic in age) showing a low metamorphism (Kornprobst, 1974). The succession is ended with Plio-Quaternary materials made of marls, pelites and conglomerates that crops out in the Tirinesse Basin. This is an intramontane basin situated at the East side of the TNP (Hlila *et al*., 2014 a & b).

Methodology

The research methodology applied to select and classify the Geosites and also to decide on the degree of protection needed to apply is the following:

- **(i)** a general recognition of selected communication ways for motor vehicles as well as foot trails for walking in the TNP;
- **(ii)** extensive reading of the existing literature on landscape and flora and fauna to identify possible Geosites in the TNP (Hillali & Temsamani, 2002; González *et al*., 2011);

(iii) field works involving visiting all the communication ways to identify and select new geosites;

(iv) acquisition of graphic documentation and realization of schemes, in addition to the performing of geological and geomorphological mapping by means of GIS software (free version);

(v) evaluation of inventoried sites, based on a scoring module that we have developed and that takes into account their geoscientific values, and other additional values.

The applied evaluation is based on a combination of the works (Grandgirard, 1999; Reynald *et al*., 2007; Pralong, 2006; Weber *et al*., 2006; Reynard *et al*., 2016; and Brilha, 2016) concerning this topic. The evaluation consists of four parts (Table 1): Scientific Value (SV), Additional Values (AV), synthesis and result of the Global Value (GV) and, separately, the Degradation Risk (DR).

For the quantitative approach of the Geosites assessment two modules are involved: Scientific Value (SV) and Additional Value (AV). Each module is composed, in turn, of several criteria. Values between 0 and 1 (with an interval of 0.25) have been used for each criterion. The SV module of the inventoried Geosites has been calculated with the following formula (Pralong, 2006) involving the Location and Preservation (LP), Representativeness (R), Frequency (F), Paleogeographic Value (PV) and the Educational Value (EV) criteria:

$$SV = (LP + R + F + PV + EV) / 5$$

Table 1.— General framework of the evaluation modules developed after Grandgirard (1999), Reynald *et al.* (2007), Pralong (2006), Wever *et al.* (2006) and Brilha (2016).

Parts	Criteria		Description
Scientific value (SV)	Location and preservation (LP)		The intrinsic criteria of the site are evaluated. It provides information about the location and conditions of preservation of the site, the frequency of the same type in a given space, and if it is a geological process that characterizes the region and demonstrates the history of the field and climate. The score assigned to this part corresponds to the average of the scores of the different criteria.
	Representativeness (R)		
	Frequency (F)		
	Paleogeographic value (PV)		
	Educational value (EV)		
Additional or added value (AV)	Ecological value (ECV)	Ecologic diversity (ed)	The extrinsic criteria of the site are evaluated. It is of minor importance in determining the value of a site. It is based on its ecological (presence or not of biodiversity; protected or not protected area), aesthetic (visibility, contrast with the environment), cultural (religious, historical, literary and geohistorical importance) and touristic aspects (accessibility, public infrastructures, density of geosites in the georoute, geotouristic risk). The score assigned to this part corresponds to the average of the scores of the different criteria.
		Protected area (pa)	
	Aesthetic value (AEV)	Visibility (v)	
		Contrast (c)	
	Cultural value (CV)	Religious importance (ri)	
		Historical importance (hi)	
		Literary importance (li)	
		Geohistorical importance (gi)	
	Touristic value (TV)	Accesibility (a)	
		Public infrastructures (i)	
		SIG density in the georoute (d)	
		Geotouristic risk (gr)	
Synthesis	Global value (GV)		The score assigned to this global value corresponds to the average of the scientific value score and the weighted additional value score.
Degradation Risk (DR)	Deterioration geological elements (Dge)		It provides information of the Geosite about the deterioration and protection by the authorities. The density of population of the area is also considered. The score assigned to this part corresponds to the weighted addition of the scores of the different criteria.
	Proximity activities cause of degradation (Ppa)		
	Legal protection (Lgp)		
	Accessibility (Acc)		
	Density of population (Dop)		

The AV module takes into account the Ecological Value (ECV), Aesthetical Value (AEV), Cultural Value (CV) and Turistic Value (TV) criteria. In turn, the ECV considers the ecologic diversity (ed) and whether the Geosite belongs or not to a protected area (pa) criteria, while the AEV considers the visibility (v) and contrast (c) criteria of the Geosites. The CV evaluation considers the possibility of religious (ri), historical (hi), literary (li) and geo-historical (gh) importance criteria, but in this case, only the value of the highest criterion of the former will be considered (and not the mean of these values) since it is very rare to find a Geosite with both religious, historical, literary and geo-historical values. Finally, the TV value is based on the accessibility (a), existence of public infrastructures (i), density of Geosites in the area (d) and the geotouristic risk (gr). The criterion of the accessibility (a) has been prioritized and only values equal to 1 for (a) has been considered. Possible sites with difficulties of access (values minor to 1 for accessibility) have been discarded.

So, the AV module of the inventoried Geosites has been calculated with the following formula (Pralong, 2006):

$$AV = (ECV+AEV+CV+TV) /4 = \{[(ed + pa) / 2] + [(v + c) /2] + [CV]+ [(gi + a + i+ d + gr) /4]\} / 4].$$

The Global Value (GV) results of the following formula involving the SV and the AV modules (Pralong, 2006):

$$GV = [(SV + AV/2) / 150] \times 100$$

The Degradation Risk (DR) has also been separately valorized (Table 1) following the procedures by Brilha (2016). For the evaluation of the deterioration, five criteria are used: alteration of the outcropping (Dge), closeness to degrading activities (Ppa), measures of protection taken by the administration (Lgp), access facilities (Acc) and population density (Dop). The former criteria take values between 0 and 1 (with an interval of 0.25) and later weighted as in the following formula. The DR is obtained after the addition of the five criteria.

$$DR = [(Dge \times 0.35) + (Ppa \times 0.20) + (Lgp \times 0.20) + (Acc \times 0.15) + (Dop \times 0.10)]$$

The thresholds for the SV, AV, GV and DR values are: 0-0.25 low, 0.26-0.50 moderate, 0.51-0.75 high, 0.76-1 very high.

Results

Geosites and results of the evaluation

An important number of sites of geological interest have been recognized and inventoried in the TNP (Aoulad-Sidi-Mhend *et al.*, 2019). Among these, 34 have provided a GV upper to 0.75 (very high), these latest being considered as geological heritage of the park (Table 2; Fig. 2). The SV (Table 2; Fig. 2) is very high in 32 cases and high in the others two, meanwhile the AV (Table 2; Fig. 2) is very high in 14 cases, high in 18 cases and moderate in only 2 cases. On the other hand, the DR (Table 2; Fig. 2) is very high in 2 cases, high in 19 cases and moderate in 13 cases. The Geosites can be referred, according to their typology (Table 2), in structural geology (SG), stratigraphy (S), petrography (PT), paleontololy (PL), geomorphology (G), hydrogeology-hydraulics (H) and geomaterials (GM).

Details and valorization of five Geosites chosen as reference

Five sites of geological interest from the case studies regarding different geological typologies have been selected as reference of the abundant wealth in geosites (not much is known about the possible visitors) in the park area (Tables 3 and 4). The description, situation, figures, photographs and scoring of these sites of reference are shown in the following text.

The Rueda Eocene limestones succession

This Geosite is the number 3 (Fig. 1B) and is one of the few example of the paleontological typology (PL). A Ghomaride Complex tertiary succession made of limestones and calcarenites with several types of larger foraminifera (unicellular microfossils) are visible close to the provincial road P4105 very near the Rueda village (Fig. 3A, B). These rocks, dated as Cuisian to Early Lutetian by Hlila *et al*. (2007), are made of diverse micropaleontological facies (Alveolina, Nummulites, Assilina, red algae, Solenomeris and Miniacina) and is visible to

Table 2.— Geosites and their scores inventoried in the TNP (according to Grandgirard, 1999; Reynard *et al*., 2007; Pralong, 2006; Wever *et al*., 2006; Reynard *et al*., 2016; and Brilha, 2016). T: typology; SG: structural geology; S: stratigraphy-sedimentology; PT: petrography, PL: paleontology; G: geomorphology; H: hydrogeology-hydraulics; GM: geomaterials. SV: Scientific Value; AV: Additional Value; GV: Global Value; DR: Degradation Risk.

N°	Geosites	T	SV	AV	GV	DR	N°	Geosites	T	SV	AV	GV	DR
1	Ali Thilat Dam (509000 /514480)	H	0,70	0,92	0,77	0,71	18	Chrafate Spring (528900/498200)	G	1,00	0,97	0,99	0,56
2	Quarry of blocks (508620 /515660)	GM	0,80	0,48	0,69	0,76	19	Chrafate Alluvial Fan (526620/496200)	S	0,95	0,80	0,90	0,62
3	Rueda Nummilitic succession (350673 /514050)	PL	0,90	0,53	0,78	0,71	20	Beni Derkoul Radiolarites (528971/96626)	PL	0,90	0,64	0,81	0,62
4	Talâat Adrhosse Klippe (516259/519522)	SG	1,00	0,97	0,99	0,66	21	Ametrasse fallen blocks (528915/497640)	G	0,95	0,66	0,85	0,62
5	Oued Laou Gorge (514979/519900)	G	1,00	0,95	0,98	0,66	22	Jbel Chrafate Panorama (528915/497639)	S	1,00	0,66	0,89	0,57
6	Ibouharen Fold (516080/521865)	SG	0,95	0,58	0,83	0,71	23	Ametrasse Tertiary Fm Succession (537441/500341)	S	0,95	0,63	0,84	0,47
7	Tirinesse Basin 520261/524360	S	1,00	0,91	0,97	0,47	24	Koudiat Sbaâ Panorama (532683/496238)	G	0,94	0,59	0,83	0,47
8	Koudiat Achacha (518931/525190)	SG	1,00	0,73	0,91	0,47	25	Raghdat Southern entry of TNP (522044/498840)	G	0,85	0,64	0,78	0,42
9	Talambote bad lands (518527/517151)	G	0,95	0,61	0,84	0,56	26	Jbel Bou Slimane Panorama (524115/502322)	G	0,85	0,69	0,80	0,33
10	Talambote Thrusting (519820/516443)	SG	0.95	0.55	0.75	0,56	27	Jbel Lakraa Panorama (351300/515000)	S	1,00	0,67	0,89	0,33
11	Akchour landslide (516559/519522)	SG	0.80	0.83	0.82	0,71	28	Oued Tassikisste Gorge (517264/531806)	G	0,85	0,92	0,87	0,53
12	Akchour Dam (520220/515270)	H	0,80	0,95	0,85	0,56	29	Jbel Kelti Panorama (528900/498200)	SG	1,00	0,84	0,95	0,43
13	Sidi Abdel Hamid Ecomuseum (511810/507950)	PT	0,65	0,92	0,74	0,49	30	Raghdat Aremlal (507660/528564)	G	1,00	0,42	0,81	0,52
14	Sidi Abdel Hamid Lookout (511770/508040)	SG	0,95	0,72	0,87	0,74	31	Pont de Dieu and Farda River (520000/512000)	G	0,85	0,83	0,84	0,45
15	Ras el Ma Spring (513050/507250)	H	0,90	1,00	0,95	0,58	32	Oued El Kelaa Gorge and waterfall (524300/511980)	G	1,00	0,66	0,89	0,55
16	Bab Taza Phtanites (519816/496000)	GM	0,90	0,56	0,79	0,71	33	Tissimlane cherty limestone (514708/508861)	S	0,90	0,63	0,81	0,43
17	Bouhala Landslice (523579/496355)	G	0,80	0,67	0,76	0,56	34	Jbel Tissouka Panorama (516616/506668)	S	0,85	0,66	0,79	0,33

the naked eye. The scoring of this Geosite (Table 3) reveals a scientific value classifiable as very high (SV = 0.90). A moderate-high value is obtained for the additional value (AV = 0.53) mainly due to the lack of cultural value and importance. The final scoring for the global value is very high (GV = 0.78) and the presence of fossils visible to the naked eye, moreover as these are microfossils, make this Geosite essential. The Degradation Risk (Table 4) is high (DR = 0.7).

The Tirinesse Basin

This is the Geosite 7 and consists of a rectangular tectonic graben of reduced dimensions (about 4 km long x 1 km wide) and with a NE-SW orientation (Fig. 1B) filled with Pliocene marine sediments. It is, indeed, a good example of stratigraphic geosite (S). Two NE-SW oriented normal faults are identified as delimiting the SE and NW borders. The infilling of the basin is from lower Pliocene age with

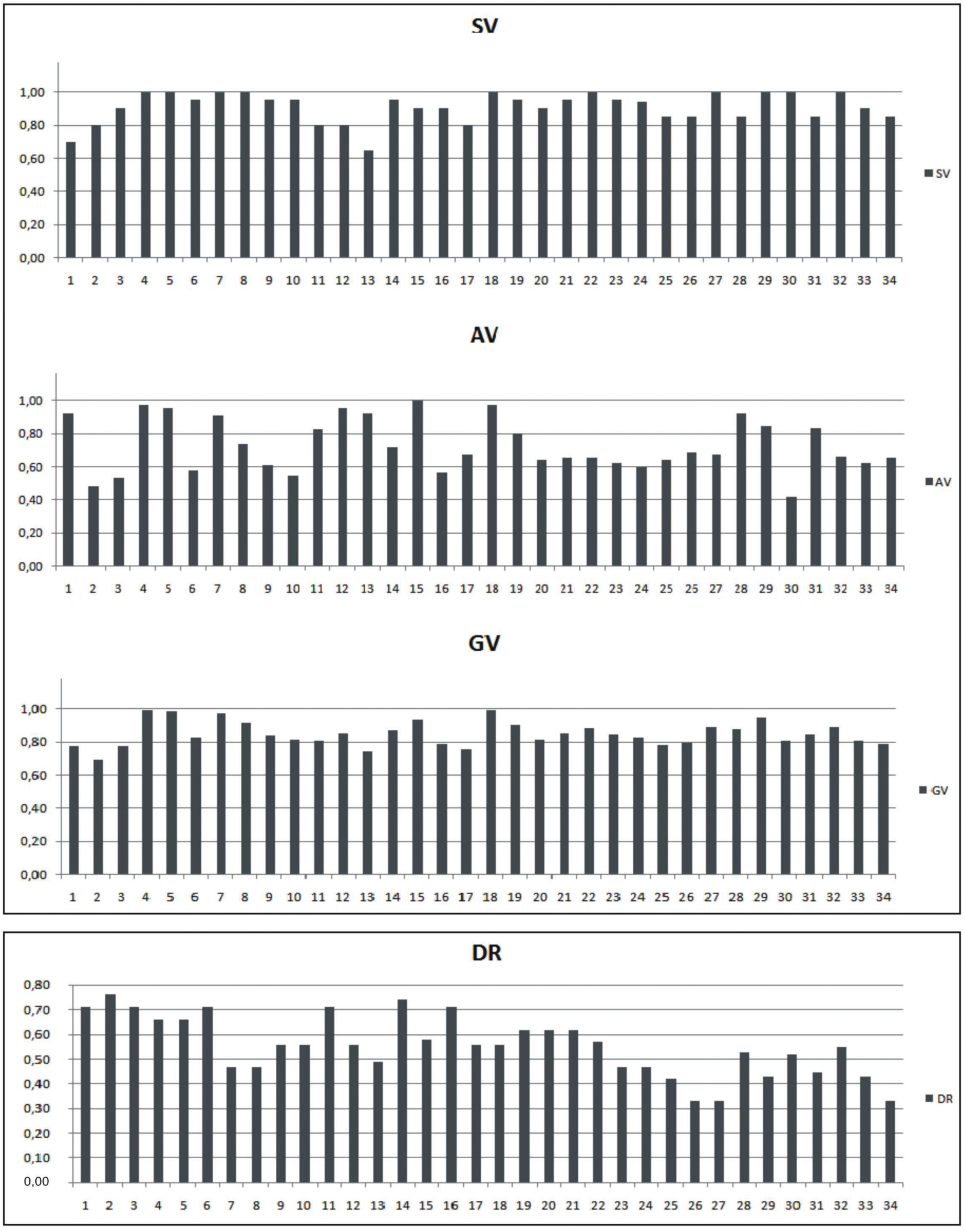

Figure 2.—Histograms representation of the values obtained in the 34 Geosites for the Scientific Value (SV), Additional Value (AV), Global Value (GV) (according to Grandgirard, 1999; Reynard *et al*., 2007; Pralong, 2006; Wever *et al*., 2006; and Reynard *et al*., 2016) and Degradation Risk (DR) (according to Brilha, 2016).

Table 3.— Detailed scoring of the five Geosites case study (according to Grandgirard, 1999; Reynard *et al*., 2007; Pralong, 2006; Wever *et al*., 2006; and Reynard *et al*., 2016) including Scientific Value (SV), Additional Value (AV) and Global Value (GV).

	Scientific value					**Additional value**												
						Ecological value		Aesthetic value		Cultural value and importance				Touristic value				
Key Geosites	Location and preservation	Representativeness	Frequency	Paleogeographic value	Educational value	Diversity	Protected area	Visibility	Contrast	Religeous	Historical	Literary	Geo-historical	Accesibility	Infraestructures	SIG density	Geotouristic risk	**Global value**
Rueda Nummuliic succession	1	1	1	0.75	0.75	0	1	1	0.5	0	0	0	0	1	0.75	1	0.75	
						0.5		0.75		0				0.88				
			SV = 0.90									**AV = 0.53**						**GV = 0.78**
Tirinesse Basin	1	1	1	1	1	0.75	1	1	0.75	0	0	0	1	1	0.75	1	0.75	
						0.88		0.88		1				0.88				
			SV = 1									**AV = 0.91**						**GV = 0.97**
Talambote thrusting	1	1	1	0.75	1	0	1	1	0.5	0	0	0	0	1	0.75	1	1	
						0.5		0.75		0				0.94				
			SV = 0.95									**AV = 0.55**						**GV = 0.75**
Ras el Ma Spring	1	1	1	0.75	0.75	1	1	1	1	1	0	0	0	1	1	1	1	
						1		1		1				1				
			SV = 0.90									**AV = 1**						**GV = 0.95**
Ametrasse Fallen Blocks	1	1	1	0.75	1	0.5	1	1	1	0	0	0	0	1	0.75	1	0.75	
						0.75		1		0				0.88				
			SV = 0.95									**AV = 0.66**						**GV = 0.85**

Table 4.— Detailed scoring of the five Geosites case study for the Degradation Risk (DR) (according to Brilha, 2016).

	Geosites				
Degradation Risk	Rueda Nummulitic Succession	Tirinesse Basin	Talambote thrusting	Ras el Ma Spring	Ametrasse Fallen Blocks
Deterioration geological elements	**0,5** x 0,35 = 0,18	**0,25** x 0,35 = 0,087	**0,5** x 0,35=0,18	**0,5** x 0,35 = 0,18	**0,25** x 0,35 = 0,087
Proximity cause degradation	**1** x 0,2 = 0,2	**0,25** x 0,2 = 0,05	**0,25** x 0,2 =0,05	**0,25** x 0,2 =0,05	**1** x 0,2 = 0,2
Legal protection	**0,5** x 0,2 = 0,1	**0,5** x 0,2 = 0,1	**0,5** x 0,2 =0,1	**0,5** x 0,2 =0,1	**0,5** x 0,2 = 0,1
Accesibility	**1** x 0,15 = 0,15	**1** x 0,15 = 0,15	**1** x 0,15 = 0,15	**1** x 0,15 = 0,15	**1** x 0,15 = 0,15
Density of population	**0,75** x 0,1 = 0,08	**0,75** x 0,1 = 0,08	**0,75** x 0,1 = 0,08	**0,75** x 0,1 = 0,08	**0,75** x 0,1 = 0,075
Final value (DR)	**0,7**	**0,47**	**0,56**	**0,58**	**0,62**

marine characteristics and related to a post-orogenic sedimentary cycle. It is a scarce example of an intermontane basin located in the Internal Zone eliminar la "d" final of the Moroccan Rif (Fig. 3C). Four members form the filling sedimentary succession of Tirinesse basin have been described (Hlila *et al*., 2014 a & b): (i) 30m of fluvial conglomerates resting unconformably over the basement; (ii) 200m of pelites and grey marls with planktonic foraminifera and gypsum in the upper part of the level; (iii) 20m of yellow sandy pelites and marly levels; and (iv) 30m of chaotic and poorly stratified alluvial conglomerates. A relict marine abrasion platform gives the area a geomorphologic important feature.

Figure 3.—A.- detail of nummulite limestones of the Rueda Nummulitic Succesion (Geosite 3); B.- detail of alveolina limestones of the Rueda Nummulitic Succesion (Geosite 3); C.- Panoramic view of the NE side of the Tirinesse Basin (Geosite 7); D.- Panoramic view of the Talambote Thrusting (Geosite 10); E.- View of the Ras el Ma Spring (Geosite 15); F.- Panoramic view of the Ametrasse fallen blocks in the foot of the Jebel Akroud (Geosite 21).

This abrasion platform is sculpted at approximately 580 m altitude in the SE border of the basin. The geosite, when scored, (Table 3) reveals a Global Value of a very high value (GV = 0.97) derived from very high values of the Scientific Value (SV = 1) and the Additional Value (AV = 0.91) making this Geosite essential in stratigraphic and sedimentological aspects. The Degradation Risk (Table 4) is moderate (DR = 0.47)

The Talambote thrusting

This is the Geosite number 10 (Fig. 1B) classified as structural geological typology (SG). This site of geological interest shows a thrusting in the Ghomaride Complex (Fig. 3D). The thrusting of Paleozoic rocks over Triassic ones is located to the right side of the Talambote River just before the intersection with the route to Talambote village.

The structure, affecting the Koudiat Tizian Unit, is visible from the route P4100 from Rueda to Talambote. The Paleozoic is made of grayish pelites, grawackes and conglomerates (usually Culm facies); meanwhile the Triassic consists of reddish clays, sandstones and conglomerates (continental red beds "verrucano"). Some meters to the East the normal succession, it can be seen where the Paleozoic is followed upwards by the Triassic. The scoring of this Geosite (Table 3) reveal a high Global Value (GV = 0.75) derived from the very high value of the Scientific Value (SV = 0.95) and the high Additional Value (AV = 0.55) making this Geosite essential for its structural geology aspects. The Degradation Risk (Table 4) is high (DR = 0.56).

The Ras el Ma spring

This is the Geosite number 15 and it is located in the Chaouen city (Fig. 1B), and it is classified as hydrogeological-hydrological typology (H). This spring is a very active source (Agence du Bassin Hydraulique du Loukkos -ABHL-, 2008), with a stable flow of about 470 l/s (Fig. 3E) rising to 1200 l/s in the humid period. Nowadays this source appears to be enclosed in a "room" from which the water is captured and transported for the local water supply system. Accessible by a footpath, this source is of a cultural interest to the local population. Additionally, close to the source, washing of clothes by the washerwomen takes place. Hence, this Geosite is also a tourist attraction point for visitors to the city. The source is located in the western boundary of the Calcareous "Dorsal" (a carbonate massif belonging to the Internal Zone) in contact with the clayish and marly sediments of the External Zone. In detail, this contact is a thrusting of the External "Dorsal" (Jbel Tissouka sheet) over the External Zones (Tanger Unit). The scoring (Table 3) reveal a scientific value (SV = 0.90) classified as very high and an additional value very high (AV = 1) for the Geosite. The Global Value results are also very high (GV = 0.93) making this Geosite a very recommendable for its hydrogeological aspects. The Degradation Risk (Table 4) is high (DR = 0.58).

The Ametrasse fallen blocks

It is the Geosite number 21 (Fig. 1B) belonging to the geomorphological typology (G). An impressive process of fallen blocks can be seen in this Geosite (Fig. 3F). The blocks descend from the cliff of the Jebel Akroud onto the village of Ametrasse forming a rock avalanche, which affected and destroyed some households in the past. This is a zone affected by instability, with a rapid but not instantaneous downstream land movement of high dimension blocks over a long distance. The last episodes of this progress which affected the Amettrasse Village took place in the 1970s. This is a typical phenomenon of gravitational instability leads to the falling of these blocks down the slopes. The fallen blocks belong to calcareous rocks from Jebel Akroud (a tectonic klippe of the Internal "Dorsal") overimposed upon the Ametrasse unit (External "Dorsal") made of marls and sandstones of Tertiary age. The zone is also affected by an important tectonic accident (Ametrasse fault) and many other faults of minor entity and jointing that fracture are the massive calcareous rocks in a very intense way. The consistency of this fragmentation favored the individualization and dislocation of the blocks downwards. The scoring of this Geosite (Table 3) shows a scientific value of a very high value (SV = 0.95). The additional value is only high (AV = 0.66) mainly due to the lack of cultural value and importance. The final scoring for the global is very high (GV = 0.85) and the essential importance of this Geosite is, without a doubt, for its landscaping and geomorphologic value. The Degradation Risk (Table 4) is high (DR = 0.62).

Discussion and Conclusions

The adherence to the rules of preservation, sustainable growth and education recommended by UNESCO are a good way to adequately protect a zone with a huge number of sites of geological interest. UNESCO (following previous works by the European Geopark Network and others individual geoparks in the whole World) started working on Geoparks in 2001 and approved the Global Geoparks program from 2015. 140 Geoparks located in 38 countries have been registered up to this date

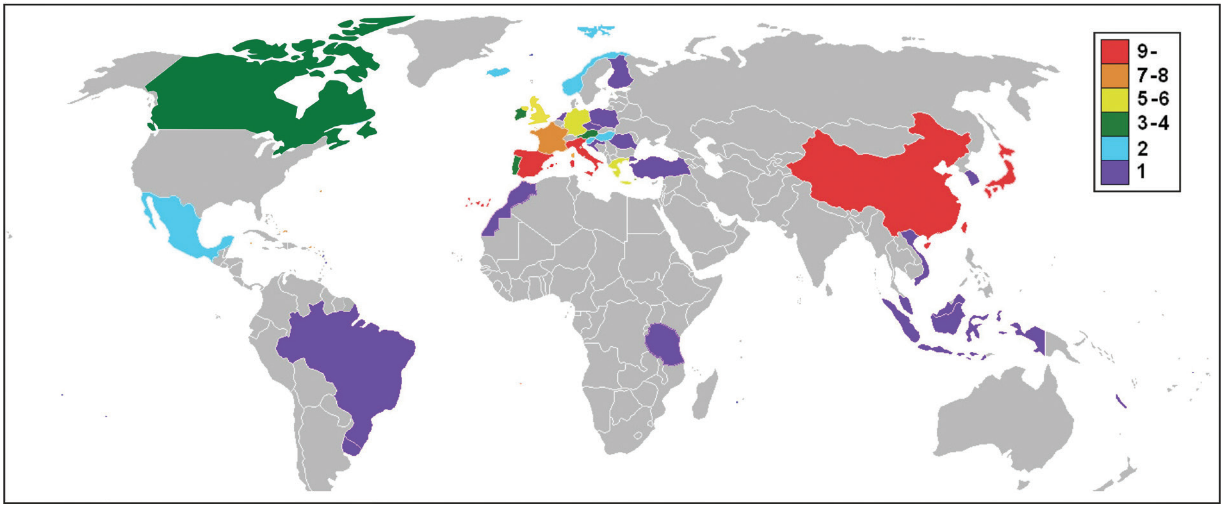

Figure 4.—Sketch map with distribution of Geoparks in countries around the World in 2019 (http://geopark-cngf.fr/geoparcs.html).

(Fig. 4). Most of them are situated in "First World" countries from Western Europe (12 Spain, 10 Italy, 7 France, 6 United Kingdom, 5 Germany, 5 Greece, 4 Portugal). It is worth noting the rising of registered parks from emerging countries such as China (with 37 Geoparks). In Asia, Japan shows a high interest with 9 Geoparks. In contrast, in North America, only Canada (3 Geoparks) and Mexico (2 Geoparks) have shown interest in the Geoparks network. Brazil and Uruguay (1 Geopark each one) have also recently incorporated to this program in South America. Morocco (the M'Goun Geopark, located in the Atlas) and Tanzania have registered one Geopark each in the African continent. The Tichoukt Massif is another zone from Morocco with a certain interest in the conservation of sites of geological interest. In this area, an itinerary with geological heritage sites has been recently released (Oukassou *et al*., 2017).

The examples presented earlier make the studied park a natural space of great geodiversity, with sites of geological interest with diverse typologies provide an additional value to its richness and memorable biodiversity (Aoulad-Sidi-Mhend *et al*., 2019). The evaluation has allowed inventorying 34 Geosites as geological heritage in the TNP (Table 2; Fig 3). In all cases, very high global values (greater to 0.75) have been found, 12 of them reaching values greater than 0.85 (Geosites 4, 5, 7, 8, 14, 15, 18, 22, 27, 28, 29 and 32). Nevertheless, this geodiversity is being threatened by anthropic interventions, making the protection and evaluation of these Geosites a priority. In fact, the evaluation of the Degradation Risk of the 34 Geosites has revealed than the DR is very high in 2 cases, high in 19 cases and moderate in 13 cases.

The quantification performed in the Geosites makes it possible to reduce subjectivity. The information gathered about the site can be easily improved and updated later when the site changes over time due to the measures taken by the authorities of the country. Even though the concrete area of the TNP has been analyzed and the richness of geosites of the area is evident once the park is compared with other parks in Morocco, the values obtained for the DR for the geosites indicate that some measures should be taken to protect the park. For all of these reason, it is imperative that all the actors involved (local-regional authorities, local population, schools and middle schools, universities and scientific institutes, NGOs, etc.) should face their responsibilities in order to make the necessary efforts (Aoulad-Sidi-Mhend, 2014) to implement the protection of the geological heritage of the TNP.

We recommend following the rules and concept of preservation, sustainable growth and education proposed by UNESCO for Global Geoparks. Hence, in a perspective of preservation and valorization of the Geosites proposed as geological heritage of the

TNP, some axes of actions can be mentioned in the following passages to establish the basis for a sustainable growth and the inclusion of the TNP in the Global Geoparks network:

a) publishing a geological guide for the TNP with the inventory of the 34 sites of geological interest mentioned in this paper highlighting the geological diversity of the park.

b) taking measures to insure sustainable growth in the area including geotourism projects, where previously mentioned sites (and other not studied here) can be integrated not only as natural resources but as natural heritage, thus offering local and foreign visitors the opportunity to learn about this geological heritage.

c) systems of signaling should be introduced along the access routes of the park, as well as, at the point where the proper site of geological interest can be observed.

d) the geomuseum (Geosite 13) sited in the offices of the park (Sidi Abdel Hamid Ecomuseum) should be developed with the possibility of obtaining guides and brochures with the information about the sites of geological interest, and also with the exposition of explanatory panels on the geology and sites of the park.

e) actions of promoting visits from primary and secondary education centers, and also universities to the TNP should be initiated. Educational material should be given to visitors and seminars should be offered before the visits to the sites.

f) awareness campaigns among the various stakeholders around the theme of conservation of this geological heritage should established, accompanied by strategies for sustainable growth of the park.

g) promoting this area from a sustainable geotourist point of view by exploiting all the tools and methods, such as information and communication technologies, to illustrate the very good sites of geological interest of the park.

The above proposed initiatives will contribute to Education and promote Tourism. In the case of Education, the TNP could contribute towards organizing activities and providing logistical support to the local and regional schools and universities. In the case of Tourism, the promotion of the geological heritage of the park can help the activation of the economic activity and sustainable growth in the northern Morocco. Consequently, the numbers of local and foreign visitors could be increased over time, leading to favorable conditions for the creation of local enterprises and cottage industries aimed at geotourism and geoproducts.

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