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Geology and Palaeontology Protected for Sustainable Development: The Case of Makay Madagascar

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ABSTRACT

The 'New Protected Area (NPA) of Makay Madagascar contains many extraordinary geological sites to be inventoried on a territory of 400 000 hectares. The active cooperation between "specialist geologist - park manager - local population - volunteer", is an efficient strategy for the discovery of beautiful typical sites: paleontological, stratigraphical, tectonic, mineralogical, petrographical and geomorphological. Their geotopes can be used for cultural, educational, tourist, economic and heritage purposes. The protected geological heritage is valued and managed for the sustainable development of the surrounding territory of the Makay NAP.

Keywords: Makay - protection - valorisation - geosites - development

I. Introduction

The concept of geo-heritage, currently advanced in developed countries such as Europe, America and Asia, is recently known in Madagascar through the scientific articles of Randrianaly et al (2015, 2016) and Raveloson et al (2018). However, the knowledge of Madagascar is a country of biodiversity conservation due to its high endemicity. The Madagascar National Park works on the management and protection of the majority of protected areas for Malagasy fauna and flora.

The New Protected Area of Makay is a park located in one of the extraordinary geological formations of the Upper Triassic and Continental Jurassic of the central Morondava Basin (Besairie, 1972). It has been particularly managed by the Association NaturEvolutuin Madagascar, co-managed with the association NaturEvolution France since its creation in 2017 First New Protected Area of Madagascar "called mixed" (natural and cultural) because Makay has been registered on the register of the cultural sites of the national heritage (decree No. 16593/2017 of 11 July 2017). It contains local and national endemic fauna and flora, already the subject of inventories and studies by national and foreign biologists (Lourenço & Wilmé, 2015; Rakotondramasy & Goodman, 2011; Roubaud et al, 2018). While geological sites remained unconsidered, they admit much greater potential associated with their biodiversity.

The last known scientific geological work in the Makay was carried out by Razafimbelo in 1987. And the successive missions of the Naturevolution Association are mainly concerned with the realization of films in 2017 to attract amateurs and explore places of interest for mountaineers for sport purposes.

The aim of this article is to propose the elaboration of pre-inventory projects followed by inventories and evaluations of geosites; leading the Makay towards international geological heritage status and used as tools for sustainable development. In support of this goal, this paper will show: the richness and beauty of geodiversity, the special features and the great potential in the sedimentary formations of the New Makay Protected Area.

II. Materials and methods

II-1-Geographic location and geological survey

Makay Park is located in the southwestern region of Madagascar (Fig1) with an area of 400,000 hectares in the districts of Beroroha and Mahabo. It is located between 20°30'South - 21°60'South (latitude) and 45°00'East - 45°70'East (longitude). Geologically, it is included in the Isalo II sedimentary formations (Besairie, 1972) of which Razafimbelo in 1987 gave the name "Makay Formation" for the continental deposits of terminal Triassic and lower Jurassic age in the centre of the Morondava Basin.

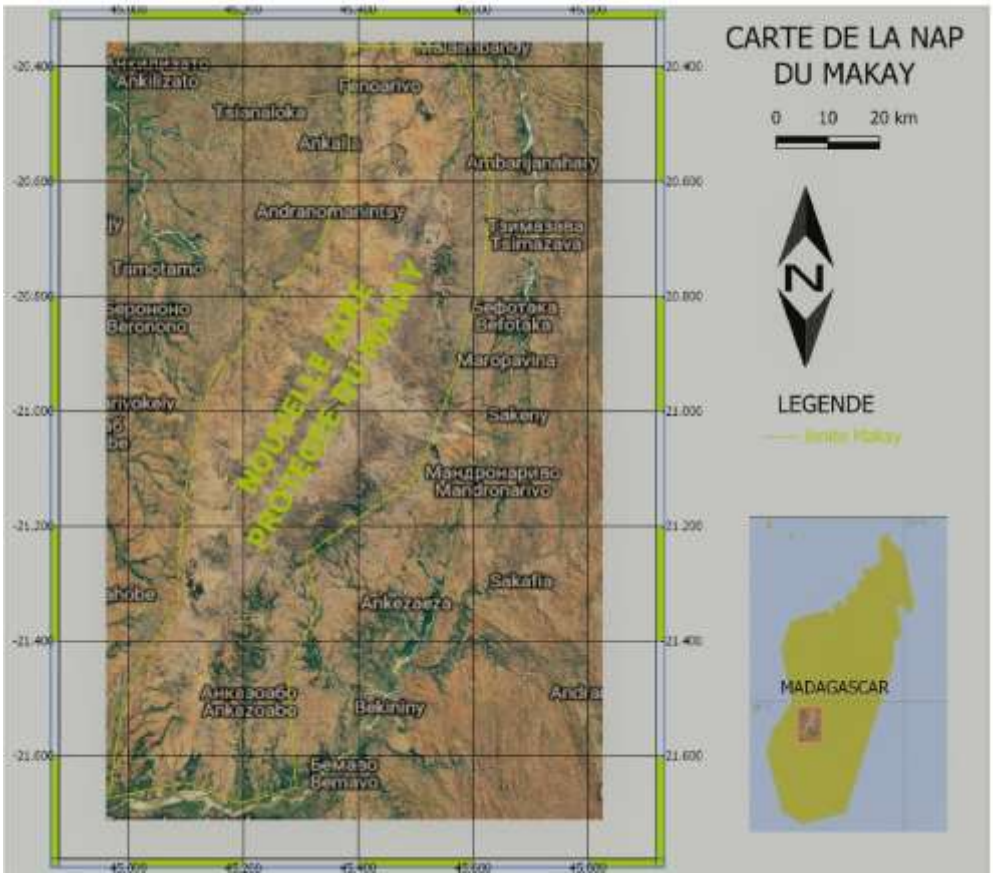

Figure 1: Location map of the New Makay Protected Area and surrounding villages, source: google map 2021

II-2-Procedures

Documentary consultation is an essential step in the development of scientific work. The knowledge of the elements useful in the elaboration of the field research has been previously researched bibliographically in the literature of the field of geo-heritage and geo-conservation. In addition, fieldwork is mandatory for all geological research. Two scientific expeditions were carried out in 2019 in collaboration with the association Naturevolution, manager of the NAP Makay. About 30 volunteers were taught and trained in situ on the recognition of geological objects and sites. As a result, they are able to assist us in carrying out surveys and in discovering the various geosites to be categorised in the park. The local trackers also play an important role, they provide the field knowledge to plan the strategies to get the best results and to avoid risks or accidents. The quadripartite cooperation between scientist - park - volunteers - local people is very effective with the active participation of each stakeholder.

III. Results

III-1-Lithology

A stratigraphic section taken at Sakapaly (Fig2) shows the detailed lithological features of the northern Makay, confirming the observation of Razafimbelo in 1987. The divisions comprising three fundamental units are shown:

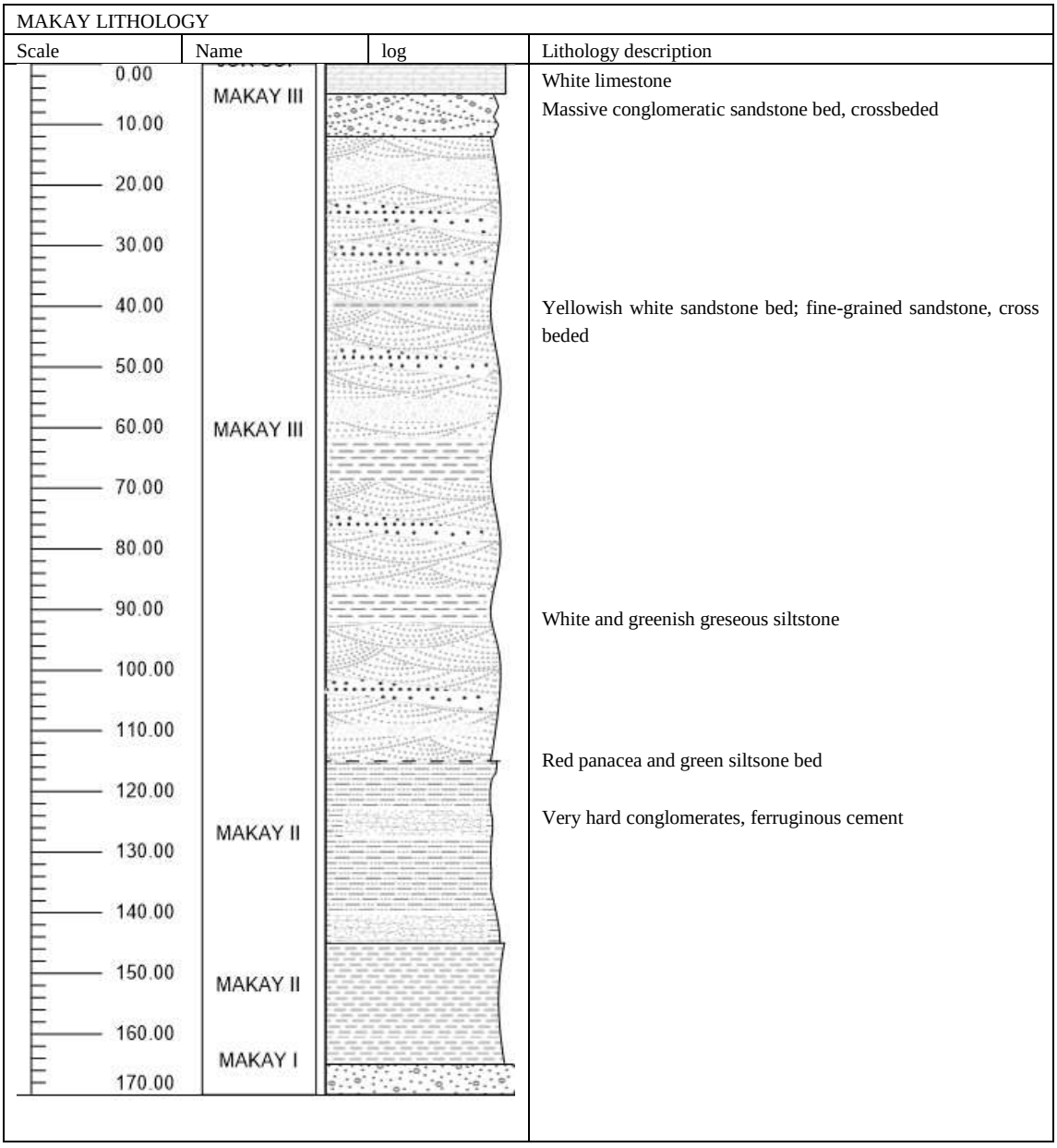

Figure 2: Stratigraphic section taken at Sakapaly showing the detailed lithological features of the northern Makay

Makay I: A basal conglomeratic part: It forms a continuous unit with a musty, bare appearance and a general western dip. It stands out in the landscape by its characteristic reddish-brown colour. It is formed of massive coarse sandstones within which irregularly distributed polygenic conglomerates can be observed. The oblique to intersecting stratification is well marked.

Makay II: A siltstone-sandstones-limestone complex: It is characterised by the grey-black colour of the red or green variegated siltstone, and the alternation of metric bed of fine grained, medium or coarse sandstones. The sandstones above become finer and the siltstone bed more frequent with the appearance of small banks of dolomitic or nodular limestone.

Makay III: sandstone part with silty clay lens: It is characterised by a series of massive coarse sandstones. The oblique to criss-cross stratification is characterised by the concentration of microconglomerates and by quartz pebbles disseminated in the sandstone mass. It ends with coarse salmon-red sandstones with fairly homogeneous angular grains.

In the Makay NPA, geological sites showing several very remarkable sedimentary formations, figures and structures (Fig3) are noted.

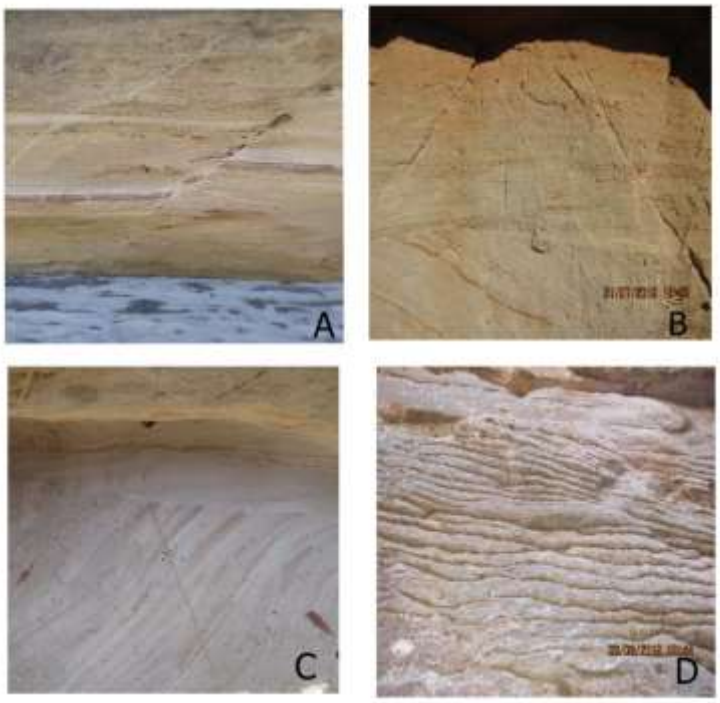

Figure 3: Photos showing sites including geological objects of stratigraphic interest in the Makay NPA

III-2-Paleontology

The southern Makay contains palaeontological sites rich in well-preserved wood fossils. These paleontological objects are very abundant at the entrance to Beronono, Tsivoko and especially in the Menampandaha valley. The fossil wood in Makay is represented in the state of epigenia of black carbonaceous wood and beige silicified wood (Fig4). Prospecting along the Menampandaha canyon has located about 40 fossil wood recording points

Figure 4: Fossil wood samples found along the Menampandaha canyon; South Makay; Paleontological objects

III-3-Geomorphology

III-3-1-Makay Massif

The Makay NPA is one of the most monumental works of nature (Fig5). The plateaus form a geological jewel, a veritable mineral fortress in the shape of a giant cerebellum, composed of loosely packed rocks that disintegrate easily. They are arid and covered by centimetric pebbles. The base of the Makay Formation is characterised by conglomerates that rest directly on the Sakamena formations. These conglomerates outcrop in the western region of Sakoazato, along the tracks to the park in the northern region. It is found in the south in the area north of the Mangoky. It represents the beginning of another cycle of sedimentation forming an unconformity with the end of the Sakamena Group cycle.

Figure 5: Photos showing the different geomorphological aspects of the Makay massifs and their erosions

The Makay is a sandstone massif north of the Mangoky River, dominating the depression where the Sakeny River flows to the east. In general, it forms a high, ruinous, desert-like ledge with difficult access, reminiscent of the Isalo massif in every respect. Two different aspects are observed in the western part of the Makay: in the South, the rectilinear cornice with the face turned towards the West characterises the Jurassic; in the North, a cuesta with the face turned towards the East characterises the Middle Jurassic.

Exceptional miraculous geological features left by hydric erosion (Fig.6) and sandstone caves serving as habitat for local cave fauna or graves (Fig7) are very remarkably significant in the Makay Massif.

Figure 6: Miraculous exceptional geological feature shapes left by water erosion in the Makay NPA

Figure 7: Sandstone caves used as habitat for cave fauna or local graves in the Makay Massif

III-3-2-Valleys

The valleys of the Makay are recognized up to the depth of 170 m from the top of the plateaus. They appear distinctly in the landscape. In their upstream part, the valleys are narrow, deep and form real dry or wet canyons (Fig8) fed with water by the waterlogged porous rocks.

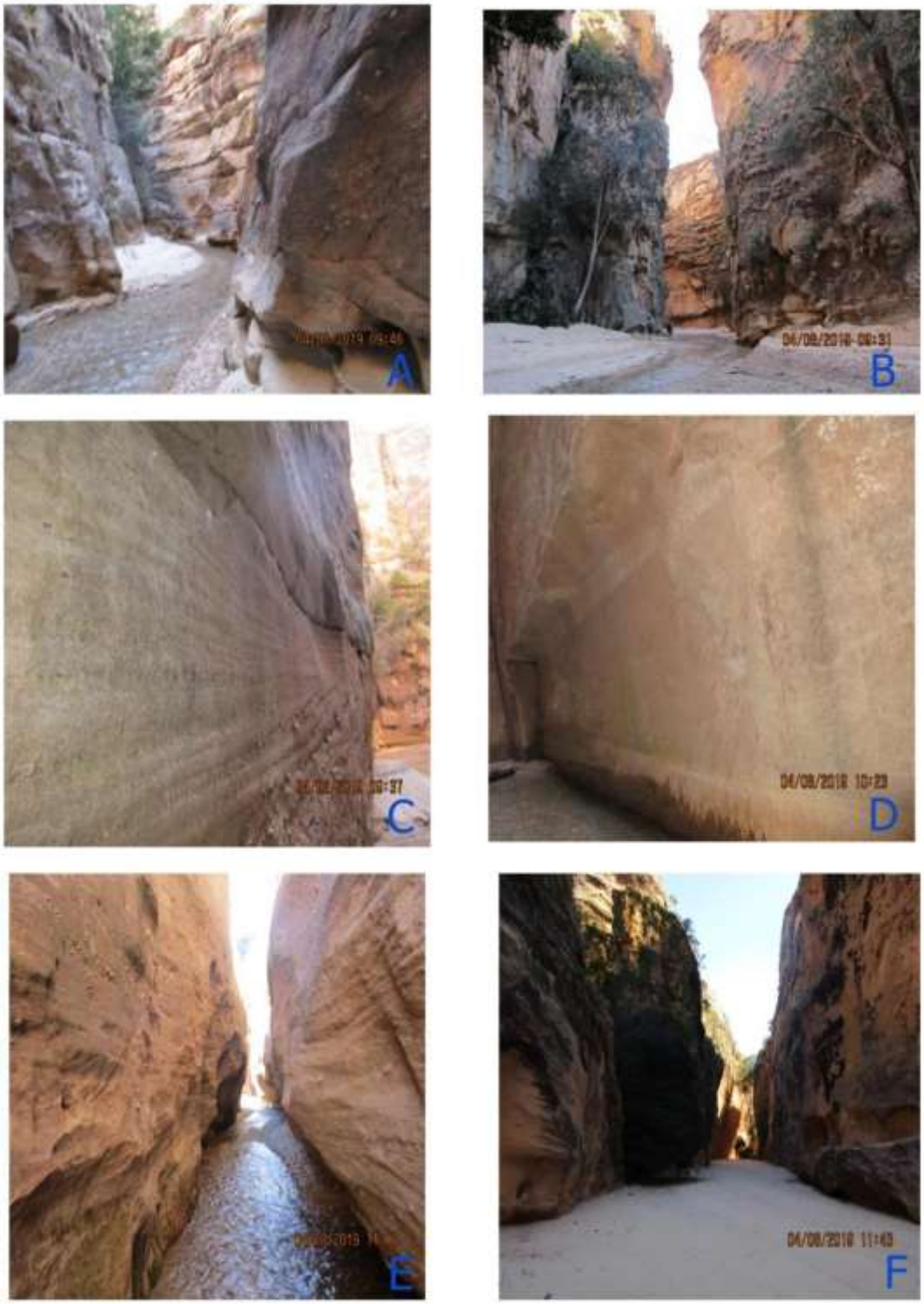

Figure 8: Sample photos showing the beautiful canyons of Sakapaly in the northern Makay NPA

On the one hand the vertical canyon walls showing figurative sculptures left by water currents and on the other hand some subvertical walls for the intricate canyon network have become a real refuge for biodiversity. The valleys widen downstream and the slopes remain generally subvertical with no counter-slope, but the basin floor is covered by sandy forests. (Fig9)

Figure 9: Sample photos of Makay valleys with sandy drills in white sand deposits

IV. Discussions

IV-1-Enhancement and Protection

The Makay is characterized by beautiful geological features, historical geoscientific knowledge, and mineral and tourism resources that could all be combined in the interest of community development (Herrera-Franco, 2020). The geological objects discovered in the Makay during this work justify its formidable comprehensive geological sites (paleontological, mineralogical, petrological, stratigraphical, tectonic and geomorphological) that would become a valuable basis for promoting the geopark (Idham Andri et al, 2020). The primary objective of the geopark is to integrate the preservation of significant examples of geological heritage into a strategy for sustainable socio-economic and cultural development at the regional level, while preserving the environment (Tranquard & Olivier, 2018; Pages, 2009). The standard characterisation of geosites in the form of scientific records, including the most important information on genesis and geoconservation characteristics, will provide a reliable basis for the estimation and comparison of their individual merits necessary for inclusion in the geosite inventory (Sinnyovsky et al,2020; Mehdioui, 2020). Geological heritage being one of the essential requirements of any geopark (Thais et al, 2020). The valorisation of geological heritage is a crucial task in geoconservation, and particularly relevant in geopark activities (Carvalho et al, 2020; Perotti et al, 2020). The development of heritage resources helps to foster conservation, contributes to more and better protection, and promotes the efficient use of these resources (Herrera Franco et al, 2020). The geopark provides a way to address the teaching-learning process of cultural values and natural values, including geology (Fernández Álvarez, 2020). This work aims to contribute to and analyse the role played by geoparks in improving the living conditions of riparian populations (Henriques et al, 2020; Ferraro et al, 2020). Geoparks are certainly the territory where geotourism can be best exploited (Valente et al, 2020). The values of the geopark's resources are an important potential for many tourism activities (Gaitán Morán & Álvarez Arellano, 2009; Mustafa Özgeriş & Karahan, 2020; Idham Andri et al 2020). The protection of natural heritage resources, aligned with geotourism, can provide a sustainable way for people to escape poverty (Randrianaly et al, 2015)

V. Conclusion

In conclusion, the New Makay Protected Area is emblematic for its richness in geosites, natural and cultural heritage through grandiose landscapes, canyons, various caves, sedimentary deposits, geological structures, vast valleys, white sand as well as its very powerful hydrographic network. The presence of the Makay Park brings several interests for the villagers around it : educational interest, cultural interest, scientific interest, especially the tourist and socio-economic interest. These different geological forms make it a heritage site. These different geological forms make it a heritage site. It requires inventories and evaluations for the protection, management, valorisation and sustainable development of the territory. This proposal is particularly ambitious, but we hope it is equal to the challenges to which it seeks to make a significant contribution, both in Madagascar and at a more global level.

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