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Research Paper

Contribution to the Valorization of the National Geological Heritage, Morocco

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Abstract: The enhancement of the geological heritage is necessary at a time when the growth and expansion of urban areas, the exploitation of fossils and minerals, are real threats to these geosites. The objective of this paper is to apply GIS technology in identifying geological geosites in Morocco by the interpretation of data related to geological geosites in Morocco using consistent net of survey control points, and allegation of other data which will help to identify and clarify this objective. Our work can be summarized in 3 axes as follows: (i) mapping of geosites using Geographic Information Systems (Mines, dinosaur tracks, fossils), (ii) contribution to a policy of preservation and enhancement of geological sites with all the partners concerned and to inform and raise awareness among the various stakeholders (government departments, local authorities, associations), as well as the general public, and (iii) proposal for a model valuation sheet to be dedicated to each geosite. The main aimis to elaborate a synthesis, which can be used as decision-making tool for the decision-makers. This paper also does not thus aspire in the least to be a work dealing with the geology of Morocco or an exhaustive inventory of the known geological geosites in Morocco. It only aspires to be a useful instrument within the reach of those who want to know a part of our geology. On other hand, we shall not hide the fact that we have also tried convey to the reader the special, unique and valuable character of Moroccan geological geosites, so that he may understand the importance of their care and preservation.
Keywords: geological heritage

INTRODUCTION:

The geological heritage is described as a common good of a community, a group of people, man, and humanity, considered as a heritage transmitted by ancestors if it is preserved by man. It therefore represents the memory of the Earth. The geological heritage was considered in connection with

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Humans, especially the palaeontological heritage.

The notion of natural heritage is a concern of our rapidly emerging society, yet interest in geosciences remains far beyond that of life sciences. There is a gap between geosciences and citizens. The notion of geological heritage covers a wide range of fields: inventory, protection, enhancement, dissemination, education and geotourism (Burek and Prosser, 2008). In this sense, the national inventory of geological heritage will make it possible to establish categories of sites and determine their importance (local, regional, national, international).

Geosites (Reynard, 2004) are areas of land that are of value to the Earth sciences. This term therefore includes mountains, hills, valleys, moraine valleys, ravines, caves, karst phenomena, banks and shores, quarries, gravel pits, mines, portions of roads or paths or boulders, sites that provide indisputable and characteristic information on a situation or event that the Earth has experienced over the course of geological time. Geosites provide an understanding of the spatial and temporal evolution of a region, the significance of surface processes and the importance of rocks as an element of landscape construction. Geosites in this sense are natural monuments of great importance, even indispensable, both for the public and for science.

Moroccan geology has some of the best and most complete outcrops recognized worldwide over a very long period of geological time (Jacobshagen, 1988; Piqué, 1994; Michard et al., 2008; see for more information on the special issue of "Géologues Journal" n°194 about the geological heritage of Morocco). However, the country's natural wealth/resources are undergoing irreversible deterioration, with fossils and minerals, for example, currently being looted, misused, sold and exported. This is a complex issue that requires us to issue a scientific opinion to make this heritage known, to enhance its value and to protect it all so that Morocco remains a world reference in geology. These riches remain unknown today by the majority of Moroccans, including managers of natural areas and even the non-specialized scientific community. This encourages "inventory" type studies in which geologists rarely carry out, but which have a fundamental role in raising public awareness of the safeguarding, enhancement and rational use of this heritage.

Geographic Information Systems (GIS) are often referred to a spacial information systems, especially when combined with their allied fields of remote sensing and surveying, and because of GIS superiority upon all other systems in data entering and analyzing, researchers tasks will be more simple and easy, and reflect the actual dealing with technology; thus reduce cost and give more assessment for better productivity enhancement (Bohman-Carte, 1994; Rekhibi et al., 2005).This work is an attempt to integrate all the data avaible concerning the national geological heritage in Morocco. Remotely sensed data along with other information are collected and stored in GIS data base. This data is analyzed using a commercial GIS package and results obtained and displayed.

Methodology:

Data collection is a very important step in this work, all the availed data was collected from different sources. In addition, the more information gathered the better the results obtained:

1. The mapping of the different geosites using Geographic Information Systems (mines, dinosaur tracks, fossils) by a meta-database that contains several

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information related to this site (location, situation, description);

2. The contribution to a policy of preservation and enhancement of geological sites with all the partners concerned and to inform and raise awareness among the various actors in charge (government services, local authorities, associations) and;
3. The proposal of a model sheet that will be dedicated to each geosite that contains several pieces of information about it (situation, nature of the site, current use of the site, general description, regional context, educational interest, geological, site condition, threats, constraints, heritage interest, regional exemplarity, development proposal, site use, means of preservation and the actors concerned).

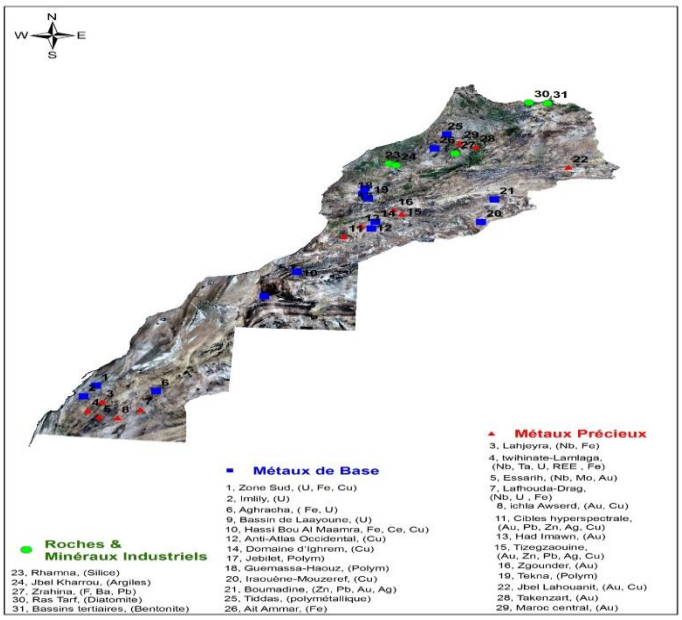

Figure 1. Situation map of the different mining deposits in Morocco with ArcGis software (modified from Department of Energy and Mines of Morocco, 1985).

RESULTATS:

Mines : The mining sector occupies a prominent place in the Moroccan economy, accounting for nearly 21% of export earnings and employing about 40,000 people. Mining has been one of the most important economic activities carried out by the Moroccan population over the centuries. Moroccan mining technologies such as copper working and steel manufacturing have been transferred across borders. Since the beginning of the 20th century, significant deposits of phosphates, lead, zinc, iron, manganese, etc., have been discovered. In terms of phosphate, Morocco contains three quarters of the world's known reserves. It is the world's largest exporter and third largest producer of raw phosphates. The inventory of Moroccan mines contains: coal, bituminous marl, phosphates, salt, iron deposits, lead-copper-zinc deposits, stanno-

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wolfram-bearing deposits, cobalt-nickel deposits, manganiferous deposits, silver deposits, gold deposits, antimoniferous deposits, fluo-barytic deposits, rare earth deposits, niobium, and tantalum deposits. Morocco's mines are classified according to Figure 2:

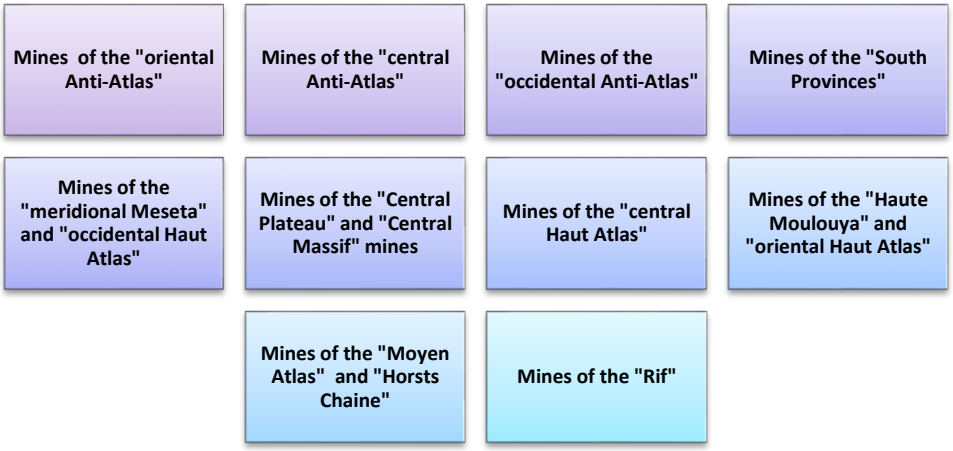

Figure 2. Flow chart of the methodology for mines.

a. Fossils : Fossils are the remains or traces of organisms that have lived through ancient geological eras. The possibility of preserving the hard parts of the living being (shell, skeleton) depends mainly on: (a) Rapid sediment recovery, and (b) Appropriate physico-chemical properties of the environment. Unfortunately, today, palaeontological databases are lacking in Morocco. Unlike other specialties, the collection of information on fossil deposits, which is an essential step in developing a database, is rare (e.g., Zili et al, 2014). The extraction of fossil specimens is carried out in the open (Jbel Issimour, El Aatchanna) or in underground works (Iferd n Ouallibou, Takacha).

Fossil stone mining, developed mainly in the Tafilalet region (El Hassani et al., 2017), is carried out by open-pit mining in trenches (Mirzzane, Marmar) whose dimensions depend on the means used in the site.

The most extracted fossils are: trilobites, orthoceras and Goniatites, crinoids, ammonites, sea urchins, shark teeth.

Fossil specimen extraction sites are found in quarries or underground works in various formations:

- Within the Cambrian to Devonian age formations for trilobites, crinoids, Goniatites and orthoceras in the Central Eastern Anti-Atlas;
- Within the Cretaceous formations for ammonites in the Agadir and Midelt regions and;
- In Eocene age phosphates for shark teeth (Salvan, 1954, 1969).

The main fossil extraction deposits in Morocco (Fig. 3):

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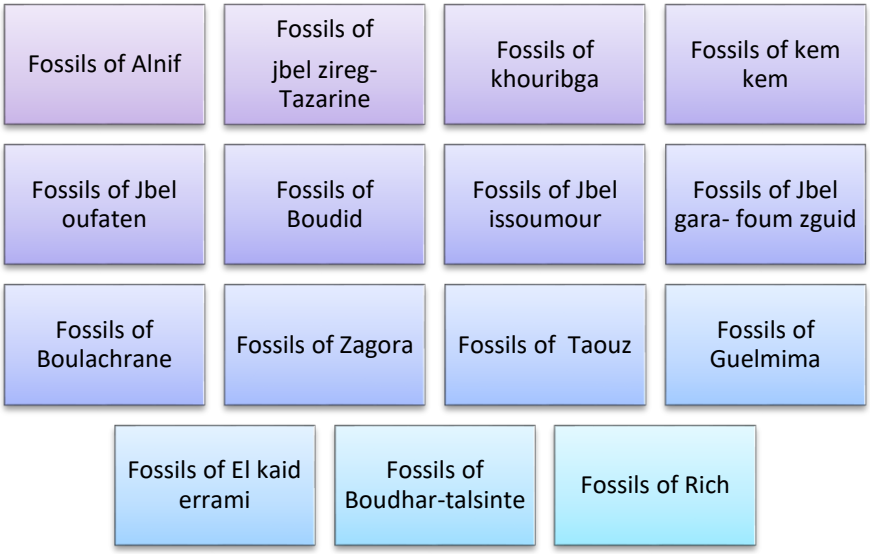

Figure 3. Flow chart of the methodology for fossils.

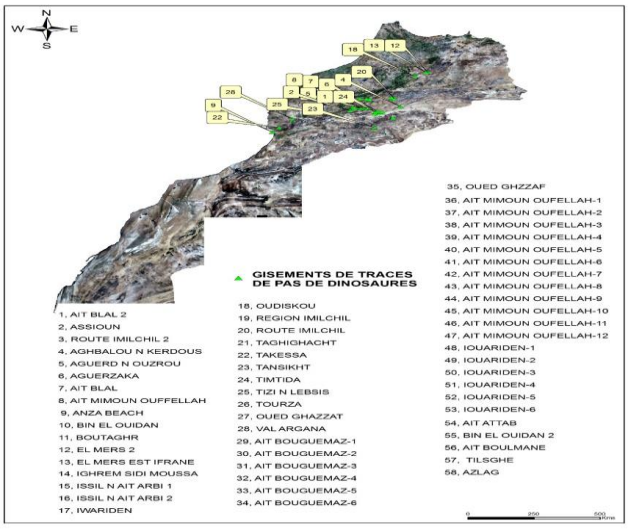

Figure 4. Situation map of the dinosaur footprints deposits in Morocco with ArcGis software.

b. Dinosaur footprints : Dinosaurs appeared during the Upper Triassic period 230 million years ago, they disappeared 65 million years ago during the Upper Cretaceous period. The Jurassic (-205 to -135 Ma) is the era of the terrible reptiles that colonized all the ecosystems of the globe. Since the first discovery of dinosaur footprints in Morocco (Plateau et al., 1937), subsequent studies have aroused the interest of scientists and the curiosity of the general public. Some have been the subject of extensive paleontological studies (e.g., Dutuit and Ouazzou, 1980; Ishigaki, 1988, 1989; Boutakiout et al., 2001, 2009; Nouri, 2007; Perez-Lorente et al., 2000; Belvedere et al.,

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2008, In: Ladel et al., 2010). They were printed in a brick red substrate of the continental dogger cracked by desiccation. They are curious tridactyl autopods.They are attributable to large carnivorous bipedal theropods (*Eubrontes sp*.) (Dutuit and Ouazzou, 1980). The Demnate deposit shows one of the longest and most beautiful tracks known in Morocco inherited by a large herbivorous quadruped called *Breviparopus taghbaloutensis*. About ten footprints have been found on yellowish fine-grained limestone slabs of Maestrichtian 16 km east of Agadir; the traces are essentially tridactyl, despite their small number (Masrour et al., 2013). The High Atlas of Ouarzazate, Adrar-n-Ouglagal region, shows a track with 80 successive tridactyl footprints printed on a limestone slab in the Lower Lias.

In the High Atlas of Azilal-Demnate, Ishigaki (1988, 1989) studied hundreds of footprints, spread over five major groups of dinosaurian footprints, classified in the suborders of coelurosaurians, carnosaurians and sauropods.

The most famous deposits are those of Aït blal, Waougoulzat, Assif-n-Sremt and Ibaqaliwn.On the Aït Blal deposit, there are traces measuring almost 30 cm in length. The fingerprints are very sharp and straight without joints like those of birds (Souhel, 1996). It should be noted that the diversity of traces would depend on the animal's locomotion and the nature of the substrate on which it walked. It is certain that these traces belong to very light animals and classified in the suborder of coelurosaurians.

Geographic Information Systems (GIS) has been used to analyze the various data concerning geological geosites in Morocco. The different types of data were integrated to produce a better picture about the presence of remarkable geological geosites. Results can be displayed in many forms such as: maps, tables and images. Various display methods are obtained and include: tables which contain descriptive information about geographic locations, charts which are graphic presentations of tabular information and layouts that include any components which can be created (Fig. 5).

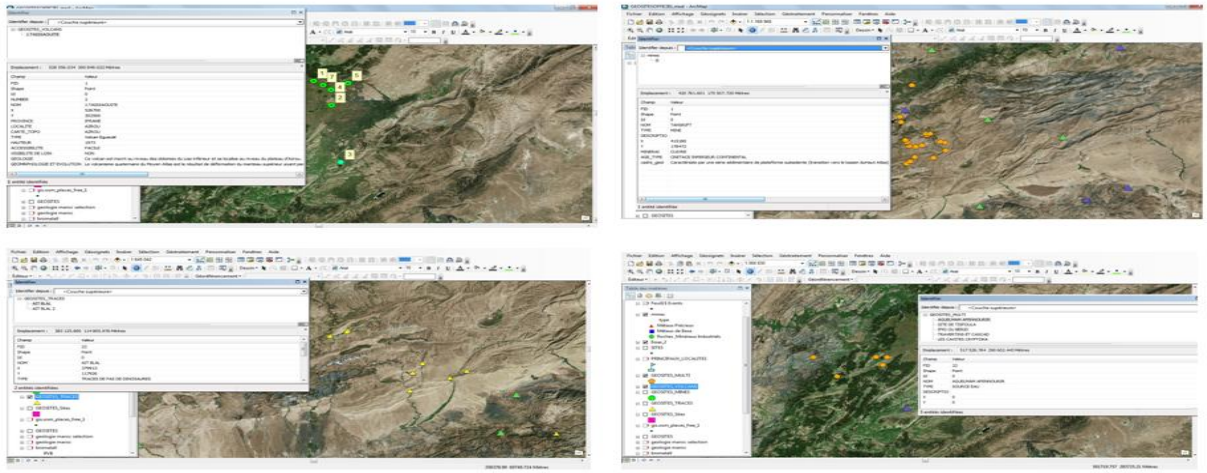

Figure 5. Data Base (distribution and description of geosites, charts of tabular information, and layout) under ArcGis software.

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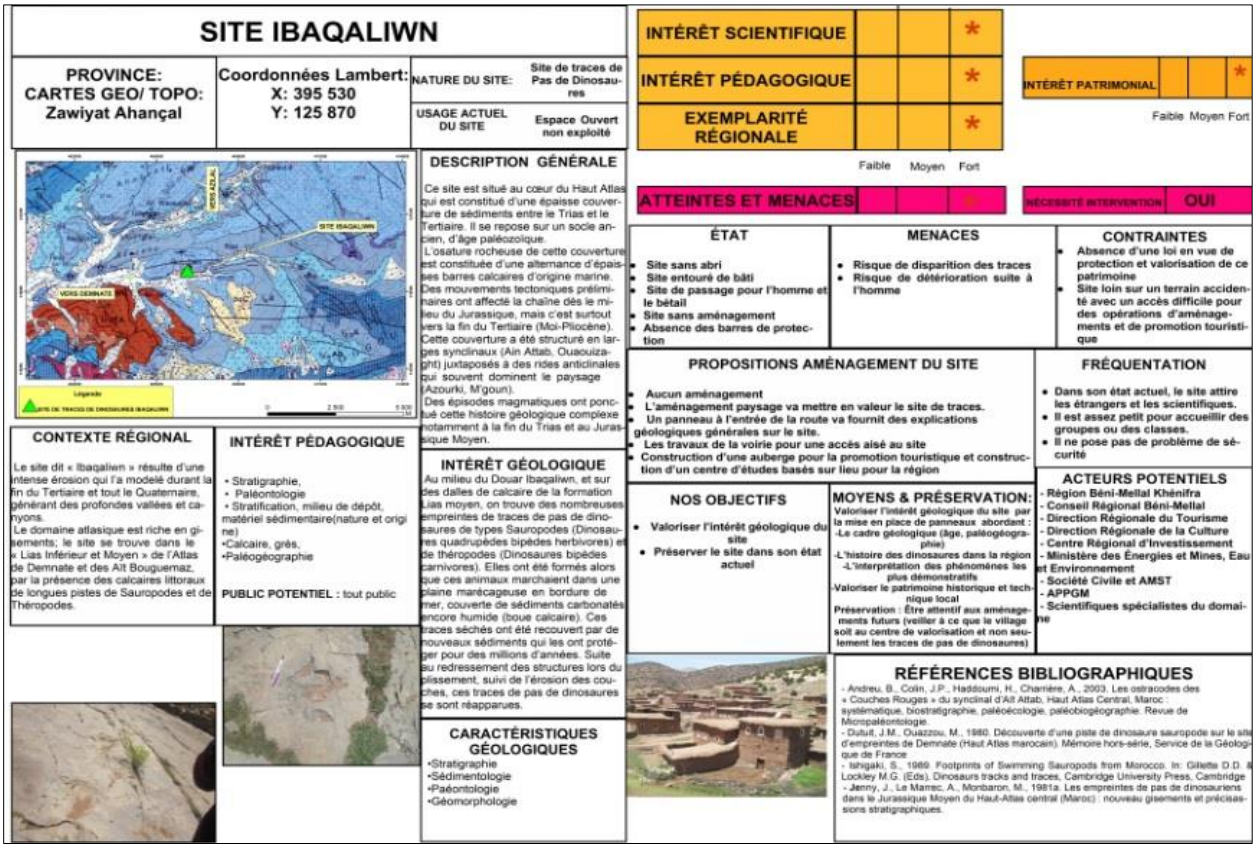
The dinosaur footprints of the Central High Atlas constitute an "in situ" a geological heritage that cannot be moved or protected in museums. As a result, it can undergo various degradations of natural and/or anthropogenic origins. Footprints have been and still are subject to different types of erosion and degradation, either natural, such as the effect of wind, water, temperature or freezing and thawing in winter for high altitudes, or human, such as the unconscious daily behavior of the inhabitants, or that of merchants or amateur scientists who make bad moulds, degrading the footprints.

Conclusion: The geological heritage must be the subject of particular attention of the whole community in view of its educational interest, its scientific, aesthetic and also for socio-cultural purposes (Heritier and Laslaz, 2008). With knowledge, responsibility and awareness, the geologist has a duty to inform decision-makers to insist that they intervene for the enhancement and protection of these geosites. From this, and to make our contribution, we propose to put a model sheet on the geosite known as Ibaqaliwn (e.g., Ibaqaliwn dinosaur tracks site, Central High Atlas, Morocco). Finally, using the Geographic Information System in national geological heritage is favorable way for studying large amount of data which is very diverse and has been obtained from different sources. This data base which has been compiled will reduce cost and time, and can limit the area for protection and valorization for national geological heritage helping the experts in getting better results.



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