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REVIEW ARTICLE

Inventory and Assessment of the Mbepit Massif Geomorphosites (Cameroon Volcanic Line): Assets for the Development of Local Geotourism

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Abstract

Mbepit Massif, located in the central part of the continental Cameroon Volcanic Line, is characterised by several geomorphosites of volcanic origin. Eight geomorphosites, namely South Rhyolitic Protrusion, South Volcano, North Rhyolitic Needle, NW cone, North Volcano, Dome-casting, Tam-chi Depression and Maar Nfou, have been selected in this structure based to their scientific and additional values. Majority of these geomorphosites have a relatively high scientific value (0.79), due to their integrity, representativeness and rarity. Regarding additional values, they have high ecological and aesthetic values, but moderate cultural value. Despite all these assets, the *Mbepit Massif* geomorphosites are not at the centre of any local geotourism development project. This lack of interest in geotourism explains the absence of tourist facilities in most of the sites and the low consideration of their educational interest. To raise local geotourism offer, it is imperative to draw the attention of competent authorities and the local population to the importance of geomorphological heritage; popularise geomorphosites through field trips, leaflets, websites, conferences and exhibitions; and establish a sustainable management policy for the selected geomorphological units. This initiative will create awareness and help to protect the sustainable touristic potential of the geological heritage of the *Mbepit Massif.*

Keywords Mbepit Massif · Geomorphosites · Volcanic origin · Geotourism · Educational interest · Sustainable management

Introduction

The Cameroon volcanic line (CVL), orientated N 30° E, is a chain of volcanoes and plutonic complexes over 1600 km long, located between the West African Craton and the Congo Craton (Fig. 1). Its volcanic activity, which dates from the Eocene to the present (2000 eruption of Mount Cameroon), is at the origin of several volcanic landforms, both of oceanic (Atlantic Ocean) and continental crust. Several plutonic massifs as well as some volcanic rocks were emplaced more than 50 Ma ago (Moundi et al. 2007).

Many studies on volcanic geoheritage, geoconservation and geotourism have emerged in recent years around the world (Migon and Pijet-Migon 2016; Németh et al. 2017; Ginting and Sasmita 2018; Pérez-Umaña et al. 2019; Yaseen et al. 2019 etc.). The CVL also constitutes a geological heritage dominated by numerous geomorphological features. Despite the important geoheritage values and the tourist potential, morphometric information across the CVL is least available. Only recently, some initiatives for carrying out geoheritage inventories and assessment were undertaken in localities of Mount Manengouba, Mount Bamenda and Mount Bambouto's (Zangmo Tefogoum et al. 2014, 2017, 2019). The Mbepit Massif, one of the most important massif of the CVL, was selected for this project. This massif was chosen because it is made up of important assets that have attracted an active multi-origin population and fostered their settlement during the past decades. It is important to draw the attention of the local population to the importance of

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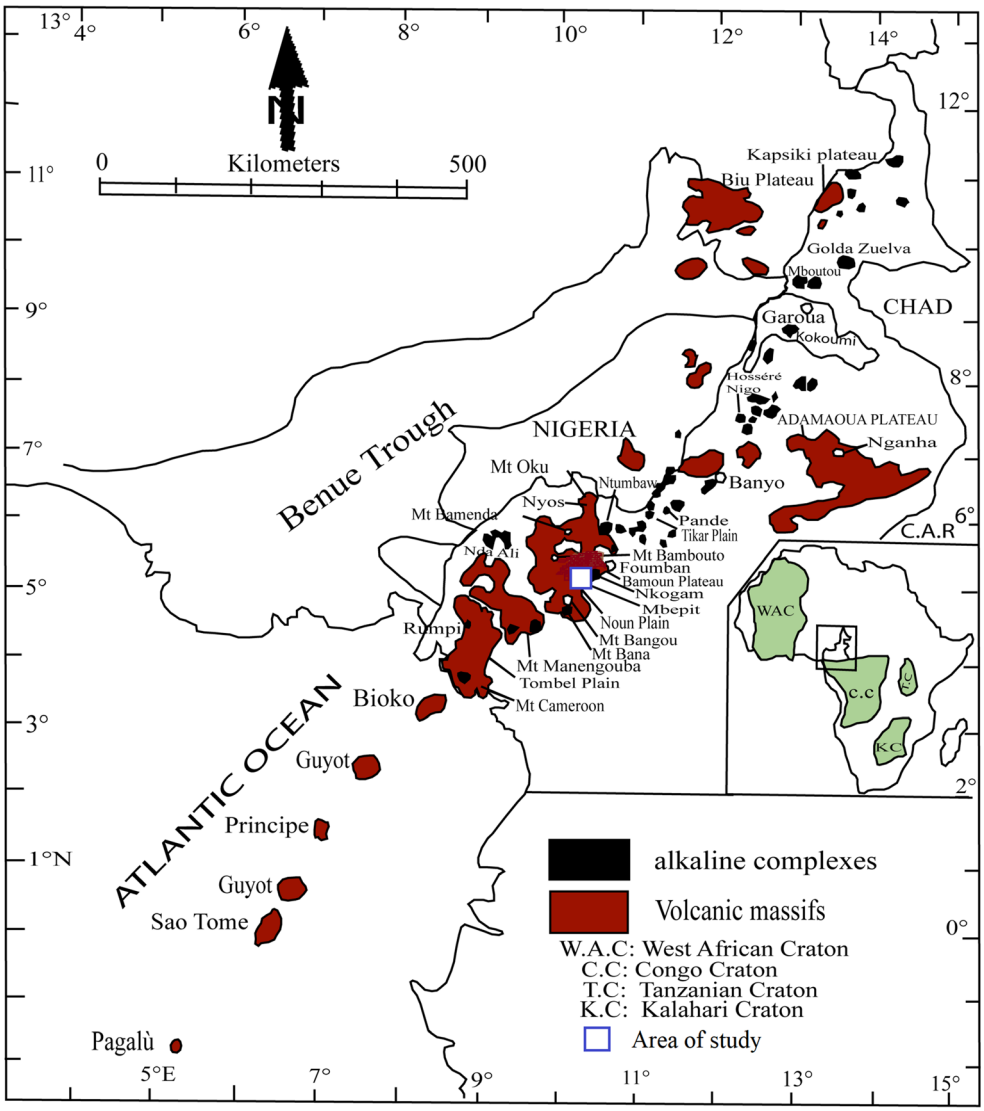

Fig. 1 General map of the Cameroon volcanic line (adapted after Halliday et al. 1988), showing the location of the Mbepit Massif (blue diamond)

geomorphological heritage and popularise geomorphic sites through systematic studies.

Mbepit Massif lies in the plain of Noun, elevated at 1988 m above sea level and 800 m above the plain. Some scientific researches conducted within this region concentrated on petrology, mineralogy, geochemistry and geochronology of rock formations, and risks related to volcanic activity (Tchoua 1972; Tchokona Seuwi 2010; Wandji 1995; Wandji et al. 2008). Thus, specifically, no research on the inventory of geosites has been conducted till date in order to promote geotourism and thus the local economy. Likewise, geoscience research in Cameroon, focused on the development of geoheritage as geotourism resource, is still scarce. The aim of this paper is to select and assess the geological heritage of the Mbepit Massif, with the purpose of promoting the geosites in Cameroon, and their utilisation in education and geotourism development.

The scientific literature reveals a multitude of concepts and definitions concerning geodiversity, geoconservation, geoheritage and geosites (notably Black and Gonggrijp 1990; Elízaga et al. 1994; Gray 2008, 2013; Pena dos Reis and Henriques 2009; Wimbledon 2011, Reynard and Brilha 2018). Some important definitions used in this paper are extracted from the ProGEO simple guide (2011, 2017). Geosite and geotope are considered by Reynard (2004) as synonyms. Several definitions of geotope have been proposed in some works (Grandgirard 1995; Panizza and Piacente 1993; Panizza and Piacente 2003; Panizza 2001, 2003; Reynard 2004). Reynard's definition (2004) of geotope, i.e. a geological or geomorphological object that has acquired a scientific (e.g. sedimentological stratotype, relict moraine representative of a glacier extension), cultural/historical (e.g. religious or mystical value), aesthetic (e.g. some mountainous or coastal landscapes) and/or social/economic (e.g. aesthetic landscapes

as tourist destination) value due to human perception or exploitation, has been retained in this study. Likewise, the term geomorphosites, which according to Bussard (2014) is a contraction of "geomorphological sites", is applicable. Geomorphosites are landforms that have acquired a scenic/aesthetic, scientific, cultural, historical, aesthetic and/or a social/economic value due to their human perception or exploitation (Panizza 2001).

The geological heritage should be employed for tourism purposes in good balance with conservation (e.g., Prosser 2011; Gray 2008, 2013). Geotourism is one of the newest concepts within the field of tourism, and primarily focuses on promoting geological and geomorphological features in landscapes as tourist attractions (Rannveig Ólafsdóttir 2019). Geotourism spans a range of visitor interests, from the specialist geotourist to the more general visitor. This also provides economic, cultural, relational and social benefits for both visitors and host communities (Gordon 2018). Thus, geotourism needs to be integrated with best practice management to preserve and enhance visitor experience and protect the resource (Leung et al. 2018).

This article first presents the geological context of the study, then describes the different analytical methods and justifies the choice of methods adopted compared with other proposals, before presenting the results of the study. The utilisation of Mbepit Massif geoheritage to promote development of local tourism would also be the discussed.

Geological Setting

Cameroon Volcanic Line

The CVL is one of the major recent magmatic provinces in Africa (Fitton and Dunlop 1985). The origin of this large magmatic province is still highly debated. It has been argued that the alignment of the volcanic massifs is the ancient track of the St Helena mantle plume, but no age progression has been evidenced along the CVL. Many other hypotheses have been proposed, suggesting the mantle plume origin for CVL (Ngako et al. 2006), or the melting of the uppermost mantle previously impregnated by the Saint-Helena hot spot (Halliday et al. 1988; Lee et al. 1994; Rankenburg et al. 2005). The popular hypotheses include that of "hot line" (Meyers et al. 1998; Déruelle et al. 2007), or the evolution due to the development of lithospheric cracks (Moreau et al. 1987). The occurrence of transitional basalts and leucogabbros in the Bamoun Plateau (Moundi 1993; Moundi et al. 1996, 2007; Ziem à Bidias et al. 2017, 2018) allows the possibility of an emerging rift in the Cameroon Line.

New geophysical measurements and numerical modelling along the CVL have provided additional constraints on the structure and evolution of this part of Africa (Adams et al. 2015; De Plaen et al. 2014). Geodynamic models that involve mantle melting due to edge-driven convection along the Congo Craton have been put forward to explain the linear structure of the CVL as well as its extension on the oceanic plate (Fourel et al. 2013; Milelli et al. 2012; Reusch et al. 2010, 2011). Within the tectonic framework of these models, there are still many unanswered questions to explain the compositional diversity, vis-à-vis the sources of magmatism.

Location and Geological Context of the Study Area

This research on the inventory of geomorphosites and their geomorphological features was carried out on the Mbepit Massif, located at the Eastern part of the Noun plain, between latitudes 5° 30′ and 5° 35′ North and longitudes 10° 40′ and 10° 45′ East (Fig. 2). This area has equatorial climate with two seasons: a short dry season (from November to February) and a long rainy season (from March to October). Maximum rainfall is between August and September (~ 323 mm), and temperature varies between 25 and 30 °C with average of 27 °C (source: climate-data.org/Cameroun/west/foumbot-894723). Mbepit Massif (one of the oldest volcanoes of the CVL) was developed during the Eocene ($^{40}K/^{40}Ar$ ages of 45.5 and 44.03 Ma; Wandji et al. 2008). These authors shown that two-thirds of the Mbepit Massif consists of rhyolitic rocks, mostly domes and thick, viscous lava flows. Two rhyolitic protrusions dominate the landscape: a 1988-m-high peak on the southern belt and a 1771-m-high needle displaying columnar jointing, on the northern belt. Due to its prolonged exposure to weathering and erosion, the present morphology of some cones does not reflect the original volcanic features.

Similarly, Tchokona Seuwi (2010) demonstrated that three major volcanic phases succeeded one another on the Mbepit Massif: an essentially effusive fissural dynamism that emitted flood basalts; a central dynamism that generated protrusions; numerous thick and highly viscous rhyolitic lava flows; and recently, effusive and moderately explosive basaltic fissural dynamism, which produced flows and projections. The latter is responsible for the construction of the Crater of Lake Nfou, the main attraction of the Mbepit Massif.

Analytical Methods

Inventory of Geomorphosites

An inventory of geological sites based on solid and clear criteria is a first step for any geoconservation strategy (Garcia et al. 2017). Many published works about inventorying methods exist (JNCC 1977; Lapo et al. 1993; Wimbledon et al. 1995, 1999; Alexandrowicz and Kozlowski 1999; Grandgirard 1999; Parkes and Morris 1999; White and

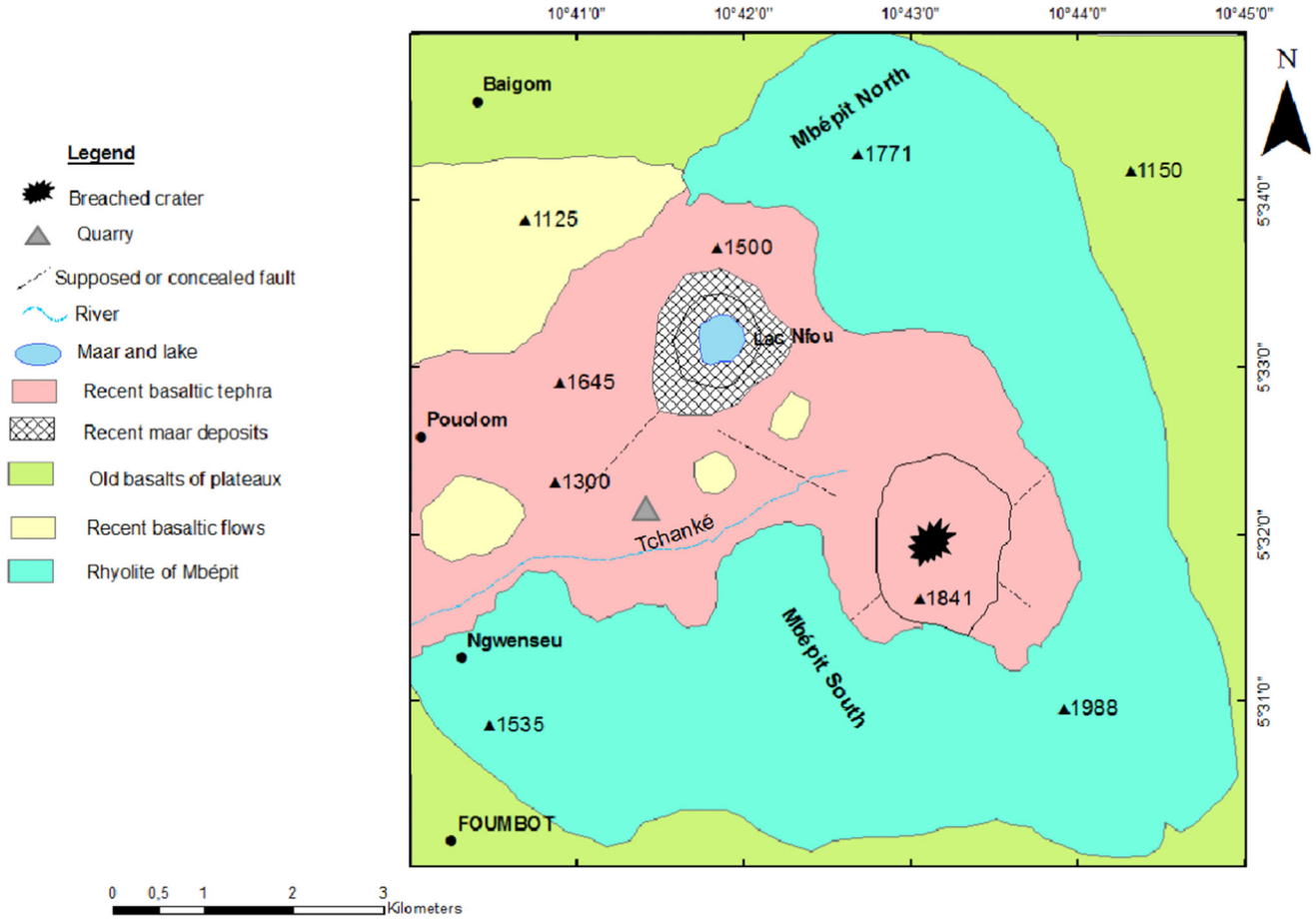

Fig. 2 Geological map of the Mbepit Massif (adapted after Wandji et al. 2008). Altitudes are shown in metre

Mitchell 2006; Pereira et al. 2007; Reynard et al. 2007, 2016; García-Cortés and Carcavilla Urquí 2009; Pereira and Pereira 2010; Díaz-Martínez and Díez-Herrero 2011; Wimbledon 2011; Fuertes-Gutiérrez and Fernández-Martínez 2012; Reynard and Coratza 2013; Sellier 2016). In general, all methods are based on a set of criteria that intend to reduce the subjectivity, always associated with the selection procedure of natural objects, and the aim of the inventory is related to its final purpose, which may consist of a national geoconservation strategy, a geotouristic project, an educational programme, etc. (Brilha 2018). According to Lima et al. 2010, the four main pillars that support a good inventory are the topic, the value, the scale and the aim (Table 1).

The main criteria used for the inventory of geomorphosites in this paper are adopted from Reynard et al. (2016). The approach of this method is divided into four stages: (1) definition of the main geomorphological contexts; (2) establishment of a first list of landforms based on a literature survey, consultation of cartographic and photogrammetric material, field survey, other existing inventories, and the assessor's knowledge; (3) classification of landforms following two sets of criteria: a spatial criterion (representative versus rare landforms) and a temporal criterion (active versus inherited landforms); and (4) selection of potential geomorphosites, which leads to the establishment of a final list. General data for the documentation of selected géomorphosites are measured according to the following main characteristics: (1) code

Table 1 The four main pillars for a good inventory (Lima et al. 2010)

Topic: subject or theme to be inventoried, for instance the whole geological heritage, just a partial component of it, like the palaeontological or the geomorphological heritage, and a specific geological framework;
Value: is closely related to the potential use of sites, essentially the scientific, educational, and/or geotouristic/-recreational use;
Scale: concerns the size of the area where the inventorying will take place (a protected area, a geopark, a municipality, a state, a country, a continent, etc.);
Aim: is related to its final purpose, which may consist of a national geoconservation strategy, a geotouristic project, an educational programme, etc.

Table 2 Criteria used for the assessment of the scientific value (Reynard et al. 2007, 2016)

Criterion	Evaluation
Integrity	State of conservation of the site. Bad conservation may be due to natural factors (e.g. erosion) or human factors
Representativeness	Concerns the site's exemplarity
	Used with respect to a reference space (e.g. region, commune, country). The selected sites should cover the main processes, active or relict, in the study area
Rareness	Concerns the rarity of the site with respect to a reference space (e.g. region, commune, country)
	The criterion serves to illustrate the exceptional landforms in the area
Palaeogeographical value	Importance of the site for the Earth or climate history (e.g. reference site for a glacial stage)

(divided into three parts: three capital letters for the name of the project, three small letters for the geomorphological context or process, three digits); (2) name; (3) altitude; (4) coordinates; (5) main geomorphological process; (6) characteristics; (7) type. Details of the entire analytical procedure are given in Reynard et al. (2016).

Assessment of Sites

There is no generally accepted method about the numerical assessment of sites. Usually, quantitative methods are based on several criteria and respective indicators to which different scores or parameters may be assigned (Cendrero 1996a, 1996b; Pralong and Reynard 2005; Coratza and Giusti 2005; Bruschi and Cendrero 2005, 2009; Reynard et al. 2007; Pereira et al. 2007; Zouros 2007; Reynard 2009; Erhartic 2010; Pereira and Pereira 2010, 2012; Bruschi et al. 2011; Vujičić et al. 2011; Fassoulas et al. 2012; Bollati et al. 2013; Reynard et al. 2016; Mucivuna et al. 2019). The method of assessment applied in this work was developed by Reynard et al. (2016) on geomorphological heritage inventories at a regional scale. This includes the modification of some criteria

Table 3 Criteria used for assessment of the additional values (adapted from Reynard et al. 2016)

Criteria	Qualitative assessment
Ecological value	
Ecological influence	Importance of the geomorphosite for the development of particular ecosystem or the presence of a particular fauna and vegetation
Protected site	Consideration is taken of sites that are already protected in a natural inventory or at regional or local level for ecological reasons
Ecological value	A sentence to summarise the ecological value.
Aesthetic value	
View points	Possibilities of the site to be observed. A site covered by a forest or very difficult to access would, in this case, have a lower score than a site visible from several viewpoints.
Contrasts, vertical development and space structuration	Contrasting landscapes (distinction of colours), landscapes with a vertical development (mountain) or landscapes with individual elements (isolated hill) that give that space structure are generally considered the nicest. On the country, less contrasting landscape, flat and monotone reliefs (e.g. alluvial plain, large plateau) are considered not nice.
Aesthetic value	A sentence to summarise the aesthetic value.
Cultural value	
Religious and symbolic importance	Spiritual and religious influence of the site
Historical importance	Role of the site in the past. Presence of vestiges.
Artistic and literature importance	Presence of the site in artistic realisations (e.g. paintings, sculptures) and in books and poems
Geohistorical importance	Role of the site in the development of geosciences
Cultural value	A sentence to summarise the cultural value.

Table 4 Criteria used for the documentation of the protection of the site (adapted from Reynard et al. 2016)

Sub-criteria	Contains
Protection status	Summarised by a sentence the level of protection of the site relatively to its link with different inventories, classifications or natural reserves stated
Damages and threats	Specify the level of damage of the site by human activities or natural processes. For the active sites (alluvial area), the change of processes allowing their formation or regeneration can be considered attack even if it is not localised in the site perimeter. As for threats, one must report if they are based on a real and feasible project in short/medium term.

of the previous method developed by Reynard et al. (2007) and used in several regional studies in Switzerland, at the University of Lausanne (Duhem 2008; Genoud 2008; Pagano 2008; Perret 2008; Maillard and Reynard 2011; Perret and Reynard 2011; Kozlik and Reynard 2013) and also applied, with some adaptations, in regional studies in Quebec (Mass et al. 2011), Romania and Malta (Coratza et al. 2012), Morocco (Boukhallad and El Khalki 2014) and Cameroon (Zangmo Tefogoum et al. 2017, 2019, 2020). It makes use of a card divided into six parts. For this work, three parts were selected: (1) assessment of the scientific value, with four criteria: integrity, rarity, representativeness, palaeogeographical value (Table 2); (2) assessment of three additional values (ecological, aesthetic and cultural value; Table 3); and (3) use and management characteristics (Tables 4 and 5). The four criteria of scientific value (SV) are independently evaluated by a numerical score ranging from 0 (zero) to 1 (very high) at intervals of 0.25 (Table 6). The final scientific value (SV) of the object is obtained by the average of the four criteria, that is:

$$SV = (\text{Integrity} + \text{Representativeness} + \text{Rarity} + \text{Palaeogeographical interest}) / 4.$$

A description of the analytical procedure is given in Reynard et al. (2016).

Results

The Inventory

After checking the four pillars of Lima et al. 2010 (Table 1), the establishment of an inventory of the geomorphological heritage of the study area was done gradually. Firstly, the review of existing geological data published about Mbepit Massif under study (Tchoua 1972; Tchokona Seuwi 2010; Wandji 1995; Wandji et al. 2008) and geological maps, has permitted to census a list of 13 potential geomorphosites. This list has been enriched with the advice of some authors that have developed research in the area. The next step involved several field investigations with two main aims: to identify and characterise all the sites included in the list of potential geomorphosites and to recognise new potential geomorphosites. So, four potential geomorphosites were not

Table 5 Sub-criteria used for the assessment of visit conditions (adapted from Reynard et al. 2016)

Sub-criteria	Contains
Accessibility (public transport)	Precisely the name of the nearest car stop (or market). If the car stop is remote from the site, one also mentions the access possibilities by motorbike.
Walking time	Give the walking time (one way) and as well as the number of kilometres and the dishevelment from the public transport stop or from the nearest parking. The walking time can be estimated according to the distance and the dishevelment.
Walking difficulty	Give information on the technical difficulty of access ways (steep slope, slippery way, no access way, etc. and not on the length or high dishevelment.
Security	Risk of accident often related to certain meteorological conditions (slippery way in rainy time) must be reported without taking into account the risk related to the inadequate behaviour of the visitors.
Site context	The quality of the environment of the site, notably the quality of landscape and panorama, quietness, sonorous/olfactory nuisance, the presence of layouts or thick vegetation that can hinder the visit, etc. must be reported.
Tourism infrastructures	Presence of touristic infrastructures (inns, restaurants, bars, tourism offices, etc.
Visit conditions	A sentence to summarise the conditions of visit of the site

Table 6 Criteria used for the assessment of the scientific value (adapted from Reynard et al. 2007 and Reynard et al. 2016)

Criteria	Quantitative assessment
Integrity	0 = destroyed 0.25 = practically destroyed 0.5 = partially destroyed 0.75 = slightly damaged 1 = intact
Representativeness	0 = nil 0.25 = weak 0.5 = moderate 0.75 = high 1 = very high
Rareness	0 = more than 7 0.25 = between 5 and 7 0.5 = between 3 and 4 0.75 = between 1 and 2 1 = unique
Palaeogeographical interest	0 = nil 0.25 = weak 0.5 = moderate 0.75 = high 1 = very high
Synthesis of scientific value	Average

selected due to lack of accessibility. However, a new geomorphosite (Dome-casting) was discovered and selected because of the related significant scientific and additional value. Then, eight geomorphosites (South Rhyolitic Protrusion, South Volcano, North Rhyolitic Needle, NW cone, North Volcano, Dome-casting, Tam-chi Depression, and Maar Nfou) were definitively selected (Fig. 3) for final assessment. Figures 4 and 5 show pictures of the selected geomorphosites, and general data for the documentation are given in Table 7.

The Assessment

Scientific Value of Mbepit Massif Geomorphosites

The scientific value of the geomorphosites of the Mbepit massif is recorded in Table 8. In general, almost all of these geomorphosites have retained their integrity (Fig. 6), hence the average score of 0.84. Nevertheless, the South Rhyolitic Protrusion and North Rhyolitic Needle get score of 0.75 for this criterion because of the phenomenon of physical disintegration that erodes their rocks. These gradually become

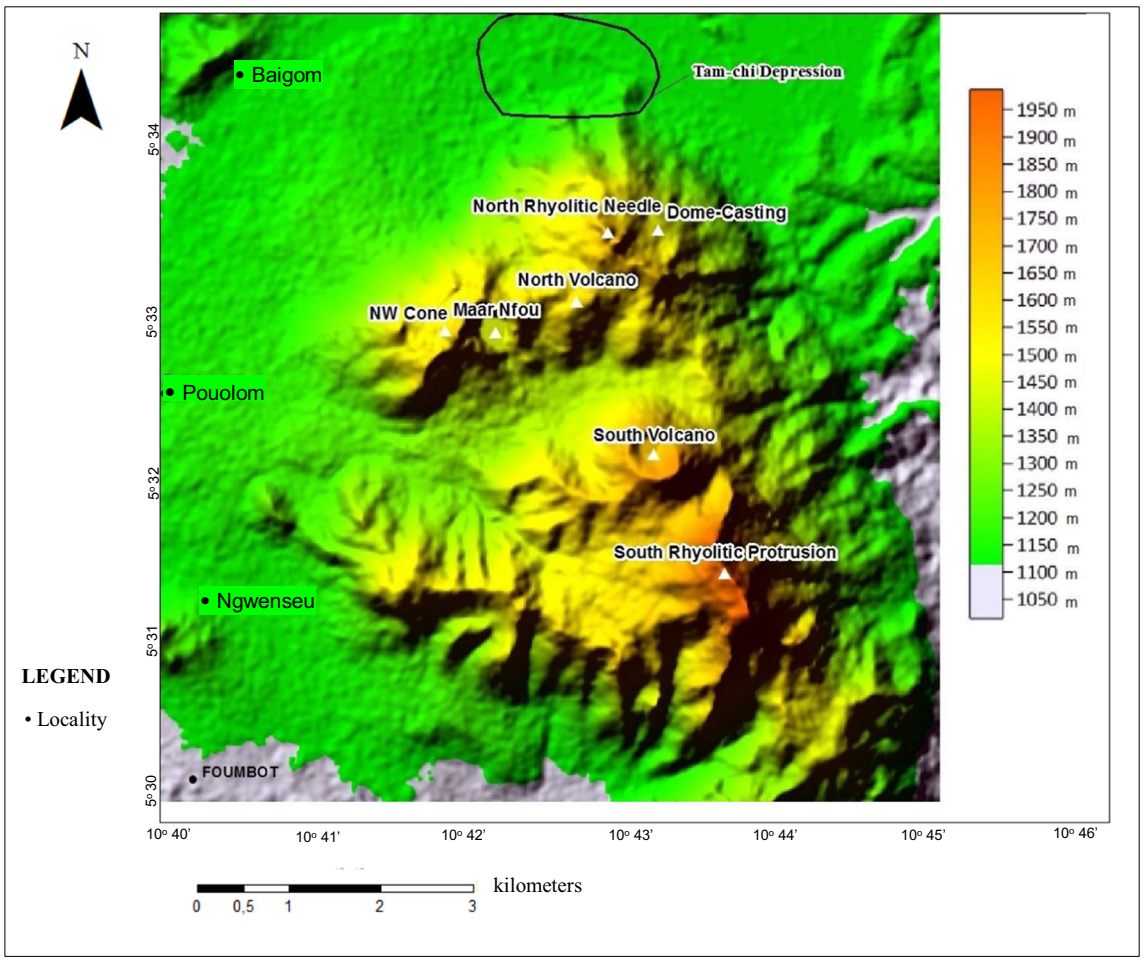

Fig. 3 Location of selected geomorphosites in Mbepit Massif

detached and fall in the neighbouring valleys. The degradation of the Tam-Chi Depression is marked by the presence of houses and crops. That justifies the lowest score of 0.5 given to Tam-Chi Depression. Geomorphosites of the Mbepit Massif are representative of regional geomorphology. Their majestic character overlooks the general relief of the surrounding plain. These very distinctive facts attribute the score of 0.91 due to their representativeness. Concerning rareness, the North Rhyolitic Needle, the South Rhyolitic protrusion, the South Volcano, the Tam-chi Depression and the Maar Nfou obtain the maximum score of 1, because they constitute unique and specific geomorphological entities in the region. On the other hand, NW Cone, North Volcano, and Dome-casting (score 0.75) have a relatively recurring relief in the region. Nevertheless, a high average of 0.91 is obtained for rareness. Palaeogeographic interest concedes the lowest average of the criteria determining the scientific value (0.50). This is largely due to the fact that the geomorphosites evaluated are not indicators of past climate. However, the score is due to the fact that they reveal a change of appearance compared with the past landscape. In the same way, the geomorphological characteristics and the different volcanic products of the Mbepit Massif make it possible to identify the variety of volcanic dynamisms at the origin of the formation of these geomorphosites which modified the original relief.

In general, the scientific value of the Mbepit Massif geomorphosites is fairly high (0.79). Figures 7 and 8 underline the evolution bend of the scientific value of the Mbepit Massif geomorphosites. Maar Nfou obtains the highest score (0.94) due to its integrity, representativeness and rarity. For a similar reason, South Volcano and North Rhyolitic Needle have a high scientific value (respectively 0.88 and 0.81). However, the Tam-chi Depression has the lowest scientific value (0.69) due to average integrity and insignificant palaeogeographic interest.

Additional Values of the Mbepit Massif Geomorphosites

Ecological Value There are various natural environments with remarkable biological diversity, with special fauna and flora species. The geomorphosites of the Mbepit Massif also play a vital role in the subsistence of organisms including man, animal and plants. On the flanks of cones and domes appear gallery forests

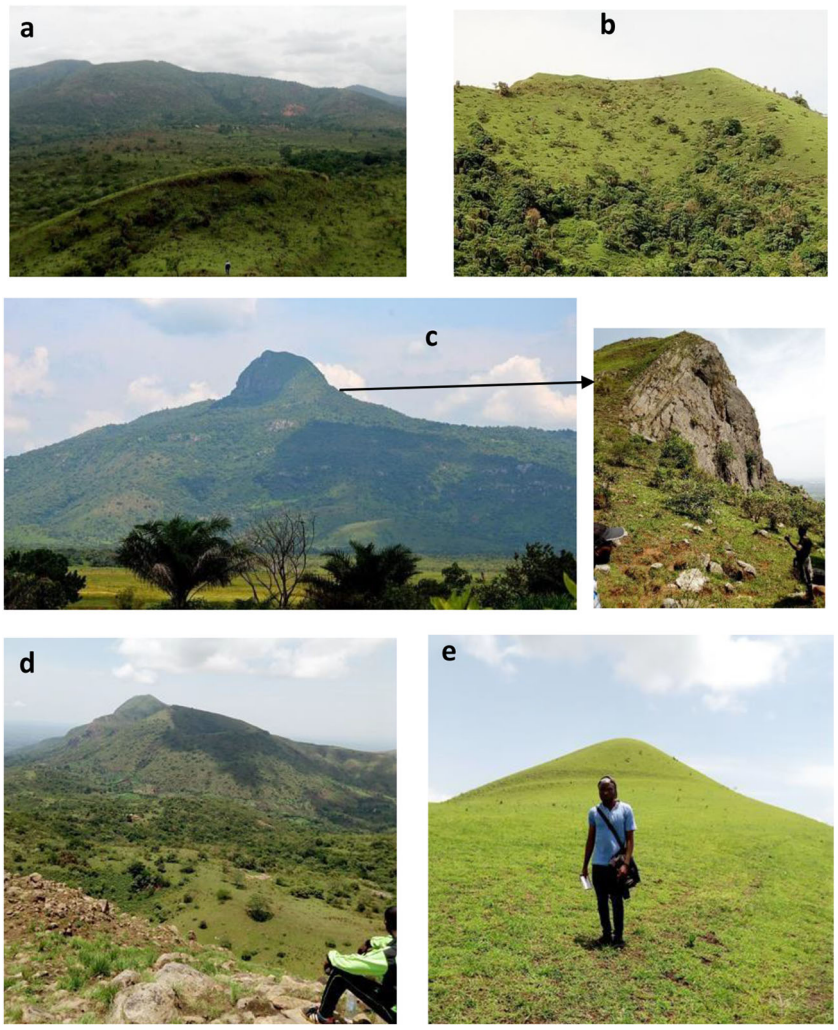

Fig. 4 Pictures of the selected geomorphosites (**a** South Rhyolitic Protrusion; **b** North Volcano; **c** North Rhyolitic Needle; **d** South Volcano; **e** NW Cone)

(Fig. 9a) serving as sanctuary for a diverse variety of living organisms which are often inter-dependent on each other for their subsistence. Thus, vegetation provides shelter and food for many species. That is one aspect of the ecological importance of mountains to living things. Another role the geomorphosites of the Mbepit Massif play is that they serve as protection from harsh weather conditions or winds of gale force. The ravines of these geomorphosites also serve as a drain during the rains that water vegetation in the lower surrounding areas. The flowing water also carries many minerals that improve the growth of vegetation.

Thus, due to the mount, forest and lake ecosystems, the Mbepit Massif geomorphosites have a significant ecological influence. However, the protection of geomorphosites in the region is limited. Only the North Rhyolitic Needle and the Maar Nfou are protected, though South Rhyolitic Protrusion, South Volcano, NW Cone, North Volcano, Dome-casting and Tam-chi Depression are not protected. The Maar Nfou is protected by the Ministry of Tourism and Leisure. North Rhyolitic Needle is protected by the traditional authorities of the Baïgom village.

Despite that weak protection, the average ecological value of the Mbepit Massif geomorphosites is quite high, because these are sites little disturbed by human action, except at the lower flanks of the mountains.

Aesthetic Value The geomorphosites of the Mbepit Massif are clear and visible from afar. They present contrasts of colour due to the diversified vegetation and the volcanic formations with various facies (rhyolites, basalts, lapilli, volcanic ash …). Thus, the rhyolitic protrusions, of light colour, overhang the vegetation, while on certain flanks of mountain a green plant carpet can be observed (Fig. 9a). The pyroclastic projections cover the soil, which then present a black colour, and contrasts with the brown soils of the part not covered by volcanic ash. The contrast of colours is also due to the variations of slope that have structured the space, as is the case in the Maar Nfou (Fig. 9b).

The variation of the altitudes (between 1120 and 1988 m) of the geomorphosites makes their vertical development perceptible. Thus, depending on whether the reference zone is the plain or the slopes of the volcanoes, there is a positive vertical development (South Rhyolitic Protrusion, South Volcano, North Rhyolitic Needle, NW Cone, North Volcano and Dome-casting) and a negative vertical development (Tam-chi Depression and Maar Nfou). These different criteria give all these geomorphosites a high average aesthetic value.

Fig. 5 Continuation and end of the pictures of the selected geomorphosites (**a** Dome-casting; **b** Tam-chi Depression; **c** Maar Nfou)

Table 7 General data for the documentation of selected geomorphosites (the criteria used are from Reynard et al. 2016)

Geomorphosites		Data					
Code	Name	Altitude (m)	Surface (m^2)	Coordinates	Main geomorphological process	Characteristics	Type
MBEvol001	South Rhyolitic Protrusion	1988	193,000	N 05° 31′ 27″–E 10° 43′ 37″	Volcanic	Natural	Surface
MBEvol002	South Volcano	1841	991,000	N 05° 32′ 12″–E 10° 43′ 11″	Volcanic	Natural	Surface
MBEvol003	North Rhyolitic Needle	1771	13,000	N 05° 33′ 35″–E 10° 42′ 53″	Volcanic	Natural	Surface
MBEvol004	North Volcano	1500	26,000	N 05° 33′ 12″–E 10° 42′ 10″	Volcanic	Natural	Surface
MBEvol005	NW Cone	1566	16,000	N 05° 32′ 59″–E 10° 41′ 51″	Volcanic	Natural	Surface
MBEvol006	Maar Nfou	1500	34,000	N 05° 32′ 58″–E 10° 42′ 10″	Volcanic	Natural	Surface
MBEvol1007	Tam-chi Depression	1100	232,000	N 05° 33′ 00″ to N 05° 35′ 00″ E 10° 42′ 00″ to E 10° 44′ 00″	Tectonic	Natural	Surface
MBEvol1008	Dome-casting	1560	1260	N 05° 33′ 37″–E 10° 43′ 12″	Volcanic	Natural	Surface

Cultural Value The geomorphosites of Mbepit Massif do not have a religious importance. There is no prehistoric or historical element to trace the geological history of these different geomorphosites except the products of volcanic eruptions. Thus, the volcanological, petrological and geochemical studies of the volcanic formations made it possible to characterise the geohistory of this region of the CVL. At the symbolic level, only the Maar Nfou is subject to a traditional interest owing to its mystical attributes by the people. The Maar Nfou site is also mentioned several times in the scientific and tourist literature. Overall, the geomorphosites of Mbepit Massif have a moderate average cultural value.

Figure 10 shows the intrinsic and additional values of each Mbepit Massif geomorphosite.

Use and Management Characteristics

Protection of Geomorphosites

The geomorphosites of the Mbepit Massif have no legal protection. Their protection status is therefore zero. Only the Maar Nfou, with a crater lake, enjoys a very low protection status. This protection is materialised in the Baïgom village by a small fence and a sign post at the entrance of the site, which informs on the management of the site by the commune of Foumbot and entry payment modalities (Fig. 11a). However, beyond the fence, the population carries out several agricultural activities and exploitation of volcanic projections that gradually degrade the road to the site. This exploitation of pozzolana in the area is the main threat because it is unregulated and abusive. Likewise, intensive arable and pastoral farming on the mountain slopes modifies the topography and the natural flora of the slopes of certain geomorphosites (e.g. NW cone, North volcano, South Volcano) in some places. Finally, the permanent threat to the selected geomorphosites remains a possible resumption of volcanic activity.

Valorisation of the Geomorphosites

Individual tourists and tourist groups can access the Mbepit Massif via cars or motorbikes. For some geomorphosites, notably North Rhyolitic Needle, South Rhyolitic Protrusion,

Table 8 Scores obtained from the assessment of the scientific value of geomorphosites in the Massif Mbepit

Geomorphosites	Integrity	Representativeness	Rareness	Palaeogeographical interest	Scientific values
South Rhyolitic Protrusion	0.75	0.75	1	0.50	0.75
South Volcano	1	1	1	0.50	0.88
North Rhyolitic Needle	0.75	1	1	0.50	0.81
NW Cone	1	0.75	0.75	0.50	0.75
North Volcano	1	0.75	0.75	0.50	0.75
Dome-casting	0.75	1	0.75	0.50	0.75
Tam-chi Depression	0.50	1	1	0.25	0.69
Maar Nfou	1	1	1	0.75	0.94
Average	0.84	0.91	0.91	0.50	0.79

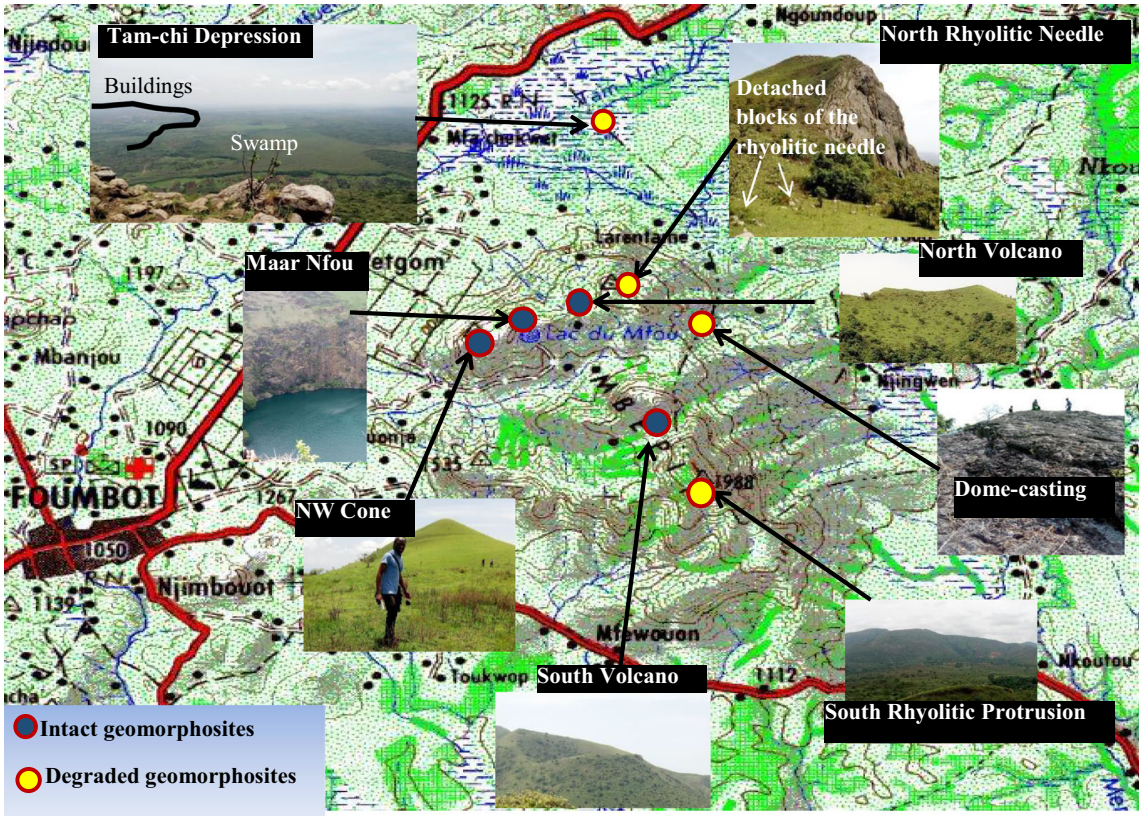

Fig. 6 Highlight of the integrity of the Mbepit Massif's geomorphosites

South Volcano, NW Cone, North Volcano and Dome-casting, fairly steep slopes and the presence of drill-galleries complicate access. Nevertheless, the tracks traced on the flanks by herdsmen facilitate access to the sites. Access to the Nfou maar and the North Rhyolitic Needle is facilitated by stairs and rest huts (Fig. 11b). These infrastructures are in a state of degradation (Fig. 11c, d) and need to be refurbished. On the peaks of North Rhyolitic Needle and South Rhyolitic Protrusion, the pedestrian path is untagged and requires a lot of caution on the part of visitors to avoid tumbling. These tracks are also strongly prohibitive to people who do not have specific abilities in mountain environments.

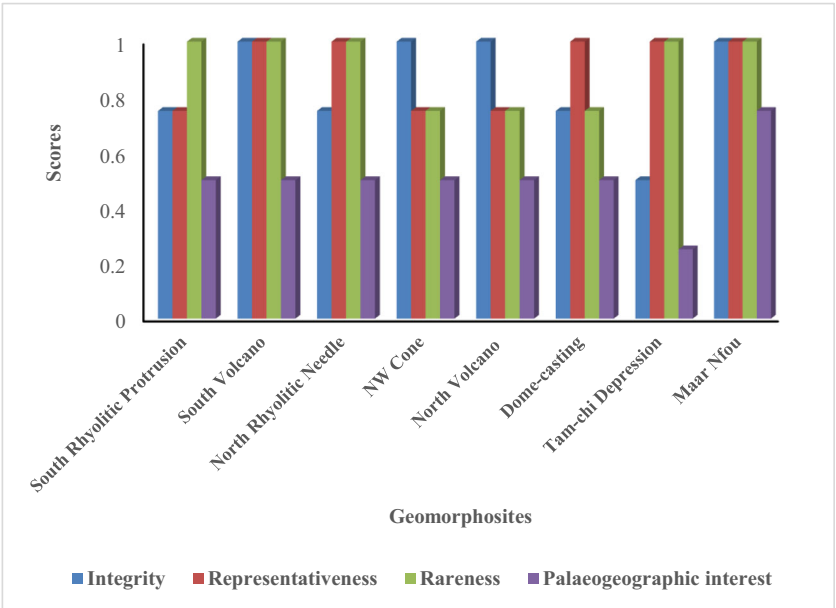

Fig. 7 Histograms of the scientific value of the Mbepit Massif's geomorphosites

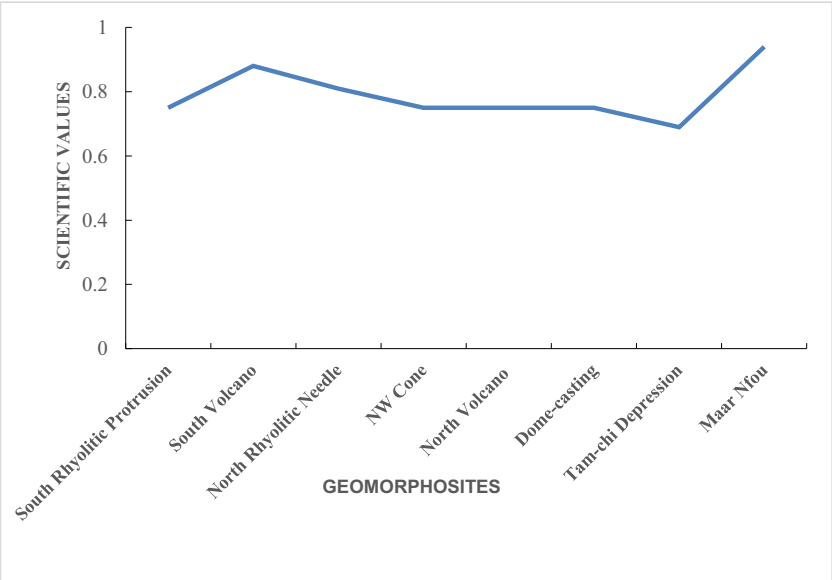

Fig. 8 Curve showing the variation of the scientific value between geomorphosites

Most of the geomorphosites of the Mbepit massif enjoy a calm environment, a preserved natural environment, a picturesque landscape with little noise or olfactory nuisance. Only pastoral farming is a source of trouble in these environments, but at a negligible level.

There is no permanent tourist infrastructure near the Mbepit Massif geomorphosites. The accommodation and catering facilities are located in the town of Foumbot, about 3 km from various sites. Despite the advantages of the Mbepit Massif geomorphosites highlighted by their aesthetic value, there are no interpretation facilities such as didactic panels, brochures, books ... providing the public with guidance and explanations on the sites. This is the consequence of the lack of valorisation of local geotourism and the fact that decision-makers are not aware of the wealth of the Mbepit Massif geoheritage.

Education Interest

Mbepit Massif's geomorphosites benefit from high readability due to numerous geological phenomena that have occurred in this area and set up a variable range of volcanic reliefs. Thus, there are volcanoes set up by explosive (NW cone, South Volcano), effusive (North Volcano, Dome-casting) and extrusive (South Rhyolitic Protrusion, North Rhyolitic Needle) eruptive dynamisms, as well as a maar (Maar Nfou) and a huge depression (Tam-chi Depression). Numerous thick and highly viscous rhyolitic lava flows of Mbepit have been erupted onto the older plateau basalts, and some rhyolites were covered by more recent basaltic lava flows and tephra later on (Wandji et al. 2008). The basal volcanic formations are clearly tuffaceous (Tchoua 1972) and contain small enclaves of basalt and of the same rhyolite. All these geological features constitute a real didactic potential and

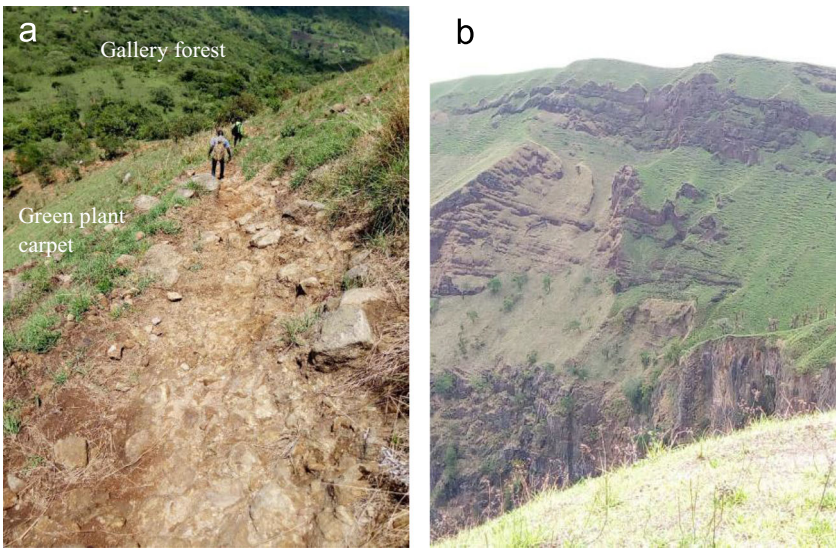

Fig. 9 Pictures **a** and **b** highlighting the contrast of colours in the Mbepit Massif range

can be easily understood by students of secondary school, universities and initiated people. Thus, the Mbepit Massif provides exceptionally good educational avenues for the dissemination of the current understanding on specific types of volcanism. Among the local people, there is a considerable level of awareness. The locals have general knowledge of certain volcanic products such as pozzolana, which is being exploited in an artisanal way to build houses, while volcanic ashes are used to fertilise agricultural lands for crop and food production. However, this work could improve the level of knowledge of local populations on the geomorphosites of their region and the related benefits.

Despite the corresponding high readability relating to the Mbepit Massif's geomorphosites, there is lack of interpretation equipment like panels, booklet, website, flyer, and virtual visit in Mbepit area. The highlights of the visit conditions and educational interest of geomorphosites are given in a synthetic map (Fig. 12).

Discussion

Utilisation of Mbepit Massif Geoheritage to Promote Development of Local Tourism

The geological heritage of the Mbepit Massif seems to be very suitable for the purposes of geotourism development because of its numerous geomorphological features. Geotourism is, however, a broad concept which encompasses many aspects of a range of tourism activities, such as transport, accommodation, destination

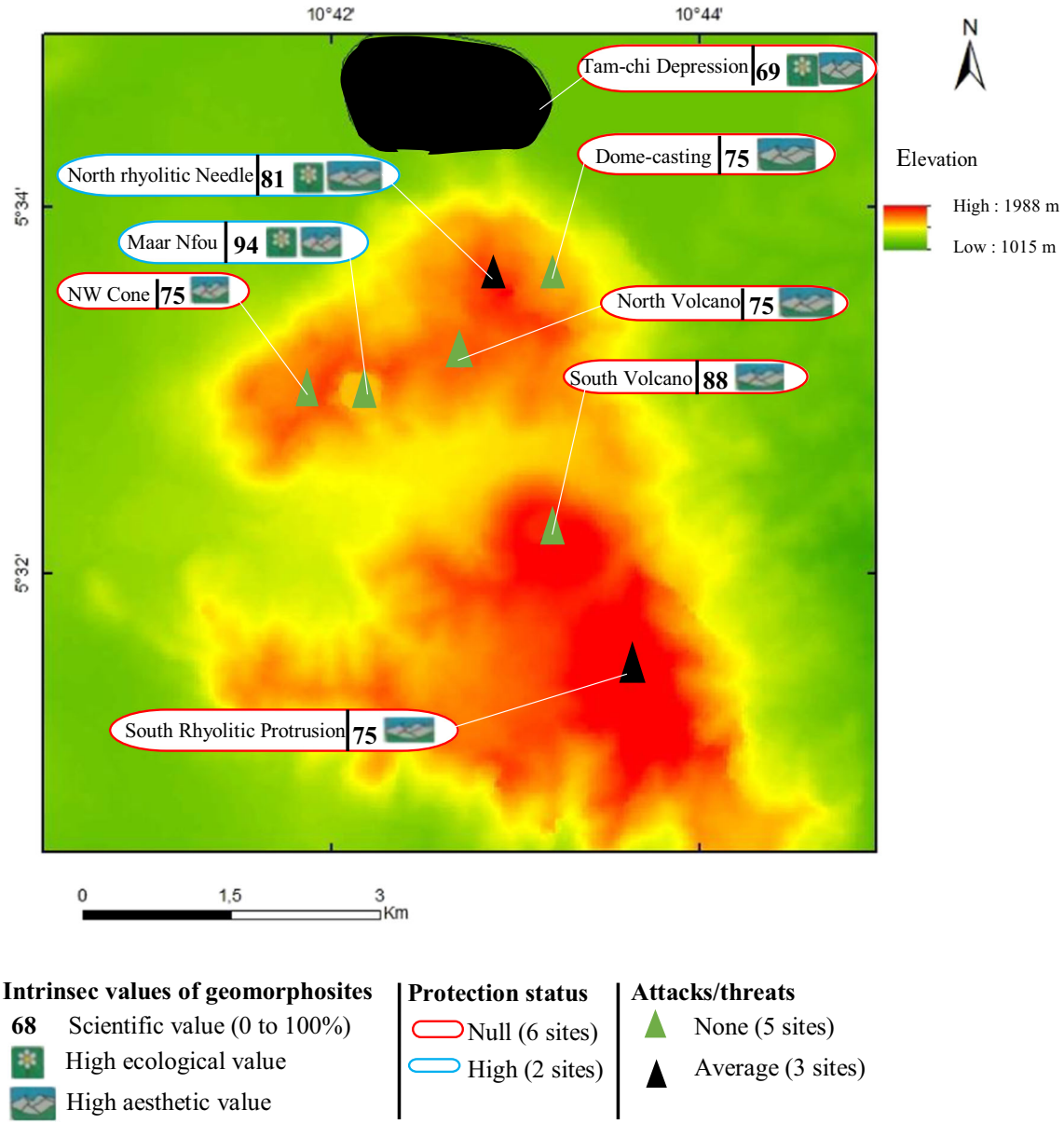

Fig. 10 Intrinsic and additional values of Mbepit Massif geomorphosites

amenities, recreation, planning and management (Ólafsdóttir 2019).

Valorisation of the Geotourism Offer

According to Rybar (2010), within the field of Geotourism, the objects with the highest ranking will be those that are worthy of being classified as geosites, be it from mineralogical, petrographic, geomorphological, tectonic or palaeontological point of view, or any other reasons, or in case the object is a part of geopark. In order to highlight the geotourism potential of the Mbepit Massif, the following specific criteria were used:

Accessibility Any visitor with a suitable vehicle can arrive directly at the foot of the Mbepit Massif in less than 20 min, from the city of Foumbot. The accessibility of the selected geomorphosites and the walking time vary depending on the distance from the site to the parking (Fig. 12), the nature of the slopes and the vegetation cover that surrounds the site. Once at the top of the massif, one can have a generalised view of all the geomorphosites. The poor quality of certain roads is to be emphasised. The tracks are sometimes difficult to access in the rainy season. However, there are bypass tracks mastered by local residents. In general, the roads leading to the Mbepit Massif need to be rehabilitated.

The Interest of the Geomorphosites of the Mbepit Massif On the one hand, this is determined by their external appearance and the fascination they engender, and on the other hand by the possibility for the public to discover clearly the geological and geomorphological features of the massif.

Visitor Safety The geomorphosites of the Mbepit Massif are open to nature and present no identified risks, except for a possible resumption of volcanic activity. In case of large numbers and depending on the age of the visitors, it is strongly recommended to be guided by local monitors for more security; some tracks can be dangerous.

Guaranteed Geomorphosites' Protection During the passage of visitors, the protection and conservation of selected geomorphosites can be guaranteed as they do not consist of fragile natural elements that can be degraded by visitors.

Capacity Limits Certain areas of the Mbepit Massif can contain dozens of visitors. It would nevertheless be preferable to reduce the staff as much as possible in the event of a visit by young people to better control them.

The Proximity of Other Potential Geomorphosites More than sixty strombolian cones line the Noun plain and are visible from the summit of mount Mbepit. This is an important factor for the creation of tourism offers including several geomorphosites.

These important assets made it possible to specify the fundamental actions to be carried out to valorise the offer of geotourism of Mbepit Massif, in particular:

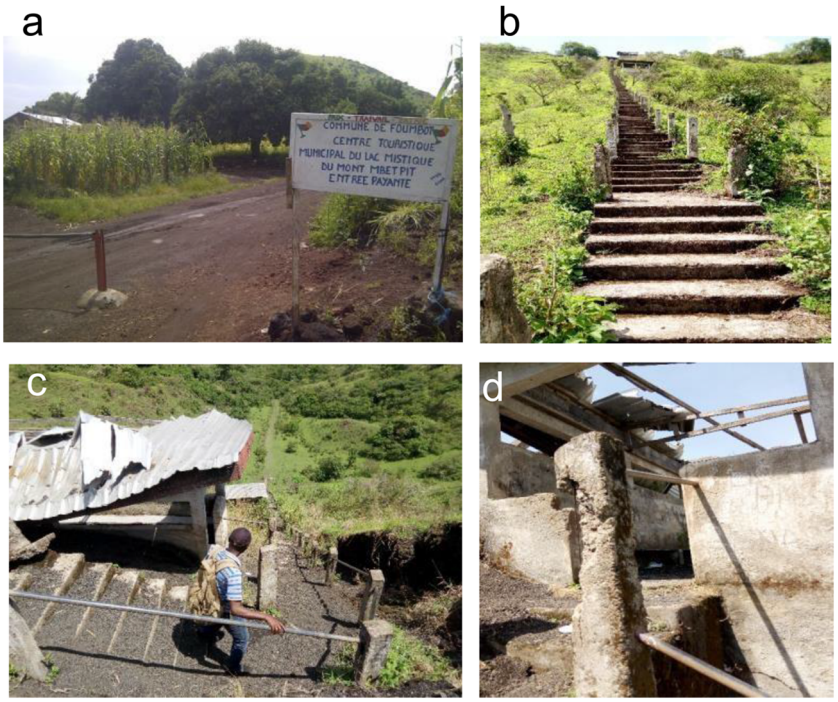

Fig. 11 **a**–**d** Some installations on the site of the Mbepit Massif. They are all damaged

- Development of tourism infrastructures

  It is important to improve off-road vehicle roads to ease accessibility, build hotels/inns and restaurants around the sites and establish interpretative panels around each geomorphosite.
- Development of geomorphosites

  The development of the Mbepit Massif can contribute to the enhancement of the geoheritage and the local tourism offer. More recently, site improvements are intended to improve the observation of the site by limiting the degradation of these sites. Thus, by building bridges and installing elevators, the overall view and staging of the site will be more attractive and thus provide more emotions and feelings to visitors.
- Event creation

  The creation of an event promotes the attractiveness of a destination and makes it possible to mobilise many actors including the media. In the case of Mount Mbepit, a race is organised every 2 years on the occasion of the cultural festival "Ngouon" (Fig. 13a) of the Bamoun people, natives of the region. This kind of initiative is to be encouraged because it allows the promotion of this site. By the same token, the organisation of geopromenades (Fig. 13b), conferences and exhibitions to promote the geomorphosites of the Mbepit massif is highly recommended.

Impacts of Geotourism

The geological sites of the Mbepit massif can generate direct economic income thanks to services such as transport, catering or paid visits to the site. Investment into the manufacturing of commercial ski lifts would contribute to

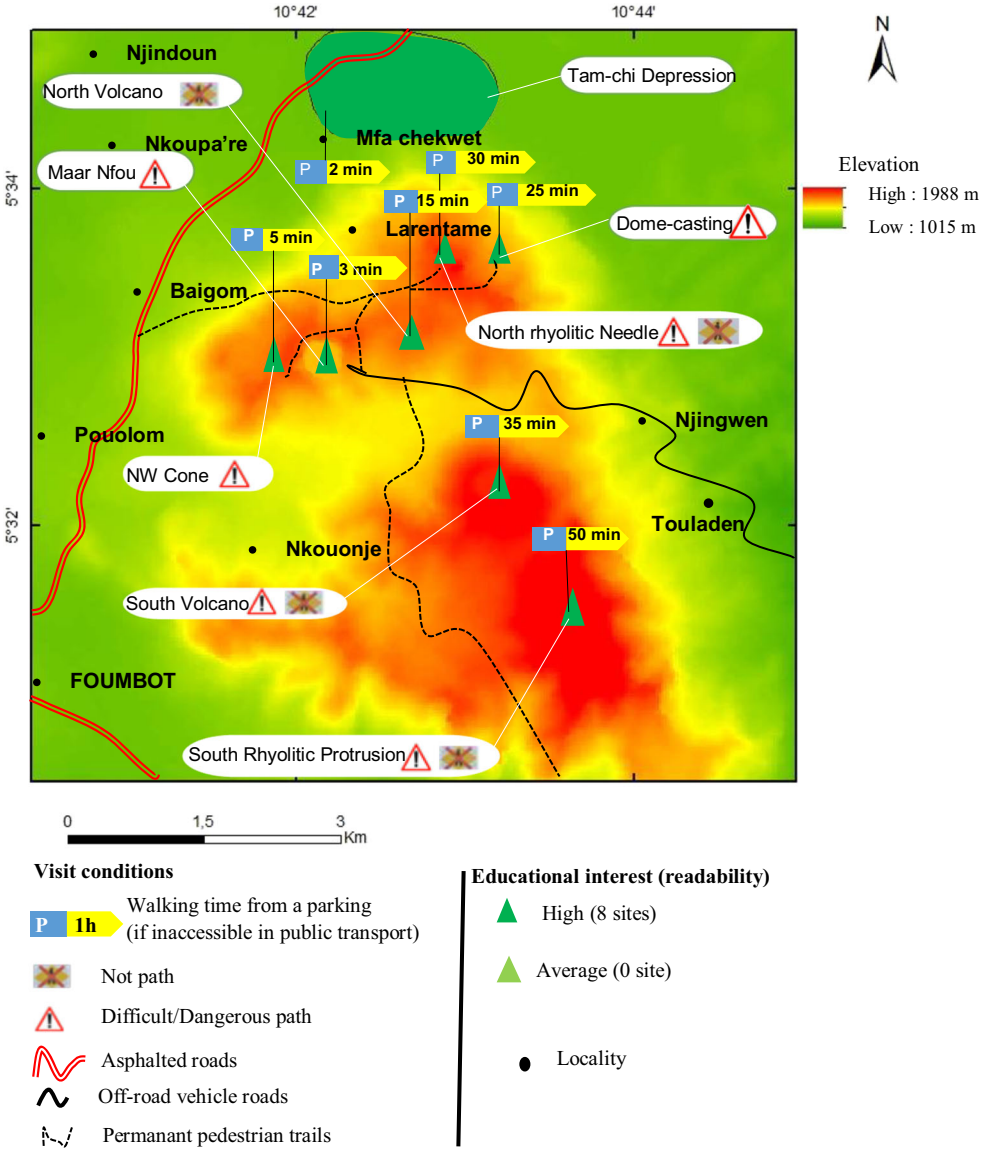

Fig. 12 Synthetic map of the highlights of the visit conditions and educational interest of Mbepit Massif geomorphosites

Fig. 13 Event to promote the Massif Mbepit's geomorphosite (**a** Mount Mbepit race organised on the occasion of the local cultural festival "Ngouon "; **b** geopromenade with students at the top of Maar Nfou)

the economic benefits. Geotourism offers can also create significant economic added value by exploiting the appropriate geological potential (Megerle and Schrembs 2009).

Similarly, geotourism includes local communities in planning, development and exploitation, thereby contributing to their well-being. It also ensures the protection of the areas through the management of tourist flows, the knowledge of the resource through research, the education of tourists or inhabitants, the participation of the local population through the training of guides, and the perpetuation of the product by putting in place effective conservation (Cayla 2009).

Final Considerations

The Mbepit Massif is dominated by geomorphosites that are mostly of volcanic origin. These are domes, volcanic cones, lava flows, a maar and a depression, all characterised by relatively high scientific and additional values. These geomorphosites are therefore a natural heritage that deserves to be valued through tourism. The current use of the natural and tourist attractions of the Mbepit Massif is less than the associated potential. The main goal of geotourism in this case is to raise awareness of the interesting aspects of Mbepit Massif and to attract as many tourists as possible to the region. In combination with geodidactic offers to raise visitors' awareness of the value of geomorphosites, geotourism on the Mbepit massif can also contribute to improving the protection of identified geomorphosites. Geo-morphological landscapes and regions with special geological features are becoming increasingly recognised as critical areas to protect and conserve for the unique geoscientific aspects they represent and as places to enjoy and learn about the science and history of our planet. Geotourism and geoeducation are key tools to be used to ensure the protection of the Mbepit Massif landforms through geoconservation. Nature conservation policies implemented in Cameroon are focused on biodiversity conservation concerns (Zangmo Tefogoum et al. 2017). These policies rely on the Law no. 96/12 of 5 August 1996 relating to environmental management. As a result, in Cameroon, geomorphosites do not benefit from legal protection. Since geomorphosites are the basis of a successful geotourism, it is important that they are preserved and protected through legal legislation by the competent authorities.

The development of geological sites establishes a way of valuing them. Currently, a lot of importance is placed on the preservation of the environment. Therefore, the infrastructures that can be set up as part of geotourism in the Mbepit Massif must be adapted to the observation of places without degrading them.

The assessment of geoheritage assets, values and benefits within a cultural ecosystem service framework can enable a more holistic approach to geotourism, recognising the connections between people, geoheritage and the landscape (Gordon 2018).

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References

Adams AN, Wiens DA, Nyblade AA, Euler GG, Shore PJ, Tibi R (2015) Lithospheric instability and the source of the Cameroon volcanic line: evidence from Rayleigh wave phase velocity tomography. J Geophys Res 120:1708–1727

Alexandrowicz Z, Kozlowski S (1999) From selected geosites to geodiversity conservation—Polish example of modern framework.

In: Barettino D, Vallejo M, Gallego E (eds) Towards the balanced management and conservation of the geological heritage in the new millennium. Sociedad Geológica de España, Madrid, pp 40–44

Black GP, Gonggrijp GP (1990) Fundamental thoughts on earth-science conservation. Jb Geol B-A Band 133(Heft 4):655–657

Bollati I, Smiraglia C, Pelfini M (2013) Assessment and selection of geomorphosites and itineraries in the Miage glacier area (Western Italian Alps). Environ Manag 51(4):951–967

Boukhallad M, El Khalki Y (2014) Méthodes d'évaluation des géomorphosites: critiques et propositions. International Workshop Geomorphosites, lever of local socio-economic development: from European experiences to Maghrebian and African projects, 1-3 2014. Abstract, Beni Mellal, p 19

Brilha J (2018) Geoheritage: inventories and evaluation. In: Reynard E, Brilha J (eds) Geoheritage. Elsevier, Chennai, pp 67–86

Bruschi VM, Cendrero A (2005) Geosite evaluation. Can we measure intangible values? Il Quaternario 18(1):293–306

Bruschi VM, Cendrero A (2009) Direct and parametric methods for the assessment of geosites and geomorphosites. In: Reynard E, Coratza P, Regolini-Bissig G (eds) Geomorphosites. Verlag Dr. Friedrich Pfeil, München. Section II, pp 73–88

Bruschi VM, Cendrero A, Albertos JAC (2011) A statistical approach to the validation and optimisation of geoheritage assessment procedures. Geoheritage 3(3):131–149

Bussard J (2014) Protection et valorisation du patrimoine géomorphologique du Parc naturel régional Gruyère Pays-d'Enhaut États des lieux et perspectives. Mémoire de Master, Université deLausanne

Cayla N (2009) Le patrimoine géologique de l'arc alpin : De la médiation scientifique à la valorisation géotouristique. Thèse de l'Université de Savoie (en ligne), http://tel.archivesouvertes.fr/docs/00/45/96/58/.pdf

Cendrero A (1996a) El patrimonio geológico. Ideas para su protección, conservación y utilización. In: El patrimonio geológico. Bases para su valoración, protección, conservación y utilización. Serie Monografías del Ministerio de Obras Públicas, Transportes y Medio Ambiente. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid, pp 17–27

Cendrero A. (1996b) Propuestas sobre criterios para la clasificación y catalogación del patrimonio geológico. In: El patrimonio geológico. Bases para su valoración, protección, conservación y utilización. Serie Monografías del Ministerio de Obras Públicas, Transportes y Medio Ambiente. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid, pp 29–38

Coratza P, Giusti C (2005) Methodological proposal for the assessment of scientific quality of geomorphosites. II Quaternario. Italien J Quat Sci 18(1):307–313

Coratza P, Galve JP, SoldatiM TC (2012) Recognition and assessment of sinkholes as geosites: lessons from the Island of Gozo (Malta). Quaestiones Geograph 31(1):25–35

De Plaen RSM, Bastow ID, Chambers EL, Keir D, Gallacher RJ, Keane J (2014) The development of magmatism along the Cameroon volcanic line: evidence from seismicity and seismic anisotropy. J Geophys Res 119:4233–4252. https://doi.org/10.1002/2013JB010583

Déruelle B, Gounouno I, Demaiffe D (2007) The "Cameroon hot line" (CHL): a unique example of active alkaline intraplate structure in both oceanic and continental lithospheres. C R Geosci 339-9:589–600

Díaz-Martínez E, Díez-Herrero A (2011) Los elementos biológicos y culturales de interés geológico: un patrimonio a conservar. In Fernández-Martínez E, Castaño de Luis R (eds) Avances y retos en la conservación del Patrimonio Geológico en España. Actas de la IX Reunión Nacional de la Comisión de Patrimonio Geológico (Sociedad Geológica de España), Universidad de León, pp 85–90

Duhem V (2008) Inventaire et proposition de mesures de valorisation des géomorphosites du PNR Gruyère - Pays-d'Enhaut (Mémoire de Master). Université de Lausanne, Lausanne

Elízaga E, Gallego E, García-Cortés A (1994) Inventaire nacional des sites d'intérêt géologique en Espagne:méthodologie et déroulement. Mém Soc Geol France 165:103–109

Erhartic B (2010) Geomorphosite assessment. Acta Geogr Slov 50(2):295–319

Fassoulas C, Mouriki D, Dimitriou-Nikolakis P, Iliopoulos G (2012) Quantitative assessment of geotopes as an effective tool for geoheritage management. Geoheritage 4(3):177–193

Fitton JG, Dunlop HM (1985) The Cameroon line. West Africa and its bearing on the origin of oceanic and continental alkalic basalt. Earth Planet Sci Lett 72:23–38

Fourel L, Milelli L, Jaupart C, Limare A (2013) Generation of continental rifts, basins, and swells by lithosphere instabilities. J Geophys Res Solid Earth 118:3080–3100. https://doi.org/10.1002/jgrb.50218

Fuertes-Gutiérrez I, Fernández-Martínez E (2012) Mapping geosites for geoheritage management: methodological proposal for the Regional Park of Picos de Europa (León, Spain). Environ Manag 50:789–806

Garcia MG, Brilha J, Lima FL, Vargas JC, Aguilar AP, Alves A et al (2017) The inventory of geological heritage of the State of Sa˜o Paulo, Brazil: methodological basis, results and perspectives. Geoheritage. 10:239–258. https://doi.org/10.1007/s12371-016-0215-y

García-Cortés A, Carcavilla Urquí L (2009) Documento metodológico para la elaboración del inventario español de lugares de interés geológico (IELIG), version 12. Instituto Geológico y Minero de, España, Madrid

Genoud M (2008) Inventaire, évaluation et projets de valorisation des géomorphosites du Val de Bagnes (Mémoire de Master). Université de Lausanne, Lausanne

Ginting N, Sasmita A (2018) Developing tourism facilities based on geotourism in Silalahi Village, Geopark Toba Caldera. IOP Conf Ser: Earth Environ Sci 126:012163

Gordon JE (2018) Geotourism and the cultural landscape: enhancing the visitor experience and promoting geoconservation. Geosciences 8:136

Grandgirard V (1995) Méthode pour la réalisation d'un inventaire de géotopes géomorphologiques. Ukpik, Cahiers de l'Institut de Géographie, Fribourg 10:121–137

Grandgirard V (1999) Switzerland—the inventory of geotopes of national significance. In: Barettino D, Vallejo M, Gallego E (eds) Towards the balanced management and conservation of the geological heritage in the new millenium. Spain, Sociedad Geológica de España, Madrid, pp 234–236

Gray JM (2008) Geodiversity: developing the paradigma. Proc Geol Assoc 119:287–298

Gray JM (2013) Geodiversity: valuing and conserving abiotic nature, 2nd edn. Wiley, Chichester

Halliday AN, Dickin AP, Fallick AE, Fitton JG (1988) Mantle dynamics: a Nd, Sr, Pb and O isotopic study of the Cameroon line volcanic chain. J Petrol 29:181–211

JNCC Joint Nature Conservation Committee (1977) Guidelines for selection of Earth Science SSSIs. Available from:,http://jncc.defra.gov.uk/page-2317. (accessed 12.08.17)

Kozlik L, Reynard E (2013) Inventaire et valorisation des géomorphosites culturels des vallées du Trient, de l'Eau Noire et de la Salanfe. In: Hoblé a F, Cayla N, Reynard E (eds) Gestion des géosites dans les espaces protégés. Collection EDYTEM, Chambéry, pp 135–142

Lapo AV, Davydov VI, Pashkevich NG, Petrov VV, Vdovets MS (1993) Methodic principles of study of geological monuments of nature in Russia. Stratigr Geol Correl 1(6):636–644

Lee DC, Halliday AN, Fitton JG, Poli G (1994) Isotopic variation with distance and time in the volcanic islands of the Cameroon line,

evidence from mantle plume origin. Earth Planet Sci Lett 124:119–138

Leung Y-F, Spenceley A, Hvenegaard G, Buckley R (2018) Tourism and visitor management in protected areas: guidelines for sustainability; best practice protected area guidelines series no. 27. IUCN, Gland

Lima FF, Brilha JB, Salamuni E (2010) Inventorying geological heritage in large territories: a methodological proposal applied to Brazil. Geoheritage 2(3–4):91–99

Maillard B, Reynard E (2011) Inventaire des géomorphosites des vallées d'Entremont et de Ferret (Valais) et propositions de valorisation In Lambiel C, Reynard E et Scapozza C (Eds). La géomorphologie alpine: entre patrimoine et contrainte. Actes du colloque de la Société Suisse de Géomorphologie, 3–5 septembre 2009, Olivone (Géovisions n° 36). Institut de géographie, Université de Lausanne. pp 1–17

Mass MO, Morissette A, Hétu B, Tita G, Vigneault B (2011) Inventaire du patrimoine géomorphologique de l'archipel des Iles-de-la-Madeleine et identification des stratégies de valorisation géotouristique. Centre de recherche sur les milieux insulaires et maritimes (CERMIM), Iles-de-la-Madeleine (Québec)

Megerle H, Schrembs R (2009) Ökonomische Effekte in den europäischen Nationalen Naturlandschaften – Beiträge der Geoparke und des Geotourismus für eine nachhaltige Regionalentwicklung. In Thüringer Ministerium für Landwirtschaft, Naturschutz und Umwelt (ed.). Weltnaturerbe Buchenwälder, Saalfeld, 247–257

Meyers J, Rosendahl B, Harrisson C, Zan Doug D (1998) Deep imaging seismic and gravity result from the offshore Cameroon volcanic line, and speculation of African hot lines. Tectonophysics 284:32–63

Migon P, Pijet-Migon E (2016) Overlooked geomorphological component of volcanic geoheritage-diversity and perspectives for tourism industry, Pogrze Kaczawskie region, SW Poland. Geoheritage 8(4): 333–350

Milelli L, Fourel L, Jaupart C (2012) A lithospheric instability origin for the Cameroon volcanic line. Earth Planet Sci Lett 335–336:80–87

Moreau C, Regnoult J, Derruelle B, Robineau B (1987) A new tectonic model for the Cameroon line, Central Africa. Tectonophysics 139: 318–334

Moundi A (1993) Le massif du Mbam (pays Bamoun, Ouest-Cameroun) : Volcanologie, Pétrologie et Géochimie. Thèse Doct. 3e cycle Univ, Yaoundé I PP 108–116

Moundi A, Menard J, Reusser E, Tchoua F, Dietrich V (1996) Découverte de basaltes transitionnels dans le secteur continental de la ligne du Cameroun (Massif du Mbam, Ouest Cameroun). C.R. Acad. Sci. Paris, t. 332, série II a, PP 831–837

Moundi A, Wandji P, Bardintzeff J-M, Ménard JJ, Okomo Atouba LC, Mouncherou OF, Reusser E, Bellon H, Tchoua FM (2007) Les basaltes éocènes à affinité transitionnelle du plateau Bamoun, témoins d'un réservoir mantellique enrichi sous la Ligne Volcanique du Cameroun. C R Geosci 339:396–406

Mucivuna VC, Reynard E, Garcia MGM (2019) Geomorphosites assessment methods: comparative analysis and typology. Geoheritage 11: 1799–1815. https://doi.org/10.1007/s12371-019-00394-x

Németh K, Casadevall T, Moufti MR, Marti J (2017) Volcanic Geoheritage. Geoheritage 9:251–254. https://doi.org/10.1007/s12371-017-0257-9

Ngako V, Njonfang E, Aka FT, Affaton P, Nnange JM (2006) The north–south Paleozoic to Quaternary trend of alkaline magmatism from Niger–Nigeria to Cameroon: complex interaction between hotspots and Precambrian faults. J Afr Earth Sci 45:241–256

Ólafsdóttir R (2019) Geotourism. Geosciences 9:48. https://doi.org/10.3390/geosciences9010048

Pagano L (2008) Inventaire des géotopes géomorphologiques du Val Bavona et du Val Rovana. Sélection, evaluation et perspectives. Master's thesis, University of Lausanne http://mesoscaphe.unil.ch/igul/memoires

Panizza M (2001) Geomorphosites: concepts, methods and example of geomorphological survey. Chin Sci Bull 46(Suppl. Bd):4–6

Panizza M (2003) Géomorphologie et tourisme dans un paysage culturel intégré. In Reynard E, Holzmann C, Guex D, et Summermatter N (Eds), Géomorphologie et tourisme. Actes de la Réunion annuelle de la Société Suisse de Géomorphologie (SSGm), Finhaut, 21–23 septembre 2001, Travaux et recherches n°24 (pp. 11–18). Lausanne : Université, Institut de géographie

Panizza M, Piacente S (1993) Geomorphological assets evaluation. Z Geomorph Suppl Bd 87:13–18

Panizza M, Piacente S (2003) Geomorfologia culturale. Pitagora Editrice, Bologna 350 pp

Parkes MA, Morris JH (1999) The Irish Geological Heritage Programme. In: Barettino D, Vallejo M, Gallego E (eds) Towards the balanced management and conservation of the geological heritage in the new millenium. Spain, Sociedad Geológica de España, Madrid, pp 60–64

Pena dos Reis R, Henriques MH (2009) Approaching an integrated qualification and evaluation system for geological heritage. Geoheritage 1:1–10

Pereira P, Pereira DI (2010) Methodological guidelines for geomorphosite assessment. Géomorphol Relief Processus Environ 2:215–222

Pereira P, Pereira DI (2012) Assessment of geosites tourism value in geoparks: the example of Arouca Geopark (Portugal). Proceedings of the 11th European Geoparks Conference, Arouca: 231–232

Pereira P, Pereira DI, Alves MIC (2007) Geomorphosite assessment in Montesinho Natural Park (Portugal). Geogr Helv 62:159–168

Pérez-Umaña D, Quesada-Román A, Zangmo Tefogoum G (2019) Geomorphological heritage inventory of Irazú volcano, Costa Rica. Int J Geoheritage Parks 8:31–47. https://doi.org/10.1016/j.ijgeop.2019.12.001

Perret A (2008) Inventaire de géomorphosites du Parc Jurassien vaudois. Essai d'intégration des géotopes spéléologiques et valorisation géomorphologique des réserves naturelles. Master'sthesis, University of Lausanne http://mesoscaphe.unil.ch/igul/memoires/bd/

Perret A, Reynard E (2011) Inventaire des géomorphosites du Parc jurassien vaudois (Col du Marchairuz, Vaud). In: Lambiel C, Reynard E, Scapozza C (eds) La géomorphologie alpine: entre patrimoine et contrainte. Institut de Géographie, Lausanne (Géovisions 36), pp 19-34

Pralong JP, Reynard E (2005) A proposal for the classification of geomorphological sites depending on their tourist value. Quaternario 18(1):315–321

ProGEO (2011) Conserving our Shared Geoheritage – A Protocol on Geoconservation Principles, Sustainable Site Use, Management, Fieldwork, Fossil and Mineral Collecting. 10 pp. http://www.progeo.se/progeo-protocol-definitions-201109 15.pdf (accessed 2012)

ProGEO (2017) Geodiversity, geoheritage & geoconservation the ProGEO simple guide 6pp. www.facebook.com/progeo.geoheritage, January 2017

Prosser CD (2011) Principles and practice of Geoconservation: lessons and case law arising from a legal challenge to site-based conservation on an eroding coast in eastern England, UK

Rankenburg K, Lassiter JC, Brey G (2005) The role of continental crust and lithospheric mantle in the genesis of Cameroon volcanic line lavas: constraints from isotopic variations in lavas and megacrysts from the Biu and Jos Plateaux. J Petrol 46:169–190

Reusch AM, Nyblade AA, Wiens DA, Shore PJ, Ateba B, Tabod CT, Nnange JM (2010) Upper mantle structure beneath Cameroon from body wave tomography and the origin of the Cameroon volcanic line. Geochem Geophys Geosyst 11. https://doi.org/10.1029/2010GC003200

Reusch A, Nyblade A, Tibi R, Wiens D, Shore P, Bekoa A, Tabod C, Nnange J (2011) Mantle transition zone thickness beneath Cameroon: evidence for an upper mantle origin for the Cameroon volcanic line. Geophys J Int 18:1146–1150

Reynard E (2004) Géotopes, géomorphosites et paysages géomorphologiques. Institut de géographie, Travaux et Recherches N° 27, 123–136

Reynard E (2009) The assessment of geomorphosites. In: Reynard E, Coratza P, Regolini-Bissig G (eds) Geomorphosites. Verlag Dr. Friedrich Pfeil, Munchen, pp 63–71

Reynard E, Briha J (2018) Geoheritage: assessment, Protection and Management. Elsevier 450p

Reynard E, Coratza P (2013) Scientific research on geomorphosites. A review of the activities of the IAG working group on geomorphosites over the last twelve years. Geogr Fis Din Quat 3: 1–10

Reynard E, Fontana G, Kozlik L, Scapozza C (2007) A method for assessing "scientific" and "additional values" of geomorphosites. Geographica Helvetica Jg 62(Heft 3):148–158

Reynard E, Perret A, Bussard J, Grangier L, Martin S (2016) Integrated approach for the inventory and management of geomorphological heritage at the regional scale. Geoheritage 8:43–60

Rybar P (2010) Assessment of attractiveness (value) of geotouristic objects. Acta Geoturistica 2:13–21

Sellier D (2016) A deductive method for the selection of geomorphosites: application to Mont Ventoux (Provence, France). Geoheritage 8:15–29

Tchokona Seuwi D (2010) Volcanisme paléogène à récent du secteur du massif de Mbépit (plaine du Noun): pétrologie, minéralogie, géochimie isotopique, géochronologie et approche environnementale. Thèse de Doctorat /Ph.D, Université de Yaoundé I, 241 p

Tchoua MF (1972) Le massif volcanique du Mbapit (pays Bamoun). Ann Fac Sci Univ Yaoundé 9:45–71

Vujičić MD, Vasiljević DA, Marković SB, Hose TA, Lukić T, Hadzić O et al (2011) Preliminary geosite assessment model (GAM) and its application on Fruska Gora Mountain, potential geotourism destination of Serbia. Acta Geogr Slov 51(2):361–377

Wandji P (1995) Le volcanisme récent de la plaine du Noun (Ouest-Cameroun) : volcanologie, pétrologie, géochimie et pouzzolanicité. Thèse Doctorat d'État, Université de Yaoundé I, 259 p

Wandji P, Tchokona Seuwi D, Bardintzeff J-M, Bellon H, Platevoet B (2008) Rhyolites of the Mbepit Massif in the Cameroon volcanic line: an early extrusive volcanic episode of Eocene age. Mineral Petrol 94:271–286

White S, Mitchell M (2006) Geological heritage sites: a procedure and protocol for documentation and assessment. AESC2006, Melbourne, Australia, pp 2

Wimbledon WAP (2011) Geosites—a mechanism for protection, integrating national and international valuation of heritage sites. Geologia dell'Ambiente supplemento 2:13–25

Wimbledon WAP, Benton MJ, Bevins RE, Black GP, Bridgland DR, Cleal CJ et al (1995) The development of a methodology for the selection of British geological sites for geoconservation: part 1. Modern Geol 20:159–202

Wimbledon WAP, Andersen S, Cleal CJ, Cowie JW, Erikstad L, Gonggrijp GP et al (1999) Geological world heritage: GEOSITES _ a global comparative site inventory to enable prioritisation for conservation. Mem Descrit Carta Geol Ital 54:45–60

Yaseen M, Ghani M, Anjum MN, Sajid M, Jan IU, Mehmood M, Ullah E, Muzaffir W (2019) A novel approach to evaluate, highlight, and conserve the geologically significant geoheritage sites from the Peshawar Basin, Khyber Pakhtunkhwa, Pakistan: insights into their geoscientific, educational, and social importance. Geoheritage 11: 1461–1474. https://doi.org/10.1007/s12371-019-00390-1

Zangmo Tefogoum G, Kagou Dongmo A, Nkouathio DG, Wandji P, Gountié Dedzo M (2014) Geomorphological features of the Manengouba Volcano (Cameroon line): assets for potential geopark development. Geoheritage 6:225–239. https://doi.org/10.1007/s12371-014-0109-9

Zangmo Tefogoum G, Kagou Dongmo A, Nkouathio DG, Gountie Dedzo M, Kamgang P (2017) The volcanic geoheritage of the Mount Bamenda Calderas (Cameroon line): assessment for geotouristic and geoeducational purposes. Geoheritage 9(3):255–278. https://doi.org/10.1007/s12371-016-0177-0

Zangmo Tefogoum G, Nkouathio DG, Kagou Dongmo A, Gountie Dedzo M (2019) Typology of geotouristic assets along the south continental branch of the Cameroon volcanic line: case of the mount Bambouto's caldera. Int J Geoheritage Parks 7:111–128. https://doi.org/10.1016/j.ijgeop.2019.06.003

Zangmo Tefogoum G, Quesada-Román A, Pérez-Umaña D (2020) Geomorphosites inventory in Eboga Volcano, Cameroon: contribution for geotourism promotion. Géomorphologie (in press)

Ziem à Bidias LA, Moundi A, Takodjou Wambo JD (2017) Transitional basalts and eruptive dynamisms around Nkoumelap locality (west of the Bamoun Plateau, Cameroon volcanic line): petrography and volcanic risks' evaluation. J Geosci Geomat 5:65–77

Ziem à Bidias LA, Chazot G, Moundi A, Nonnotte P (2018) Extreme source heterogeneity and complex contamination patterns along the Cameroon volcanic line: new geochemical data from the Bamoun Plateau. C R Geosci 350:100–109

Zouros N (2007) Geomorphosite assessment and management in protected areas of Greece. Case study of the Lesvos Island-coastal geomorphosites. Geogr Helv 62(3):69–180