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MORPHOSTRUCTURAL AND GEOMORPHOLOGICAL OUTLINE OF MOROCCO

Abstract: The paper bears the characteristic of the surface relief of Morocco. This relief is connected with the mode of closing of the Mediterranean Sea by the African continent. The closure of the Mediterranean Sea is built by Hercynides. In the Mesozoic and in early Paleogene they were folded, what resulted in formation of the mountain ridges separated by intramontane basins, in which sedimentation took place. In the Oligocene and later in the Neogene periods as well, the tectonic movements yielded formation of two mountain ridges: Rif mountains in the north and Atlas Mountains in the south. The Moroccan plains extending in the west-east direction widespread from 300 to 400 km and they accommodate the extension of the mountain ridges, which are the basis of the regional division. The Moroccan surface relief may be divided into three parts: the mountainous one comprising Atlas and Rif Mts, the Atlantic one consisting of plains and elevated denudation flats, and the largest one of eastern Morocco and Sahara that includes platforms more or less distinctly separated by mountains (Figure 1).

Four morphostructural units may be distinguished in Morocco. The first one comprises the area most stable tectonically in the past, which extends from Mauretania in the south to the zone of the southern Atlas Mts in the north. It includes the ridge of Antiatlas, flats and hamadas of Presahara, as well as the whole Atlantic zone of Sahara. The second unit includes mainly meridional ridges of the Atlas Mts. They are built from rocks of various age. Their uplift took place in early Paleogene. The uplifted and fractured sediments underwent numerous deformation and erosion cycles. The third unit, Meseta, consists of plains and uplifted flats of the Atlantic Moroccan coast as well as elevated Moroccan-Oranian plains extending to the east from the Middle Atlas Mts. These areas are built from rocks folded in late Paleozoic (Hercynian orogenesis), which till the Middle Triassic remained stable. In the old massifs, in which the large-scale uplift took place, extensive areas of accumulation formed. Depressions originated by subsidence became basins filled by sediment beds of frequently large thickness. The Rif unit, occurring northernmost, was the area of the marine sedimentation till Miocene. The subsequent orogenic movements caused the overthrusting of the beds to the south, toward the southern Rif groove, which separates the Rif unit and the Meseta and Atlas units. This young unit of the flysch type was eroded and denudated most intensively.

The paper also presents a short description of the Moroccan soils which development and spatial differentiation are connected mainly with the relief, lithology and climate.

Key words: Morocco relief, Moroccan morphostructural units, Morocco soils.

Morocco occupies northwest edge of Africa and belongs to Maghreb – a geographical region limited by the Mediterranean Sea from the north, by the Atlantic Ocean from the west and by the Sahara from south and southeast. This geographically favoured region is a bridge between Europe and Africa. Large area of Morocco, length of its coast line (3000 km of the Atlantic coast and 500 km of the Mediterranean Sea coast) and high relief dynamics play an important role in diversification of the natural environment and landscapes.

The relief of the country refers to a shape of the Mediterranean Sea continental closure by Africa. This closure is constituted by Hercynides developed at the end of the Palaeosoic era. During Mesosoic and in the beginning of Tertiary the Hercynides were metamorphosed into furrows and sedimentary depressions. During Oligocene and then in Neogene tectonic stresses typical for the Mediterranean region finally produced two mountain ranges – the Rif in the north and the Atlas in the south of Morocco.

The Moroccan plains, 300 to 400 km long in the east-west direction, refer to mountain ranges constituting basis for geographical regionalisation. Topographically Morocco can be divided into three parts: the mountainous one – covering the Atlas and the Rif, the Atlantic one – covering plains and flattened areas and the largest part – eastern Morocco with the Sahara. This part is constituted by platforms separated by small mountain ranges.

Structurally Morocco consists of four parts:

– The stable unit which spreads from Mauritania in the south to the southern Atlas in the north; this unit therefore encompasses the Antiatlas, plains and hamadas of the Presahara and the Atlantic Sahara;
– The mountainous unit of the Atlas consisting of uplifted ranges of folded cores of various ages, faulted and uplifted during Tertiary, undergone numerous deformational and erosional cycles;
– The meseta unit consisting of plains and elevated flattened areas of the Atlantic Morocco and elevated Morocco–Oranian plains, east of the Middle Atlas. The unit encompasses strata folded at the end of Palaeozoic (Hercynian orogenesis), which remained stable since the mid-Triassic surface levelling (disregarding high-radius slow uplift). In old massifs such movements produced wide sedimentary basins with a relatively thick sedimentary cover and also phosphorite basins;
– The Rif unit in the north, which aligns with a border of the Algerian Tell Atlas. This unit was submerged and acted as a sedimentary area until Miocene. Dynamic compression favoured sliding of rock strata southward, in the direction of the southern Rif furrow, which separates the Rif unit from the meseta unit and the Atlas unit.

1. Southern unit of the Antiatlas and the Sahara

The Saharan and Presahara region spreads south of the Atlas range and connects Morocco with tropical Africa. They are associated with the African shield, which underwent only limited deformations since the end of Precambrian. This ancient base (granite, rhyolite and schist), folded, faulted and levelled (Ifni-Kerdous-Saghro--Ougnat) was covered with very thick Palaeozoic series, beginning with limestone which constitutes the core of the Antiatlas covered with shale, sandstone and quartzite. General structure evolves into a different erosive relief in the southern and southeastern direction, characterised by elevated ranges and wide depressions developed in shales (regions of: Bani, Dra, Tafilalt). This structure continuous under contemporary covers of the Seguiet el Hamra hamada in SW, the Tindouf in the centre and the Guir in the east. Very monotonous, elevated plains, which spread over large areas, are associated with this structure. Sediments of these plains are cemented by Pliocene lacustrine limestone. Other, older sediments cover Palaeozoic sediments, in particular, Cretaceous cover which is a substratum for stony deserts in southwest (region of Laayoune) and the region of Tafilalt (Kem-Kem in the south and Meska in the north N).

The substratum rises again in the SE and S direction. The Palaeozoic series constitute an Appalachian type of landscape with ridges and depressions. Further, there is a levelled Precambrian substratum built with granitoides and metamorphic rocks which continuous in the direction of Mauritania.

This wide area underwent Maghrebian sea transgression, which developed a long strandflat, built with sandstone and marine limestone. Last modifications were triggered by neotectonic movements and climatic changes. According to tectonic evolution, it is possible to determine: zones of continuous uplift and erosion (mountains and flattened areas), more stable zones in depressions covered by superficial sediments (particularly the Dra furrows) and basins such as the Souss, the Khéla with Ouarzazate or the Tafilalt. Extraordinary character of relief is explained by aridity of climate: lack of sharp edges, high inclination of slopes with eroded base with depressions below; aeolian processes and forms in sandy basins; deeply dissected karst-deflation depressions, some of which lie below sea level, etc.

2. The Atlantic unit

The Atlas Mountains consist of massive, elevated parts, developed as a belt 150-200 km wide stretching from the Atlantic Ocean to the Algerian border. The High Atlas and the Middle Atlas are young mountains with high summits. They are rich in water, forest cover and grassland. Northern slopes drastically differ from southern ones, which receive much more sunlight.

Overlapping folds are built with Palaeozoic (mostly Carbon), epicontinental marine sediments. This sediment cover was uplifted together with pieces of the Hercynian and Precambrian shield, especially in the western High Atlas, where they constitute highest mountain ranges in northern Africa.

The Atlas includes highest summits in Morocco (4165 m a.s.l. in the High Atlas, 3331 m a.s.l. in the Middle Atlas). The mountains consist of broad massive subunits, with edge relief. The structural subunits are elongated. The most important boarder is that of the Southern Atlas overlap and runs along the southern base of the High Atlas. The character of relief is determined by the prevailing tectonic style, represented by box folds, especially in the Azilal range; in the eastern High Atlas there is also compressed and shifted anticlines. Last and contemporary uplift explains huge differences in elevation and clear sharpness of the relief seen in a cross-section.

Lithological differentiation of rocks and a complex tectonic pattern constitute many geological problems. Four main relief types can be determined:

– karstic plateau of plate structure built with limestone, modified by karstic processes, locally undulated or levelled (NW Middle Atlas);
– isolated mountain crests in the middle of wide syncline depressions or wide depressions, cut and levelled, developed according to tectonic directions in the eastern part of the High Atlas and the Saharan Atlas in Algeria;
– massive limestone structures constituting heavily folded mountain ranges, inclined and cut, constituting the central part of the High Atlas, most remote region in Morocco;
– Precambrian and Palaeozoic substratum, which underwent maximal uplift south of Marrakech, in the western part of the High Atlas. The substratum, heavily faulted, with deeply incised valleys and steep slopes is depleted from slope covers due to intensive erosion. High relative relief is common.

3. The meseta unit

The eastern region (elevated Morocco-Oranian plains and plateau of the Atlantic Morocco) is developed on a platform, which underwent tectonic deformations recently. It is possible to determine two types of relief within this unit: old massifs and accumulation plains.

Broad "amphitheatre" of the Atlantic Morocco is developed on the coastal plains (Gharb, Chaouia, Doukkala) and interior plains (Tadla, Haouz), which are separated by elevated plains of various homogeneity (Plateau central, Rehamna, Plateau des Phosphates). The region is under influences of the oceanic climate. Favourable climatic conditions allow for development of fertile soils and make irrigation possible.

The Palaeozoic substratum became heavily folded during the Hercynian orogenesis and was totally levelled in the beginning of Triassic. This area was not submerged until Cretaceous, but then and during Eocene it was covered by sea several times. The sea transgressions produced sedimentary basins of the Khouribga and the Gantour in which marl-limestone and sandy series accumulated as well as famous phosphorate sediments. Tectonic evolution together with erosion processes produced valleys incised in old massifs. Uplift played an important role (Plateau Centralne, Rehamna, Jbilet) and produced many surfaces of planation such as the Plateau Oulmès. It is worth mentioning that such a relief is similar to erosion-depression-type of relief other than

the Appalachian type (an example from the Azrou depression), but it is clearly seen, that sedimentary areas are linked to the structural relief of cuestas and edges.

The Moroccan unit of the Atlantic meseta is famous due to subsidence along the ocean coast, which produced plains and depressions. The interior plains constitute the Atlas piedmont and are drained by big oueds (wadis): the Oum Rbia for the Tadla plain, the Tensift for the Haouz plain. Wide accumulation fans developed at the base of the mountains. The central part of the meseta is built with young sediments.

Coastal plains are more complex because elevated plains and areas of Maghrebian sea transgressions surround them. This is why they consist of two parts: the coastal belt of undulating relief which has marine or aeolian genesis and the interior zone which is covered by sediments eroded from the land and meshing with the former sediments due to tectonic stability of the area. In some places there is old sandy alluvium and contemporary black clayey sediments developed on edges of the area and thus the edaphic conditions are very differentiated.

In the east of the Middle Atlas, the meseta unit is more complex. It is composed of a depressed and levelled tunnel along the Moulouya valley and elevated stable plains where lacustrine limestone accumulated in the end of Tertiary. Such elevated plains belong to the plate landscape, which underwent numerous stages of levelling and successive phases of accumulation. Its shape was finally modelled in Pliocene.

The northern part of the meseta and the Atlas Mountains is a complex zone and borders with the Rif unit along the depression of the southern Rif. The depression acted as a sea bay and, in Tortonian and Messinian periods, it became a sound connecting Atlantic with the Mediterranean Sea. This depression subsided and became a trap for marine sediments and, in Pliocene, for lacustrine sediments such as the Sais limestone. Part of this depression subsided even until Quaternary. This pertains to what is now calling the Gharb plain, which still subsides, and acts as an erosion base for the Sebou oued with its tributaries.

4. The Rif unit

The wide arch of the Rif Mountains is composed of overlapping rock layers and inclined southwards. In Miocene the rocks were moved to there nowadays position. The Rif Mountains constitute an Alpine-type range composed of subunits running more or less parallel to the coast of the Mediterranean Sea.

The rocks of the Rif started to form in a geosyncline were mostly shales and sandstones accumulated since Triassic. In a southern part of the sedimentary basin there are also limestones and marls.

In the southern most part of the mountains there are clayey-marl layers of the pre-Rif origin. The interior part of the Rif consists of flish layers underlain by para-autochthonous flysch. In the northern part of the range, there are rock layers composed of sediments deposited in the central zone of the geosyncline – limestones of the Dorsala formation and Palaeozoic layers of the Mediterranean Sea coast. The Rif is young and has never been a subject of a general planation. In a contrast

to other areas, the Rif is a range, which is actively cut by tributaries of the Ouerrha River on its southern side and by short oueds, which drain directly to the Mediterranean Sea.

Soils

Contemporary soils have been developed under influence of climate and vegetation cover. Climatic conditions have undergone major cyclical changes since the Mio-Pliocene emergence from the sea. Climate, structure of relief and lithology explain spatial differentiation of the soils cover. These elements strongly determine development and differentiation of Moroccan agriculture.

In humid and semi-humid maritime environments acrisols sometimes include ferrous precipitates and coatings. This is because in areas of artificial watering, leaching leads to degradation of upper soil horizons and creation of clayey horizons, which, in turn, favour hydromorphic processes. Locally, there are soils which can be classified as podzols.

In a continental environment soils are very thick due to consecutive processes of laterisation, leaching and calcareous coating. Forest cambisols containing much humus can be found in mountains. Commonly found rock outcrops are the substratum for lithosols and rankers.

Semi-arid environment is characterised by calcareous coating. One can also find: soils poorly developed on stony surfaces of terraces and slopes, terra rossa on limestone outcrops, vertisols on plains built with clays and loams which are characterised by high retention.

In dry climate of the Sahara, processes of salinization of soils are common and they enhance upon artificial watering. Halomorphic soils sometimes develop in lower sections of valleys and in mouths of oueds. Initial, poorly developed soils are found in semi-deserts and in deserts (rocky edges, regs and hamadas, ergs, isolated dunes on plains and in valleys).

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