

Tectonic and geomorphological landscapes and their geodidactic and geotouristic involvement: Case study in Precambrian and Paleozoic reliefs of Tata - Morocco

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ABSTRACT: Tata territory at south-east of Morocco is rich in natural potentials. Its relief is composed of Precambrian and Paleozoic lands that are shaped by tectonics and erosion, thus giving rise to landscapes of different forms and values. The geomorphosites that multiply through the Tata-Tagmoute way are very interesting for Earth Sciences. They represent an excellent archive of phenomena and processes which have led to the deformation of the crust. This article aims to contribute to the understanding of the conditions of the genesis of these geomorphosites and to the assessment of their geodidactic and geotouristic involvement in the local economy of this landlocked arid zone.

KEYWORDS: natural potentials, geomorphologic landscapes, geomorphosites, erosion, tectonic, geodidactic, geotourism

1 INTRODUCTION

Tata area at south-east of Morocco is rich in natural potentials. Its relief is composed of Precambrian and Paleozoic lands that are shaped by tectonics and erosion, thus giving rise to landscapes of different shapes. These landscapes represent geotopes and geomorphosites that multiply on the Tata-Tagmoute way; and are very interesting for Earth Sciences. In this paper, we will (i) define the concepts, (ii) analyze the geological setting of the study area, (iii) present the structural and geomorphological geosites of Tagmoute; and (iv) discuss as well their didactic and economic use.

In general, the terms « geotopes » and « geosites » [1] have the same meaning. They are also called « Earth science sites » et « geoscience sites » [2]. The term “geosite” comes from a Greek root “geo” (=Earth). When it is combined with the Latin word “situs” (=site) gives a lexical form meaning “geological site” or “site of geological interest”. Therefore, a geosite is a natural landscape feature that testifies processes that have formed and shaped our planet. For this reason is the product of different relationships between various factors acted in the past and that still affect the present. A geosite provides an indispensable contribution to the scientific understanding of the geological history of a given region [3] according to the typology proposed by Reynard in 2004 [2]. According to him, the geotopes are divided into 8 types: structural geotopes, paleontological geotopes, sedimentological geotopes, mineralogical geotopes, petrographic and geochemical geotopes, stratigraphic geotopes, geomorphological geotopes, hydrological and hydrogeological geotopes, speleological geotopes, geohistorical geotopes and geocultural geotopes. This article focuses on the structural and geomorphological geotopes and their importance of Earth and for tourism.

2 SITE OF STUDY

The province of Tata is located on the southeast edge of the axial zone of the Western Anti- Atlas and in presaharian area in the south of Morocco. It is characterized by its landforms particularly important, but also by its oases where the majority of the population live.

The rural town of Tagmoute is located 45 km north of Tata (Fig.1) combining oases and mountains. It is situated on a plateau whose altitude is 1000 m at the foot of the Anti-Atlas. It covers 1,087 km², but much of the area is formed by arid mountains. The agricultural area is estimated at 630 ha of which 400 ha are irrigated by water sources and 230 ha by rainwater next to the irrigated area [4]. The climate is characterized by high temperature during the summer and very low in winter.

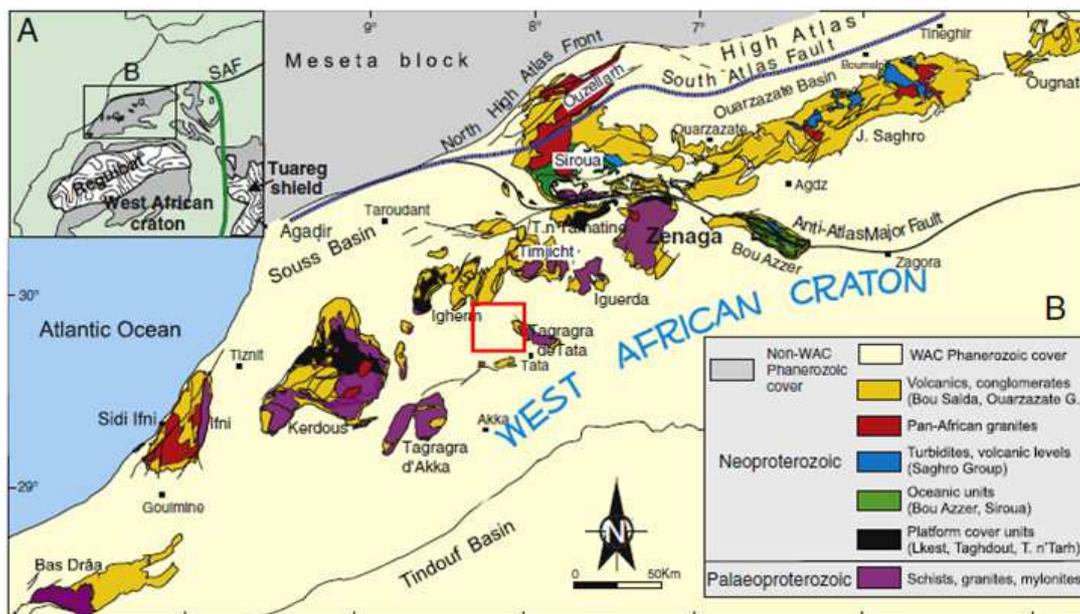


Fig. 1. The square in red on the map is the study area, Tagmoute, (at north of Tata and between Tagragra of Tata and Ighrem inliers). "A" represents the map of Morocco and its situation in relation to the West African Craton. "B" represents the geological map of the Anti-Atlas mountain range (Morocco) based on Thomas et al, 2002, 2004 ; Gasquet et al, 2008 (adapted).

According to the General Population and Housing Census of 2014, the rural district of Tagmoute has 4581 inhabitants spread over 1090 households [5]. The main activity of the local population is agriculture which is practiced on the shores of the wadis (Fig. 2). The main agricultural floors are composed of palm, olive and almond trees, with other harvest especially wheat intended for home consumption. The vegetable crops have declined because the *khettara* located near the Douar of *Tagenza* no longer works. The *khettara* is an antiquarian system of water mobilization for irrigation and drinking in many parts of Morocco and North Africa [6]. Technically, the *khettara* is a tunnel built to provide water for gardens in palm groves where it is not possible to dig wells.



Fig. 2. Agriculture on the shores of the oued at Tagmoute valley, Douar Assa (2015, L. MBarki)

Despite its semi-arid climate, Tagmoute area shows high biodiversity especially in terms of flora. The fieldwork done in Tagmoute has allowed the collection of the main species of local flora. The vegetable procession is mainly composed of 6 species (Figure 3) which dominate the valley: *Phoenix dactylifera*, *Argania spinosa*, *Prunus amygdalus*, *Olea europaea*, *Ceratonia siliqua* and *Punica granatum* *Pistacia lentiscus*. Shrubs and plants are associated with these tree resources. They are represented in particular by the following species: *Lavandula mairei*, *Anacyclus maroccanus*, *Rumex vesicarius*, *Asphodelus tenuifolius*, *Hammada scoparia*, *Echium horridum* (Fig. 4) and *Centaurea-pubescens*, *Cistanche violacea*, *Chenopodium murale*, *Euphorbia dracunculoides* subsp. *Inconspicua*.



Fig. 3. The main species fruit trees in Tagmoute zone (April, 2015, L. MBarki)

The population interviewed at *Tagmoute* including farmers, village women, experts plants say that the flora is in general used for food, medicinal or aromatic or cosmetics purposes. However, a laboratory work is needed to confirm or disconfirm these statements, and to determine the doses of use of each of the species.



Fig. 4. The main species plants in Tagmoute zone. (April, 2015, L. MBarki)

3 GEOLOGICAL SETTING

The Anti-Atlas belt is subdivided in two structural domains on both sides of the so-called WNW–ESE trending “Main Anti-Atlas Fault” [7] (Fig. 1). The northeastern domain consists of Neoproterozoic series deformed during Pan-African tectonic events while the south-western one mainly includes Palaeoproterozoic series heterogeneously deformed by Pan-African events. The juxtaposition of the two domains would have resulted from a collage of terranes during Pan-African times [8]. The region of Tata belongs to the southwestern domain that is why it is called The Central-Western Anti-Atlas [9].

The area of Tata is limited on the west by the Precambrian massif of *Kerdous*, bounded on the north by Precambrian inliers of *Ighrem* and *Agadir Melloul*. It is bordered in the south and Southeast by the Ordovician crest of *jbel Bani* (Mountain of *Bani*) and the Devonian lowland plain of *Draa* (Fig.1).

Tata sector is located on the southeast edge of the axial zone of the Western Anti-Atlas. North of this area, the reliefs are particularly important, with average altitudes from 1200 to 1700M, consisting adoudounian Dolomites forming ledges surrounding the Precambrian buttonhole *Tagragra Tata* and *Agouliz*. North of Tata, the syncline of *Tagmoute* to heart formed of Middle Cambrian shales, are eroded and form-covered plains of Quaternary terraces.

Tata group (Adoudounian), was constituted by marine carbonates and siltstones, and represents the earliest Cambrian. It consists, above a serie of detrital base by tree geological formations encountered throughout the Anti-Atlas: at the base, there are lower limestone, the series « lie-de-vin »; and upper limestones above the top. The Tata group (Adoudounian), constituted by marine carbonates and siltstones, and represents the earliest Cambrian [10].

4 STRUCTURAL AND EROSIONAL LANDSCAPES

According to Cartig [11], the Late Variscan Anti-Atlas of Morocco is typical type of foreland fold-belt. Tectonics of the Anti-Atlas in the Akka-Tata area shows the following characteristics: 1. A polyharmonic style of buckle folding within a nearly 10-km-thick Palaeozoic cover series. 2. Fold style and fold wavelength are controlled by the relative thickness of competent quartzite and carbonate layers within an abundant matrix of incompetent shales. 3. Two successive phases of folding developed first folds orientated NE–SW, second folds in an E–W direction. Interference led to regional scale dome and basin geometry within the Devonian *Jbel Rich*. 4. Both folding phases involve basement that is uplifted in a typical ‘Laramide’ – Rocky Mountain foreland style. 5. The age of both folding phases is most probably Late Carboniferous, corresponding to the final ‘Alleghenian’ phase collision in the Appalachian – Anti-Atlas orogeny.

The Anti-Atlas is reviewed and examined in the light of its geodynamic significance as a Palaeozoic basin and fold belt. Caritg S. et al [12] consider that folds of competent Palaeozoic marker beds are the predominant geomorphic and structural feature of the Anti-Atlas [13]. In Tagmoute area, the folds are very important in number and types. They are varied in terms of amplitude, cylindricity and the surface.

The area under study is characterized by early subequatorial folds that interfere with the major NE-SW folds. In order to determine the tectonic style of these early wrinkles that affect only the basic coverage, their relationship with the movements of Precambrian blocks when hercynien tightening, Faik F. [9] approached the importance of movements relative vertical and lateral, Precambrian blocks and their effects on the structuring of the cover. He makes use of a systematic structural analysis, guided by a detailed mapping study showing the location plicatives different directions.

4.1 STRUCTURAL GEOTOPES

In this region, the Paleozoic cover is structured by Hercynian synschistose folds at heterogeneous character. The folds have three axial directions: N-S, NE-SW and E-W (10). But it does not reflect the existence of a triple tectonic superposition [9]. The interference between the N-S and E-W directions gives crossed plies and structures in domes and basins [7] [15] [16].

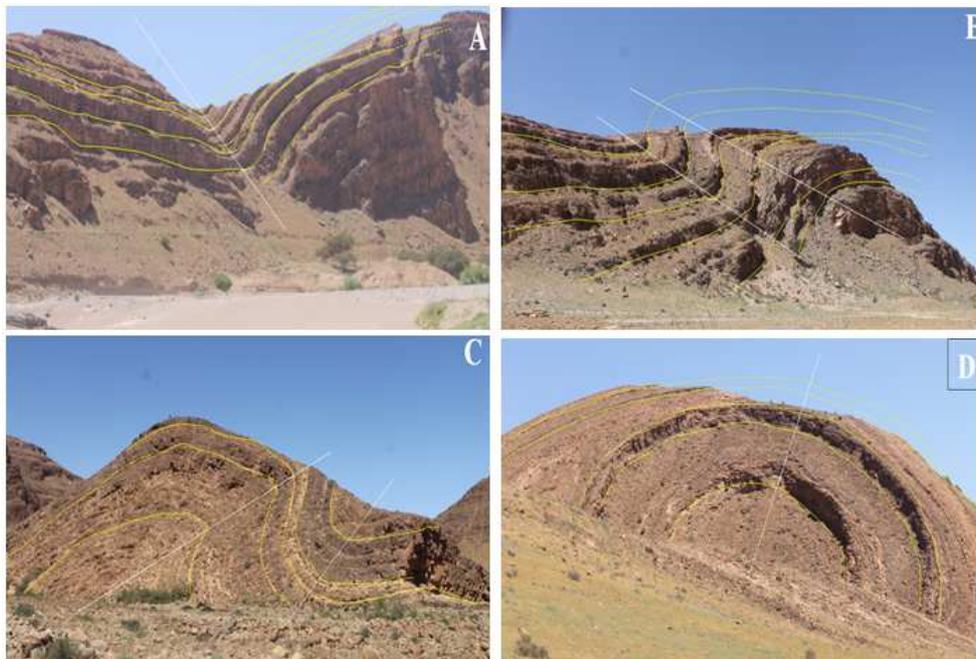


Fig. 5. Structural Geomorphosites in the Tagmoute area (photo M'Barki L., 2014)

Figure 5 shows the predominant types of folds found in the layers of Tagmoute:

Figure 5A represent the limbs of two juxtapposed folds. Their intersection forms a synclinal with normal limb.

Figure 5B shows an inclined fold to the left whose form of overturned fold. The layers of the summit of the anticlinal are eroded.

Figure 5C: asymmetric fold into the adoudounian dolomites (at the left). At the right, it resemble to an interaction between kink-band, but the form on the left resemble to a concentric folds

Figure 5D shows a symmetrical and cylindrical-fold. According to Faik [14], this form is due to a folding of sub-equatorial phase.

4.2 EROSIONAL GEOTOPES

The reliefs of Tagmoute represent excellent erosion areas. They are affected by various factors: climate, topography, water, physical and chemical characteristics of the rocks, anthropization ... Several types of geomorphosites multiply on the

Tata-Tagmoute zone: geomorphosites which have the form of a crescent because of the erosion (Fig. 5A). Other landscapes having the form of hearts are formed by mechanical erosion of rocks. They are spectacular and metrical depressions sculpted by erosion (Fig. 6B). The circular main portion extends at the bottom by a point which designates the water flow direction (Fig. 6C). These geomorphosites of "hearts" are formed in sedimentary rock with flexures or slightly crinkled with a large radius of curvature in this area [17].



Fig. 6. Geomorphological forms from erosion to Tagmoute (Tata, Morocco). (A) shows the eroded layers in the form of folding. (A) shows the depressions forming the top under the effect of water and the mechanical response of the rocks which lead to hollowed forms (C). White lines and contours delimit the erosional forms. The arrows in blue show the direction of water.

5 INTEGRATING OF GEOMORPHOSITES IN LOCAL DEVELOPEMENT

The importance given to this area is motivated by several reasons including: (1) presence of natural resources, (2) the educational importance of these resources to approach the phenomena and processes (3) geotourism, ecotourism and recreational opportunities. The integration of these landforms in tourism and educational contexts will have a positive impact on the development of the region and promotion of its natural and cultural heritage.

5.1 GEODIDACTIC INVOLVEMENT

The acquisition of knowledge on geological phenomena accompanying mountain chains of training is one of the skills to be acquired through the program of the final year of Moroccan Baccalaureate [18]. The deformations are interesting shapes for attaining this objective by understanding both the classification of folds and faults and the relationship between tectonic deformations and forces. This will help learners to grasp the relationship between these tectonic and the conditions of the genesis of obduction and subduction chains [19].

The different landscapes that exist in the area under study will help to establish "Schools in site". Their importance is to enable learners to understand closely the geological forms, phenomena and processes.

5.2 GEOTOURISTIC INVOLVEMENT

The potential of this area are numerous:

- Diverse biotic resources (tree resources, aromatic and medicinal plants, etc):
- Rich abiotic resources having recognized scientific and aesthetic values (reliefs, folds, faults, erosion forms, etc) which provide much information about the history of the Earth.
- A rich human heritage whose most prominent aspects are the granaries and traditional crafts.

In order to exploit and develop the natural and cultural heritage, we propose to contribute to the development of this area by:

- Establishing scientific trips of nature trails to discover the natural beauty and cultural heritage of this region.
- Founding geo-eco-tourism circuits connecting Tagmoute and other areas of Tata province to incorporate other elements of geodiversity, namely gemorphosites karst (Tissint, Messalite, Agouliz ...), sites of rock carvings (Tiygane, Umm Elaleg, Moumersal ...), etc.

6 CONCLUSION

It is hoped that this paper has revealed the importance of landscape forms in the local development of this region. In fact, the geosystems of the Tata province hide a lot of information about the history of Earth. By various geological phenomena and processes that succeeded on it (orogenic cycles, erosion, ...), also the beauty of forms they have generated, Tagmoute is an area of great educational importance for many peopole: mainly tourists , researchers and learners.

In an economic environment characterized by the decline of a seaside torurism, the Moroccan government is supposed to guide these efforts to promote the Tata province and all areas with similar potential. Such promotion is likely to ensure two objectives: 1. to develop disadvantaged areas, and 2. To open domains for developing the national economy. However, decision makers shoud consider both the environmental approach by protecting natural resources and the participatory approach by involving indigenou population in all ations of development.

REFERENCES

- [1] Goudie, *Encyclopedia of Geomorphology*, London, Routledge, 2 vol., Ed. 2004
- [2] E. Reynard, "Géotopes, géo (morpho) sites et paysages géomorphologiques", in : E. Reynard, J.-P. Pralong, "Paysages géomorphologiques", Compte rendu du séminaire de 3^{ème} cycle CUSO 2003, Lausanne, Institut de géographie, *Travaux et recherches*, n° 27, pp. 123-136, 2004.
- [3] D. E. Bruno, "Geosite, concept of", *Encyclopedia of mineral and energy policy*, Springer-Verlag Berlin Heidelberg, 2014. DOI 10.1007/978-3-642-40871-7_6-1
- [4] B. SOURISSEAU, *Etude de quatre oasis de la région de Tata (Maroc)*. (Eds.). (2003).
- [5] Haut Commissariat au Plan (Maroc), http://rgph2014.hcp.ma/Resultat-du-Recensement-general-de-la-population-et-de-l-habitat-2004_a59.html
- [6] M. Ouhssain, *La gestion sociale de l'eau au Maroc de azerf*, Revue HTE N°141, Décembre 2008
- [7] G. Choubet, "Histoire géologique du Précambrien de l'Anti-Atlas", Notes Mémoires service géologique Maroc, n°162, pp. 1-352, 1963.
- [8] A. Saquaque, H. Admou, J. Karson;, K. Hefferan and I. Reuber, "Precambrian accretionary tectonics in the Bou Azzer-El Graara region, Anti-Atlas, Morocco" *Geology*, 17(12), pp. 1107-1110, 1989.

- [9] Faik, F., Belfoul, M. A., Bouabdelli, M., & Hassenforder, B., "The structures of the Late Neoproterozoic and Early Palaeozoic cover of the Tata area, western Anti-Atlas, Morocco: polyphased deformation or basement/cover interactions during the Variscan orogeny?", *Journal of African Earth Sciences*, 32(4), pp. 765-776, 2001.
- [10] A. Soulaïmani, M. Bouabdelli and A. Piqué, "The Upper Neoproterozoic - Lower Cambrian continental extension in the Anti-Atlas (Morocco)", *Bulletin de la Société Géologique de France*, 174(1), pp. 83-92, 2003.
- [11] Caritg, S. (2003). *Géologie structurale dans l'Anti-Atlas occidental du Maroc. Implications tectoniques sur les relations entre dômes de socle et couverture plissée en front de chaîne de montagne*, PhD thesis, Université de Neuchâtel.
- [12] Caritg S., Burkhard M., Ducommun R., Helg U., Kopp L. and Sue C., "Fold interference patterns in the Late Palaeozoic Anti-Atlas belt of Morocco", *Terra Nova* 16 : 27-37, 2004,
- [13] Burkhard, M., et al. (2006). "Tectonics of the anti-Atlas of Morocco" *Comptes Rendus Geoscience* 338(1): 11-24.
- [14] Faik F., *Evolution stratigraphique et structurale d'un segment de la marge nord du craton ouest africain (Tata, Anti-Atlas occidental, Maroc) : du rifting fini-protérozoïque a l'orogénèse hercynienne*, 2005, Thèse de Doctorat d'Etat, Université Ibn Zohr – Faculté des sciences, Agadir
- [15] D. Jeannette, "Influence de structures panafricaines sur des déformations hercyniennes, bordure septentrionale de la Boutonnière d'Ighrem, Anti-Atlas occidental". *Notes Mémoires Service Géologique Maroc* 32 (3081, 25-31, 1981.
- [16] B. Hassenforder, "La tectonique panafricaine et varisque de l'Anti-Atlas dans le massif de Kerdous (Maroc)", Thèse Doctorat en Sciences, Université Louis Pasteur, Strasbourg, France, 246 p., 1987.
- [17] Fadli D., *Les "cœurs" de Tata et leurs dérivés : géomorphosites emblématiques pour un géotourisme incontournable du sud marocain*, Le 4ème Workshop International WIGET4 "Géo-Eco-tourisme dans la province de Tata et ses régions oasiennes pour le développement durable", Tata-Maroc, 11-15 Avril 2014, Conference proceedings).
- [18] Ministère de l'Education Nationale et de la Formation Professionnelle, Maroc, *Cadres des références des examens de l'examen national normalisé du Baccalauréat, Cadre de références des Sciences de la Vie et de la Terre*, 2014

ACKNOWLEDGMENT

We would like to thank Mohamed Bassidi for his valuable linguistic feedback.