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Geoconservation in Africa: State of the art and future challenges

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ABSTRACT

The rich African geodiversity is underrepresented among the Earth's geoheritage and still remains to be analyzed and disclosed. This requires inventory and evaluation of geosites with the aim of being protected, as well as valuing and monitoring procedures fostering sustainable development through geoeducation and geotourism.

This work presents the current state of geoconservation in Africa based on a bibliometric and mapping analyses of available literature. A total of 244 online documents were analyzed according to its three epistemological dimensions: Basic, Applied and Technical Applications.

The obtained results show that the different dimensions of geoconservation in Africa are biased and geographically limited. Most of them refer to geoheritage diagnosis, i.e., they correspond to inventory and assessment initiatives concerning territories mainly located on the coast and on the northern and southern edges of the African continent, therefore related to Basic Geoconservation. Results also show that Africa displays different types of geoheritage, a dimension that corresponds to Applied Geoconservation, but geoheritage's diagnosis and typology is scarcely developed. Technical Applications of Geoconservation refer to the set of materials, methods and/or scientific services that are useful to society. They include protection legal instruments and public policies assigned to nature conservation or the production of relevant resources for geoeducation and geotourism. While geotourism can display significant development in Africa, conservation and geoeducation are poorly represented. Such results will allow defining a road map for geoconservation in this continent thus assisting decision makers to establish specific priorities for the conservation of the abiotic dimension of nature in Africa.

1. Introduction

The long 4-billion-years autobiography of Africa can be told from its geological, biological and cultural perspectives along several Heritage Corridors ("The Africa Alive Corridors"), each representing a chapter in the overall story (Toteu et al., 2010). Within this holistic approach to African natural heritage 20 Heritage Nodes per Corridor have been identified, including Geoparks and geosites, Ramsar Sites, biodiversity hotspots, Biosphere Reserves, Trans-frontier Peace Parks, World Heritage Sites, archaeological sites, rock-art galleries, historical cities, etc.. But much of the rich geodiversity outcropping in Africa still remains to be analyzed and disclosed despite recent efforts to bring to light what is considered a geological paradise for its geodiversity and richness of natural resources (Martínez-Frías and Mogessie, 2012; Errami et al., 2015). This extraordinary geodiversity is made of unique and typical geosites which require inventory and evaluation with the aim of being protected, as well as valuing and monitoring procedures fostering sustainable development through geoeducation and geotourism (Ngwira, 2020).

In 2009 the African Association of Women in Geosciences created the African Geoparks Network aiming at: identifying and inventorying geosites; promoting and increasing the awareness amongst policy makers and the general public, in particular local communities, about the protection of and the benefits of geoparks creation for local socio-economic sustainable development; building the capacity of the local population in the field of geoheritage and geoconservation (Errami et al., 2015). The first paper about the African geological heritage published in a specialized journal that covers all aspects of geoheritage and its protection (the Geoheritage journal) was published in 2011 (El Hadi et al., 2011) and refers to the Bou Azzer ophiolitic complex (Anti-Atlas, southern Morocco). A recent initiative undertaken by the Journal of African Earth Sciences is the edition of a special volume dedicated to "Geoheritage in Africa: Potential, Assessment, and Conservation", that welcomes both regular research papers and short reports on existing and potential African geosites (Tewksbury et al., 2021). These two reference journals can play a major role in disseminating geoconservation approaches to the rich African geodiversity and

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contribute to reduce its underrepresentation among the Earth's geoheritage.

The gap between Africa and the other continents regarding geoconservation is closely related to human development issues. Africa is the least-developed continent outside of Antarctica, with most of the African countries occupying the lowest positions regarding Human Development Index Ranking or HDI (UNDP, 2021). This advanced metric tracks a wide range of indicators, from Adult Literacy Rate and Life Expectancy to the Gross National Income per capita (GNI), i.e., the dollar value of a country's final income in a year, divided by its population. All data is compiled into a number between 0.00 and 1.00 and each country into one of four different classifications between Very High (0.80–1.0), High (0.70–0.80), Medium (0.55–0.70) and Low (0–0.55). According to the 2020 HDI Report, Mauritius is the only country among the Africa's 54 countries considered to have very high human development (WPR, 2022; Fig. 1). In fact, the top 10 most developed countries in Africa are: Mauritius (0.804); Seychelles (0.796); Algeria (0.748); Tunisia (0.740); Botswana (0.735); Libya (0.724); South Africa (0.709); Egypt (0.707); Gabon (0.703), and Morocco (0.686).

Henriques et al. (2011) characterize geoconservation as an emergent geoscience within the Earth and Space Sciences and define the three main dimensions of this new scientific field: Basic Geoconservation related with its scope and methods, as well as with the production and validation of knowledge; Applied Geoconservation concerning the multiple interrelations with other earth sciences; and Technical Applications of Geoconservation as the set of materials, methods and/or scientific services that are useful to society. A recent work about the current status of geoconservation strategies so far implemented in Brazil has been developed based on the analysis of successful geoconservation initiatives representing a three-module geoconservation framework: diagnosis which includes inventory, assessment, characterization and indications of protection and use; conservation related to legal protection, conservation and monitoring; and promotion which regards valorization, interpretation and dissemination (Garcia et al., 2022). Each step of this geoconservation chain traduces specific activities related to two of the three dimensions previously established for this emergent geoscience: while diagnosis feeds science knowledge *sensu lato* (Basic Geoconservation and Applied Geoconservation), conservation and promotion actions correspond to Technical Applications of Geoconservation (Henriques et al., 2011).

Geoconservation has a very poor record in many countries of Africa where studies regarding the different dimensions of geoconservation are scarce (Reimold, 1999; Errami et al., 2015).

This work presents the current state of geoconservation in Africa in the above three epistemological dimensions based on bibliometric and mapping analyses of available literature. The obtained results will allow defining a road map for geoconservation in this continent thus assisting decision makers to establish specific priorities for the conservation of the abiotic dimension of nature in Africa, in agreement with the statements and recommendations of the Declaration of Antananarivo concerning geological heritage and its conservation in Africa (DA, 2019).

2. Materials and methods

The present work analyses the content of published papers related with geoconservation issues in Africa since 1999 (Reimold, 1999). Its development has taken into account the

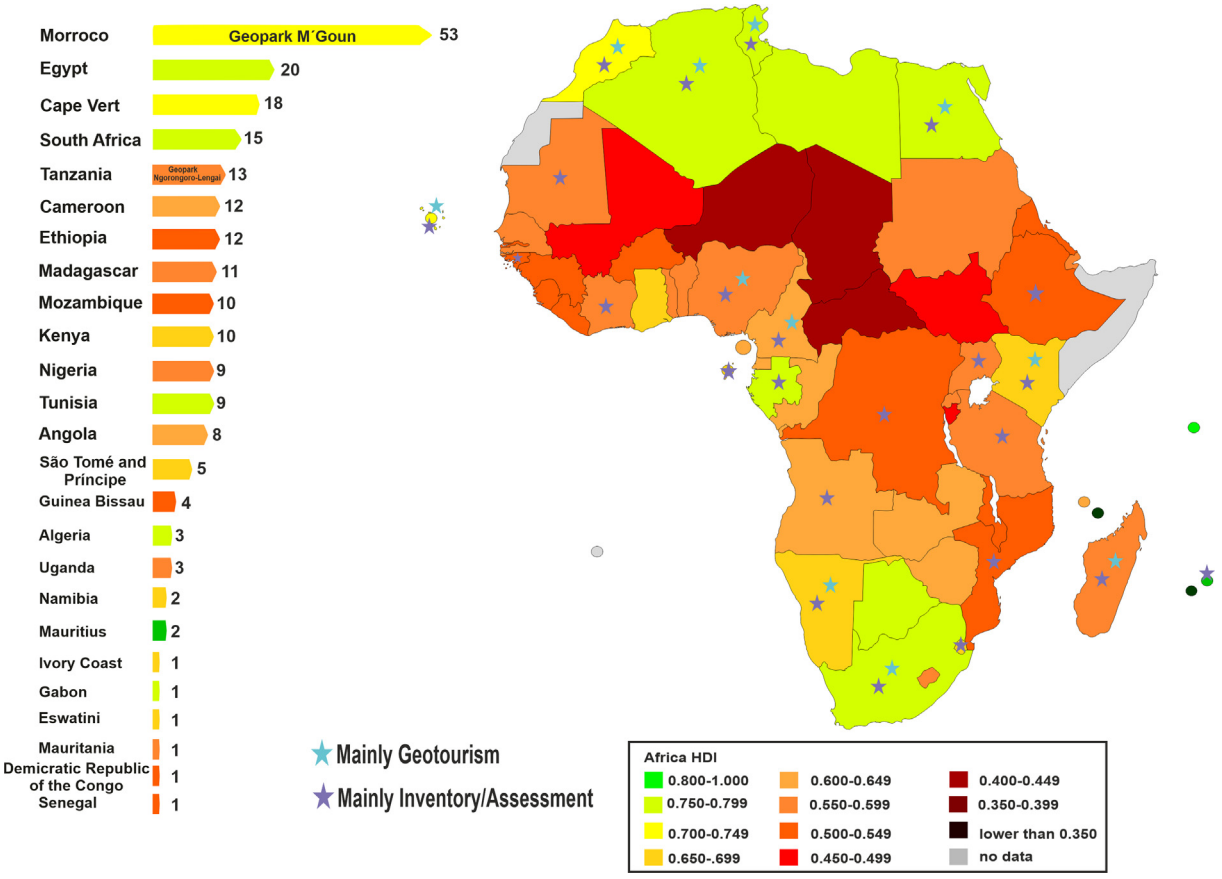

Fig. 1. The 2020 Human Development Index Ranking Report for African countries (modified after WPR, 2022) and distribution of literature mainly related to inventory/assessment procedures and geotourism activities by country.

three-phase methodology proposed by Herrera-Franco et al. (2021): (i) search criteria and source identification, (ii) software and data extraction, and (iii) data analysis and interpretation.

The primary source of publication data for this study is the Clarivate Analytics' Web of Science Core Collection© database, a publisher-independent global citation database covering the Science Citation Index Expanded and the Social Sciences Citation Index (Clarivate, 2021). But other published literature comprising academic publications that have documented original empirical and theoretical work in this area including journal articles, books, government policy, documents, websites, and research reports were also taken into account when accessible online through other databases for scholarly literature like Scopus© (Elsevier, 2021) and Google Scholar© (GS, 2021). Documents arising from the authors' personal knowledge were also included; they refer mainly to publications in Portuguese, which are out of scientific data bases (Henriques et al., 2013). However, they result from the growing scientific cooperation among the Community of Portuguese-Speaking Countries in earth sciences, namely in geoconservation issues (Henriques et al., 2010). Data collection presented some constraints, and it may be incomplete due to difficult access to internal reports eventually developed by national agencies and/or unpublished theses eventually held at universities, among other document types. All the collected data are included in Table 1 (Supplementary Material).

In total, we analyzed the content of 244 documents, which have been characterized in terms of its contribution for the development of geoconservation in the African continent. It was considered the three dimensions of geoconservation established by Henriques et al. (2011), represented by three sets of specific actions and activities, i.e., diagnosis, conservation, and promotion (Garcia et al., 2022). As so, the analyzed publications were classified in three clusters corresponding to:

- substantive meaning of geoconservation as a science, i.e., knowledge related to specific concepts, principles and methodologies of geoconservation as a science corresponding to Basic Geoconservation;
- uses of knowledge on geoconservation in other geoscientific areas therefore enabling to distinguish between different types of geoheritage, like paleontological, mineralogical, geomorphological, volcanological, etc. - as proposed by Ruban (2010), Habibi et al. (2018 and references therein) and Henriques and Neto (2015, 2019) - and corresponding to Applied Geoconservation;
- materials, instruments and/or scientific services of practical value provided by geoconservation aimed at valuing and promoting the geological heritage, like the establishment of protection legal instruments and public policies assigned to nature conservation or the production of relevant resources for geoeducation and geotourism and corresponding to Technical Applications of Geoconservation.

The data analysis and interpretation (bibliometric and mapping analysis) have been focused on the contribution by countries for the overall knowledge so far developed on different dimensions of geoconservation in Africa grounded in descriptive statistical methods.

3. Results

In general terms, it can be said that the development of geoconservation in Africa remains rather incipient when compared with other continents. As pointed by Sallam et al. (2018), present knowledge of geological heritage is strongly developed in Europe and South East Asia, and it is rather incomplete in Africa. During the 1970s UNESCO created several programmes aiming at preserving nature representing different sectorial approaches to nature and cultural heritage: the Man and Biosphere managed since 1971 by the Natural Science Sector; the World Cultural and Natural Heritage managed since 1977 by the World Heritage Centre which runs within the Cultural Sector (Henriques and Pena dos Reis, 2019). The Geosciences and Geoparks Programme, which runs within the Natural Science Sector, was created only in 2015; at present, there are 169 UNESCO Global Geoparks in 44 countries (UNESCO, 2021). They include two African Geoparks: the M'Goun UGGp in Morocco and the Ngorongoro Lengai UGGp in Tanzania, which represent only 1% of the three current UNESCO site designations in Africa (Biosphere Reserves and World Heritage Sites; Fig. 2).

Studies regarding the different dimensions of geoconservation in Africa are biased and geographically limited. Results show that most of them refer to geoheritage diagnosis, i.e., they correspond to inventory and assessment initiatives concerning territories mainly located on the coast and on the northern and southern edges of the African continent, therefore related to Basic Geoconservation (Fig. 3). Among the available literature it is possible to recognize that Africa displays different types of geoheritage, besides the generic geological heritage type: geomorphological, volcanic, paleontological, and mineralogical (Fig. 4). This dimension corresponding to Applied Geoconservation cannot represent the rich geodiversity outcropping in 20% of the planet's total land area, which needs to be unraveled. Conservation, valuation, and monitoring cannot proceed if geoheritage's diagnosis and typology is scarcely developed. The production of relevant resources for geoeducation and geotourism, corresponding to Technical

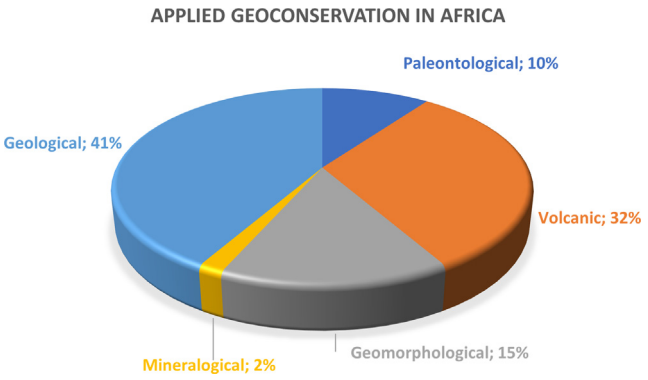

Fig. 2. The impact in Africa of the three current UNESCO programmes aiming at preserving nature and cultural heritage.

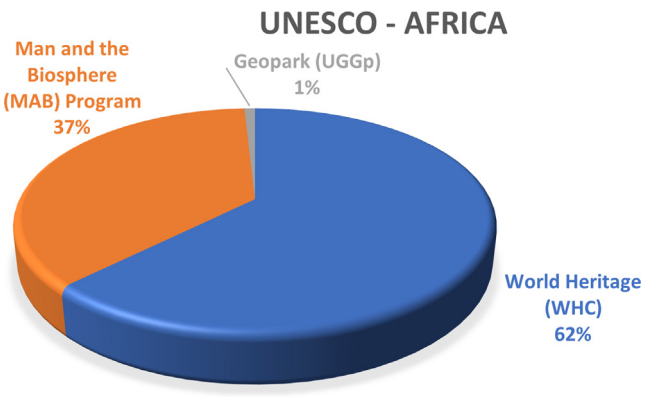

Fig. 3. Distribution of documents mainly related to inventory/assessment, conservation, and valuation/monitoring contents.

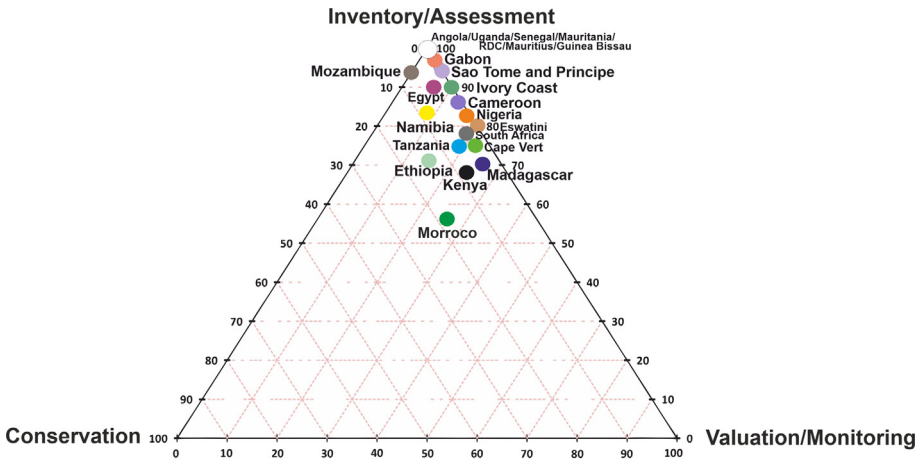

Fig. 4. Distribution of documents mainly related to types of geoheritage per country in Africa.

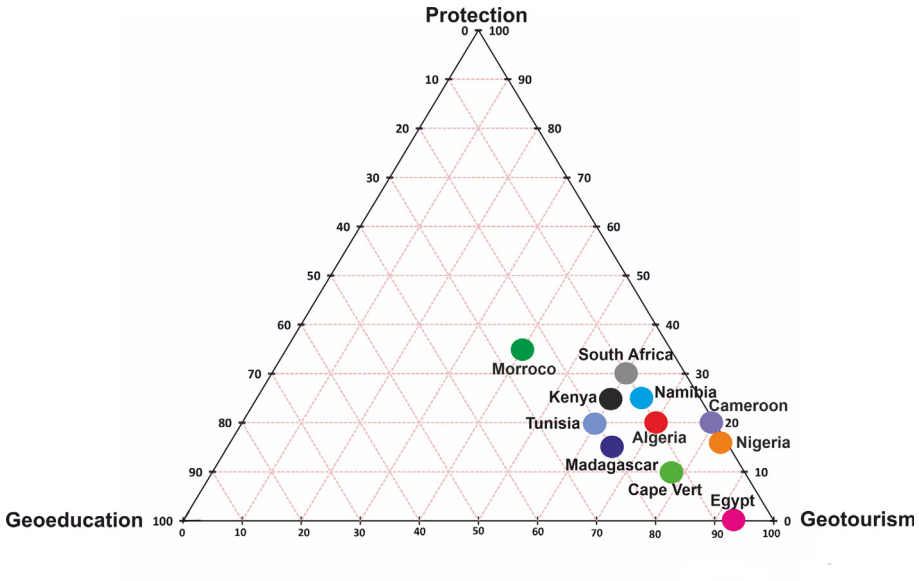

Fig. 5. Distribution of documents mainly related to protection, geoeducation, and geotourism contents.

Applications of Geoconservation, are of great help to implement geoheritage-based projects fostering economic and social development among African communities (Matshusa et al., 2021a). This kind of geoheritage promotion exists especially in countries where legal instruments and public policies assigned to nature conservation also exist. This is the case, for instance, of two southern countries: the National Heritage Council of Namibia, which is the administrative body responsible for the protection of Namibia's natural and cultural heritage (NHC, 2022); the South African Heritage Resources Agency, which is the national body responsible for the protection of South Africa's cultural heritage resources, that include sites as well as geological collections and specimens (SAHRA, 2022). The first one displays medium human development and the last one is one of the top 10 most developed countries in Africa (Fig. 1; WPR, 2022). In many other countries, Technical Applications of Geoconservation are mainly restricted to geotourism initiatives (Fig. 5). When the community is involved in geoconservation through formal and informal local-based initiatives, this can represent a key element for co-management of natural conservation strategies and for the support of local equity and empowerment in territories where no legal framework has yet been developed and/or is scarcely implemented aiming at the preservation of its geoheritage (Berkes, 2004; Okazaki, 2008; Tavares et al., 2015). This target can be strongly potentiated through conservation and geoeducation policies.

4. Discussion

Geoconservation requires inventory and evaluation procedures which play a decisive role in the implementation of any subsequent conservation action of the geological heritage (Henriques et al., 2011). The content analysis of the existing literature regarding African geoheritage developed in the present research shows a prevalence of works related to inventorying and assessment procedures and to geotourism activities.

The geoheritage inventorying and assessment methods most frequently used were conceived in European countries with a vast

accumulated scientific knowledge and are difficult to apply to other socio-economic contexts. As pointed by Xavier et al. (2021), the existing literature regarding geoheritage inventorying and assessment should be reviewed as valuation criteria need to be adapted to each territory, scale, and inventory purpose. Effective protection of the geological heritage value requires the local communities and actors' involvement in all of the geoconservation procedures, through a community-based geoheritage assessment, and not only at the final part of the process, when it is expected from local communities to preserve the physical integrity of the geological heritage (Tavares et al., 2015; López-Otálvaro, 2019). According to such model, the geoheritage assessment is grounded on the need of integrating both the geoheritage properties displayed by the geological objects and usually recognized by experts (i.e., relevance grade) and the social role attributed to geological objects by communities outside Earth scientists (i.e., abstract perceptiveness) (Pena dos Reis and Henriques, 2009). Their implementation allows bringing academia and public administrations closer to the common goal of promoting geoconservation by sharing similar conceptions and values and collectively recognizes the heritage value of special places within their territory (Carvalho et al., 2020). Moreover, it can be adjusted to different political and social contexts and allows the continuous incorporation of new analytical elements for the same territory. This is particularly useful in Africa and other south hemisphere territories like Brazil where the geological knowledge is limited due to its size, available resources and accessibility constraints to some vast areas (Xavier et al., 2021).

Garcia et al. (2022) recognize that in Brazil items related to the diagnosis and promotion of the geological heritage are most prevalent than those regarding conservation; they consider that most of the people involved in diagnosis and promotion are geoscientists, whilst conservation involves the participation of national or local government administrators and the existence of adequate legislation. However, the existence of legislation proved to be very controversial in many countries around the world, including South Africa (Cairncross, 2011; Matshusa et al., 2021b; Ruban, 2012). In fact, geoconservation strategies based only on the scientific perspective, despite its social dimension, is usually unsuccessful in terms of both legal geoconservation acts and effective geoconservation behavior (Pena dos Reis and Henriques, 2009; Matshusa et al., 2021a). The implementation of targeted local geoconservation projects with global impact rooted in culturally specific values, norms, beliefs, and attitudes directed at changing harmful behaviors is the most effective way of promoting geoeducation and geotourism, and therefore global sustainability (Werlen et al., 2016; Henriques and Brilha, 2017; Henriques et al., 2020).

Education, namely geoeducation, provides opportunities for social/cultural, academic, scientific and professional growth and development. This is a particularly important issue in Africa where most of the areas are not explored, not mapped and many of the potential natural resources are not known (Martínez-Frías and Mogessie, 2012) or correspond to publications that do not include local researchers, therefore enhancing the so-called parachute Science (Raja et al., 2021).

On the other hand, the rich African geoheritage can provide sustainable development through geotourism, therefore contributing to achieve the Sustainable Development Goals of the 2030 Agenda (Gill, 2017; Matshusa et al., 2021a). But this requires promoting significant and relevant learning on geology and on geoconservation and training citizens as geoscience communicators and educators committed towards the conservation of geodiversity and towards the understanding and appreciation of the geological sciences by tourists and communities living and working in the territory (Henriques et al., 2012; Gill, 2017). In fact, geoconservation is an emergent geoscience with a clear and deep social interrelation, namely through education for sustainable development (Henriques et al., 2011). Promotion of Earth Sciences-based education for sustainable development, namely through geoconservation, is a vital tool in training African citizens capable of fostering economic and social development through geotourism, and so improving their HDI toward nature-based human development (UNDP, 2020).

5. Conclusions

The African continent makes up 20% of emerged Earth and 4-billion-years of its history. But the most significant features of such a narrative are not yet fully known. It is assumed that they are represented in sites and geological materials within the immense geodiversity of Africa, but they need to be discovered, assessed and used as a tool of sustainable development of local communities. Geoconservation refers to inventory, evaluation, conservation, valuation and monitoring of the geological heritage. The content analysis of the existing literature regarding African geoheritage is scarce and limited to a small part of the 54 countries. Moreover, such documents are mainly related to inventorying and assessment procedures, therefore related to Basic Geoconservation, implemented in regions located on the coast and on the northern and southern edges of the continent. They also reveal few geoheritage types identified so far, and few materials, instruments and/or scientific services of practical value aimed at valuing and promoting the geological heritage in Africa. In this sense, to overcome this imbalance in African geoconservation, both Applied Geoconservation and the Technical Applications of Geoconservation require an urgent increase up growth. While Applied Geoconservation tasks are mainly assigned to experts, the establishment of protection legal instruments and public policies assigned to nature conservation, as well as the geoeducation policies, depend mostly of policy makers, while the production of relevant resources for geotourism requires a fruitful articulation between experts and entrepreneurs.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gr.2022.05.022.

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