Geoconservation in Madagascar: Challenges and strategies

Lala Andrianaivo ([1]) & Voahanginirina J. Ramasiarinoro ([2])

([1]) University of Antananarivo, Ecole Supérieure Polytechnique, PO Box 1500, Antananarivo 101, Madagascar. E-mail: andrianaivo@univ-antananarivo.mg
([2]) University of Antananarivo, Faculty of Sciences, PO Box 906, Antananarivo 101, Madagascar. E-mail: ramasiarinoro@yahoo.fr

ABSTRACT

Present knowledge about Madagascar geoheritage is dispersed and incomplete. There is no database of the geosites representative of the geological frameworks. To resolve these problems, a working group from the University of Antananarivo is developing a project aimed at their classification and at establishing a conservation strategy for the most relevant geosites.

The adopted methodology and adequate strategies include: field works, geosites inventory and compilation of data sets; quantifying their value or relevance and their categorization; development of a classification system including international exchange classification; enhancement and dissemination of the geoheritage; definition of management structure; elaboration of geosites management plan and its conservation; establishing order defining responsible institution; and implementation into National Network of Protected Areas. The challenges are to: increase the protected areas for the geoconservation; reduce the natural resource degradation process; mainstream the geoenvironment into all sectoral plans and develop geoenvironmental effects.

Presently, most of the 90 geosites identified are not included in the conservation and management plans. We plan these spectacular landscapes, geological aesthetic beauty and geomorphological importance to be included in the new categories of protected area such as Protected Landscapes (IUCN category V), Natural Monuments (category III) and Natural Resource Reserves (category VI).

KEY WORDS: Geoconservation, geoheritage, geosites, protected area, Madagascar.

RESUME

La connaissance actuelle au sujet du patrimoine géologique de Madagascar est dispersée et incomplète. Il n'y a aucune base de données sur les géosites représentatifs étudiés. Pour résoudre ces problèmes, un groupe actif de l'Université d'Antananarivo développe un projet qui a pour but de faire une classification et d'établir une stratégie de conservation pour les géosites le plus pertinents.

La méthodologie adoptée et les stratégies adéquates incluent: travaux de terrain, inventaire des géosites et compilation de l'ensemble des données; quantification de leur valeur ou leur pertinence et leur catégorisation; développement d'un système de classification selon la nomenclature internationale; amélioration et dissémination du géopatrimoine; définition de la structure de gestion; élaboration de plan de gestion des géosites et de conservation; définition de l'institution responsable; et mise en œuvre dans le Réseau du National des Aires Protégées. Les défis sont de: augmenter le nombre des aires protégées concernant la géoconservation; réduire le processus de dégradation des ressources naturelles; sensibiliser et développer des reflexes géoenvironmentaux dans tous les plans sectoriels.

Actuellement, la plupart des 90 des géosites identifiés ne sont pas inclus dans les plans de conservation et de gestion. Ces paysages spectaculaires, leur beauté ou esthétique géologique et l'importance géomorphologique seront planifiés pour être inclus dans les nouvelles catégories d'Aires Protégées telles que Paysages Protégés (catégorie IUCN V), Monuments Naturels (catégorie III) et Réserve Naturelle Intégrale (catégorie VI).

MOTS CLES: Géoconservation, géopatrimoine, géosites, aires protégées, Madagascar.

1. INTRODUCTION

The island of Madagascar, the world's fourth-largest island, lying in south-west Indian Ocean, is famous for its richness in natural resource and natural heritage including geoheritage. The conservation and management of natural heritage are important issues in environmental and land planning policies. The integration of the geological heritage and its conservation strategies in these policies promote its valorization.

However, the Madagascar geological heritage was, until recently, poorly known because of the traditional concept of nature conservation focused mainly on biodiversity issues, and the lack of implementation of strategies for geoconservation. Present knowledge about Madagascar geological heritage is dispersed and incomplete justifying the urgent establishment of a geoconservation strategy by the geological community. For instance, a national geosites inventory has never been conducted using a systematic methodology by any institution with legal responsibility to accomplish this task. This is the main reason why a working group comprising researchers and geoscientists from the "Ecole Supérieure Polytechnique (ESPA)" of the University of Antananarivo is developing a project aimed at the identification, classification and conservation of the most relevant geosites.

2. METHODOLOGY

Data sets were compiled using the following methods:

- Compilation of data sets using published records of geological heritage sites (Petit, 1971; Wesley, 2010), geological maps and use of published or unpublished thesis (Battistini, 1964; Mottet, 1972; Ratsimanosika, 2012) ;
- Compilation of geological information from field guides and 1:100.000 geological maps and explanatory notes;
- Consultation of technical papers compiled in the unpublished list of Madagascar Geological Survey (Besairie & Collignon, 1971) and others scientific books (Pezzotta, 2002; MAP, 2007-2012);
- Identification of updated national parks available online (MNP, 2010-2013; UNESCO, 2010-2013);
- Identification and location of key sites on 1:100.000 scale topographic sheets (FTM, 2011), followed by our own field works.

3. GEOSITES INVENTORY AND STRATEGY FOR GEOCONSERVATION

Amongst the different outcomes expected for this project we emphasize the following:

- geosites inventory of the most important Madagascar geosites;
- scientific cooperation among geoscientists for the identification of geosites according to the methodology proposed by the International Union of Geological Sciences (IUGS);
- quantifying their value or relevance and their categorization;
- development of a classification system including international exchange classification (International Union for Conservation of Nature - IUCN, IUGS);
- an on-line database of the geosites representative of the Madagascar geological frameworks;
- enhancement and dissemination of the geoheritage;
- definition of management structure (foundation, etc.);
- elaboration of geosites management plan and its conservation (e.g. vulnerability assessment);
- establishing order defining responsible institution (Geological Survey, Ministries);
- legislative proposals focusing on geoconservation and
- implementation into National Network of Protected Areas.

The first aim of this geoconservation strategy requires the definition of the frameworks representing the most important geological features in Madagascar and covering the different types of geoheritage, e.g. geomorphological, petrological, paleontological, natural monuments, tectonic or stratigraphic heritage.

More than 90 frameworks were defined (Ratsimanosika, 2012), according to their scientific value, at both national and international levels, resulting from research including engineering thesis and from a discussion forum within the working group. The subsequent review revealed that an additional site required assessment. The scientific characterization of each framework must be completed with the identification of the most representative geosites, which are proposed by geoscientists with expertise in each geological context.

In the following, some examples of major thematic areas in Earth History will be described, that are of fundamental interest in the sciences of geology and geomorphology, and that can be considered of universal conservation value (Table 1).

This inventory aims to be the most complete and up-to-date information about the Madagascar geological heritage, including the list of the most relevant geosites for scientific, educational and tourism uses, and sorted according to their importance and need of conservation. This way may constitute the background for a national policy for geoconservation and for the acceptance of geoheritage issues in nature conservation and land-use strategies. It is also expected that this work will contribute to the enhancement of public awareness of geological heritage as an important natural resource with major strategic importance for the country.

4. PROTECTION AND CONSERVATION OF NATURAL HERITAGE

In 2003, the protected areas network covered about 3% (17,000 km²) of the surface of Madagascar's mainland (Figure 1). In addition, in December 2005, the first extra 10,000 km² of the new Protected Areas System of Madagascar were granted protection status. Presently, there are 47 protected areas with national relevance and managed by the Madagascar National Parks Association (MNP-ANGAP): 5 Strict Nature Reserves (IUCN category Ia), 21 National Parks (IUCN category II) and 21 Wildlife Reserves (IUCN category IV). Many other protected areas present interesting geological features but, in most cases, they are not included in the management plans or conservation projects. We plan these spectacular landscapes, geological aesthetic beauty and geomorphological importance of Madagascar's geological heritage to be included in the new categories of protected area such as Protected Landscapes (IUCN category V), Natural Monuments (IUCN category III) and Natural Resource Reserves (IUCN category VI) according to the "Durban Vision".

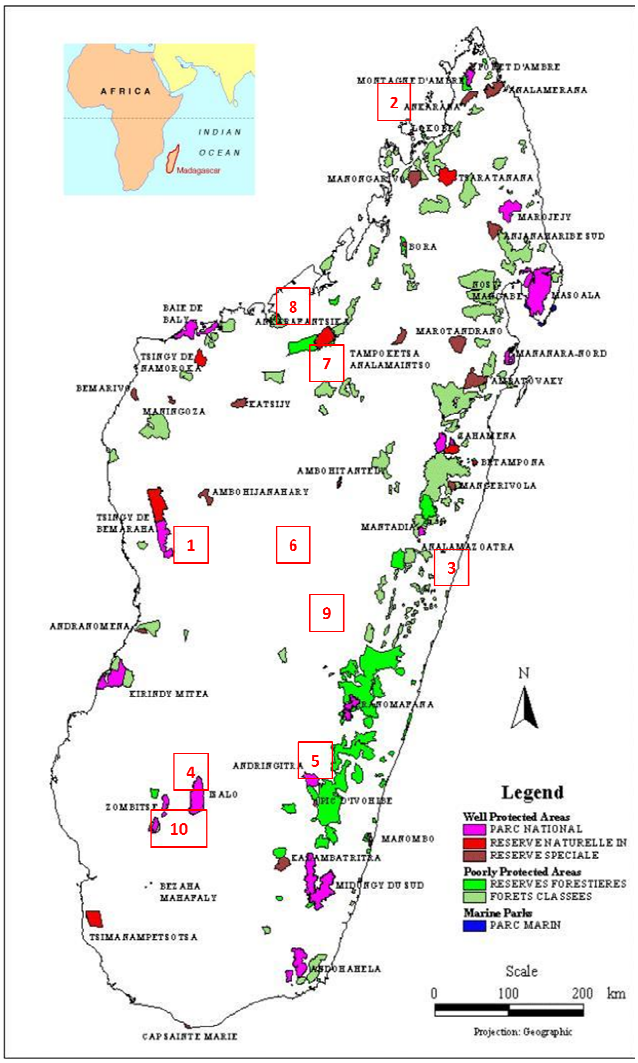

Figure 1 – Protected areas of Madagascar and location of the examples of sites with geoheritage significance in this study (numbered).

Some examples of the proposals of Madagascar to candidate in these new categories of protected area are summarized in Table 1.

Table 1: Examples of sites with geoheritage significance

Theme IUGS/UNESCO	[Site number]- Locality	Classification IUCN
Karst site	[1] "Tsingy de Bemaraha sud"	II, III, V
Oceanic islands – islets	[2] Archipelago of the Mitsio	Ib, IV, V
Coastal site	[3] "Canal des Pangalanes"	III, V
Stratigraphic sites	[4] Isalo ruin shaped mountain	II, III, V III, V
Mountain system	[5] "Cannelures et pic d'Andringitra"	II, III, V
Volcanic sites	[6] Itasy volcanic field	III, V
Weathering and erosional features	[7] Ankarafantsika "lavaka"	II, III
Fossil sites	[8] Berivotra dinosaurs site	III, VI
Other ungrouped sites	[9] Rice-growing and hydraulic cultural landscape of Betafo	V, VI
Other ungrouped sites	[10] Sapphire mine of the Ilakaka giant placer deposit	VI

4.1. SITES OF GEOHERITAGE SIGNIFICANCE: SOME EXAMPLES

Karst site: Tsingy de Bemaraha

This karst limestone formation is known as "tsingy" in Malagasy (Figure 2).

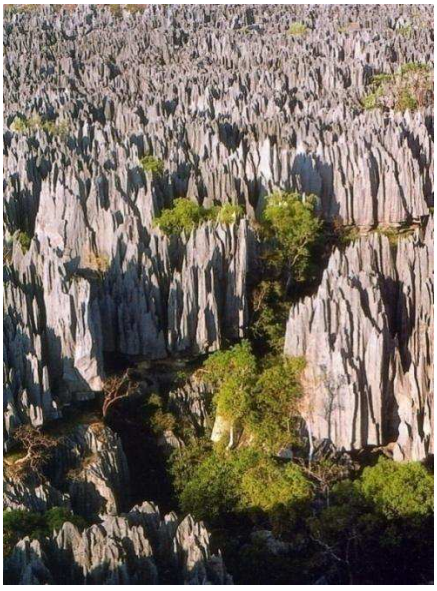

Figure 2 – Tsingy de Bamaraha

The site is an important teaching resource for unique geography, geology and zoology (the preserved mangrove forests, wild bird and lemur populations). It demonstrates weathering and erosional features and cave development which is extremely uncommon. It is an important tourist attraction of international relevance.

- Environmental and conservation note:
  The tsingy area is divided into two parts. The most significant karst system, in the northern part of the area, has significant protection under both Strict Nature Reserve (Réserve Naturelle Intégrale) and World Heritage Status. The southern part of the tsingy is protected within the Tsingy de Bemaraha National Park.

Archipelago of the Mitsio

The Archipelago consists of Tertiary phonolite, with associated basalt lava and fringing gravels and contains a variety of landscapes related to the development of volcanic structures (Figure 3).

Figure 3 – Archipelago of the Mitsio

- Environmental and conservation note:
  Because the Ankoay is one of the rare birds in the world, Protected Area status for this archipelago is not yet completed but ongoing. It is listed as one of the most beautiful natural sites to the UNESCO world heritage.

Giant sand dunes: Canal des Pangalanes

It is the highest coastal dune system located in the eastern part of in the island. This most significant dune system, of Quaternary age, is a key research and teaching site conveying geomorphological and climatological information (Figure 4).

- Environmental and conservation note:

This area is potentially very important, and should be protected from disturbance. Dune system is particularly susceptible to many forms of degradation and development of the site. So, use of vehicles within the dune system and degradation of vegetation cover are the most significant problems anticipated.

Figure 4 – Giant sand dunes of the *Canal des Pangalanes*.

Stratigraphic sites: Isalo ruin shaped mountain

Continental sandstones of early Triassic age representing the last formation of the Malagasy Karoo. Basically, the landscape displays three distinctive morphological landforms: ruin shaped mass (Figure 5), isolated tabular mountains, sandy domes.

Figure 5 – Isalo ruin shaped mountain.

- Environmental and conservation note:
  The western border and the vicinity of the area should be protected from illegal sapphire mining. The eastern part of the area is protected within Isalo National park.

Andringitra "cannelures" and surroundings

The mountain chain consists of syenite and granite. It is known for its rough terrain, as well as deep valleys and ridges (Figure 6). The landscape is more fantastic and particular because of the density and the astonishing development of "cannelures" (French word for "flutings"). The site is a significant and useful teaching resource.

- Environmental and conservation note:
  The site and surroundings are robust, undergoing natural weathering. It should require no further action. Site and the vicinity have adequate protection within Andringitra National park.

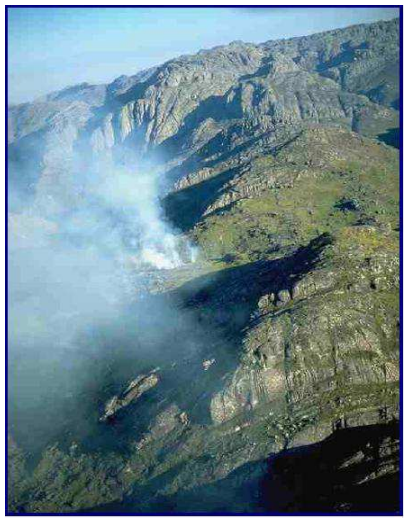

Figure 6 – Andringitra *cannelures*.

Itasy volcanic site

The main volcanic features are trachyte domes of Pleistocene age and basanitic scoria cones. The site is a prominent local landmark and represents the development of the modern landscape (Figure 7). It is an important teaching site and a popular tourist destination. Deep soils developed on basalt are important for agricultural and socio-historical development of the area.

Figure 7 – Kassigie volcano landscape.

- Environmental and conservation note:
  The regional integrity is affected by agricultural activities. The area seems robust and, apart for major quarrying, requires no further protection. However, recent studies indicate the evidence of neotectonism in this volcanic field (Andrianaivo and Ramasiarinoro, 2011; Hartnady et al., 2009). Additional research needs to be undertaken; and comprehensive risk assessment for both present day active faults, volcanic- and earthquake-related hazard on this site requires coordinated approach using modern seismotectonic method.

Weathering and erosional features: "lavaka"

Lavaka (Malagasy word for ‘‘hole’’) are large hillslope gullies that form in the deeply-lateritized and saprolitic basement rocks mainly in the high plateau central of Madagascar. Lavaka differ from the more conventional types of gullies by their shape and enormous size they are able to obtain (Figure 8). The Ankarafantsika site demonstrates lateritic profile development within sandstones, and clay and is a significant teaching site for geological and geomorphological processes. The site is an important tourist attraction.

Figure 8 – Lavaka in the Ankarafantsika National Park

- Environmental and conservation note:
  The locality is confined and protected by Ankarafantsika National Park. Further protection from development seems no need; but if any increasing erosional process will appear, this would require reassessment and should be closely monitored.

Fossil site: Dinosaurs of Berivotra

It is a type of locality for a large number of fossils including dinosaurs and crocodiles (Figure 9). These dinosaurs and all of the backboned animals that lived at the same time near the end of the Cretaceous Period are now extinct. According to the paleontologists from Stony Brook University in the United States, in collaboration with the researchers from the University of Antananarivo in Madagascar, the area of Berivotra constitutes a part of an ongoing large-scale research project. The site is subject to spasmodic collection to amateurs and professionals, and still yields high grade material.

Figure 9 – Expedition field area of Berivotra

.The site is located within the *Route Nationale* 4. Any upgrade of the road should be accompanied by full collection and recovery of material. Further expansion or earthworks in the vicinity should be accompanied by a full paleontological investigation. Full collection and research needs to be undertaken on this site.

Rice-growing and hydraulic cultural landscape of Betafo

Betafo is famous for its terraced rice paddy fields (a gentle amphitheatre shape). This artisanal irrigation network includes all activities aimed at expanding and developing water resources efficiently and effectively in particular to support the development of agriculture (Figure 10). The site has an important value for the historical and socio-cultural development of the local people.

Figure 10 – Spectacular terraced rice paddy field of Betafo.

- Environmental and conservation note:
  The site has protection as a result of its use as agricultural area (rice field) and its proximity to the Betafo River and the town centre. It is listed as one of the UNESCO world heritage site (submitted as tentative site in 1997).

Sapphire mine of the giant Ilakaka placer deposit

The gem deposits (sapphire, ruby, alexandrite, topaz, tourmaline, garnet) occur within alluvial terraces (paleo-placers) along the *Route Nationale* 7 in south-west Madagascar and consist of reworked Triassic Isalo sandstones known as upper Karoo Malagasy (Figure 11).

Figure 11 – Sapphire mine of Ilakaka.

- Environmental and conservation note:
  Impacts of sapphire mining on Isalo National Park are surprisingly light, especially since this park's western border is adjacent to the limits of Ilakaka. Artisanal sapphire mining currently creates a number of environmental problems such as deforestation and sedimentation which generally disrupts water ecosystems. Advent of proposed quarrying expansion in the area should be closely monitored and controlled to retain any ecosystem and aesthetic value.

4.2. CHALLENGE AND STRATEGIES FOR GEOCONSERVATION

It is important to note that the "Tsingy de Bemaraha Strict Nature Reserve" in western Madagascar is a Geologic Treasure in the World Heritage Site System according to the World Heritage List of United Nations Educational, Scientific and Cultural Organization. This geosite comprises karstic landscapes and limestone uplands cut into impressive "tsingy" peaks and a "forest" of limestone needles, the spectacular canyon of the Manambolo River, rolling hills and high peaks.

In this project, an adequate strategy for geoconservation is supported by a methodology based on several stages. The challenges are to:

- Increase the protected areas for the geoconservation and geodiversity by
  - Inventorying and quantifying the value of geosites;
  - Establishing new site, marine and coastal protected areas;
  - Ensuring financial sustainability for the management of protected areas and the geodiversity;
  - Managing the protected areas and coastal geodiversity;
  - Valuing the geodiversity in a sustainable manner.
- Reduce the natural resource degradation process by
  - Enhancing and disseminating the geological heritage and monitoring of the geosites;
  - Developing and implementing sustainable use plans for geosites including lake, marine, and coastal areas;
  - Promoting private sector financing to assist in geoheritage management.
- Mainstream the geoenvironment into all sectoral plans and develop geoenvironmental reflex.
  - Contribute to the protection and conservation of sensitive zones through comprehensive environmental assessment.
  - Internalize the geoenvironmental stake into sectoral, regional, and communal policies.
  - Implement the Education Policy Relative to the Environment.

5. CONCLUDING REMARKS

The inventory of the Madagascar geosites is not yet complete. Its geological heritage is presently under study promoted by the ESPA - University of Antananarivo. In this project, until now, more than 90 geosites were identified, most of them with national and international scientific relevance. The geological frameworks were defined in this work and have been reconsidered and included in this approach.

Despite the lack of structured strategy for geoconservation and monitoring of geosites, this flaw is being taken care of by an ongoing research project.

In order to increase the protected areas for geoconservation and to reduce the natural resource degradation process, the following suggestions are highly solicited:

• As the conservation of geosites in Madagascar is not gaining strength and knowing that this flaw is more difficult to resolve because it is entirely dependent on political decisions, this protection of the geodiversity needs legal mechanisms in place and collaborative work between experts from different institutions.

• Sufficient financial resources are needed to extent the protected areas and their management, with priority being given to the protection of the geodiversity.

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