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THE GEOLOGICAL HERITAGE ON THE MONTESINHO NATURAL PARK (NE PORTUGAL) - AN INTERPRETATION STRATEGY FOR AN AREA WITH HIGH GEOLOGICAL COMPLEXITY

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Abstract: The geological complexity and the exotic character of several formations of the Montesinho Natural Park (NE Portugal) print peculiar characteristics to the landscape. This part of the Iberia is characterized by the occurrence of a pile of allochthonous units thrusted over autochthonous Late Proterozoic and Palaeozoic metasediments and igneous rocks. The two major exotic terranes comprise a continental allochthonous terrane of Precambrian to Lower Cambrian age and a Silurian-Lower Devonian ophiolite complex thrusted by the allochthonous unit. More recent Cenozoic tectono-sedimentary events left their imprints on the landscape, namely with the presence of three unconformity-bounded sedimentary sequences. This complex geology has been detailed in recent scientific research allowing an accurate reading of the landscape. However, if on one hand that complexity is a valuation factor, on the other hand it renders the knowledge transfer to the general public more difficult. Raising public awareness of the regional geodiversity and its heritage relevance is thus a challenge to undertake. In this paper an interpretative panel is presented where the main features of the landscape and their relationship with the units and the geological processes are pointed out.

INTRODUCTION

The Portuguese national park system - which includes one national park, twelve natural parks, nine natural reserves and three protected landscapes, among other local areas totalizing about 7% of the Portuguese territory - was created almost exclusively for biological and cultural reasons. As in many other countries, geology is absent from the majority of the portuguese protected areas statutes (Brilha 2002). Some efforts are being developed by Portuguese geologists in order to change this situation. On the other hand, the integration of relevant geological information in the park management plans is now desired by park managers. In this context, a project of inventory and characterization of the geological heritage is under development in two natural parks from north-eastern Portugal (Dias and Brilha 2002).

The Montesinho Natural Park (MNP), one of the areas under study, is limited by Spain in its northern and eastern borders. It was established in 1979 constituting one of the larger national protected areas with about 750 km^2. Its creation was due to the harmony between the resident population and the natural environment. About 9000 inhabitants are distributed among 92 villages where ancient and rich traditions were preserved due to the isolation. A rough relief is the main reason for this isolation. The whole area of the MNP is dominated by mountains, Montesinho on the eastern part and Coroa on the western part.

The importance of the MNP is multidisciplinary:

i) Particular geological setting (rich geodiversity with several exotic formations);
ii) Biodiversity;
iii) Archaeological richness (for instance, evidence of ancient roman gold mining);
iv) Cultural traditions.

The complex and exotic geology and its marks on the landscape are the main geological characteristics of this park. Landscapes and their conservation are very important in protected areas management (Phillips 1997) and in nature conservation as a whole (Gonggrijp 1999). Denoting the high importance of landscapes, the International Union for Conservation of Nature (IUCN) defines Category V (Protected Landscape/Seascape) as one of the six types of protected areas (http://iucn.org/themes/wcpa/pubs/pdfs/WCPAInAction.pdf).

In this paper, we will present the strategy used for the production of an interpretative panel to be located in a selected viewpoint of the MNP. The main difficulty is related with the association of two relevant factors: a complex geology and a general public with low geological familiarity. This hard task is strengthened because 45% of europeans feel that they are neither interested nor informed about science and technology and two thirds consider themselves uninformed, according to a recent survey conducted by the European Commission (http://europa.eu.int/comm/public_opinion/archives/eb/ebs_154_en.pdf). Nowadays, the Portuguese education system integrates geology courses during some of the nine compulsory years. Therefore, the general population is gradually gaining the basis to understand basic geological information, which is a key-factor for the increase of public awareness of geological heritage. This will also contribute for the empathy between local people and MNP management, a key feature to the success of any nature conservation policy (Elcome and Baines 1999).

THE GEOLOGY AND LANDSCAPE OF THE MONTESINHO NATURAL PARK

Autochthonous sequences of the Central Iberian Zone, as well as a pile of thrust units of the "Galiza - Trás-os-Montes" Zone, occur in the MNP area. The mafic and ultramafic rocks of the Bragança Massif, one of the four allochthonous massifs in northwest Iberia, is the main geological feature. The autochthonous sequence is mainly composed of Ordovician quartzites and slates. The nappes comprise from bottom to top (Ribeiro 1974; Iglésias et al. 1983; Ribeiro et al. 1990; Meireles 2000a,b):

1) Parautochthonous thrust complex, including metasediments of Silurian - Devonian age having lithological affinities with the subautochthonous;
2) Lower allochthonous thrust complex of the Lower to the Upper Palaeozoic;
3) A fragmented Palaeozoic ophiolite complex;
4) An upper continental allochthonous terrane of Precambrian to Lower Cambrian age.

These nappes are thrust over a Silurian - Devonian subautochthonous metasediment sequence. Variscan granitic rocks also occur in the MNP area.

Finally, Cenozoic tectono-sedimentary events left their imprints on the landscape, namely with the presence of three unconformity-bounded sedimentary sequences (Pereira 1997, 1999a,b; Meireles et al. 2002).

The late Variscan tectonic episodes caused the rupture of the Iberian Meseta plateau. The Aveleda and Baçal surfaces are inside a graben controlled by the NNE-SSW (Portelo fault) and the N-S (Aveleda fault) fault systems. The Portelo fault belongs to a major lineament of the late-Variscan tectonic episode in NW Iberia (Bragança - Vilariça fault system). This is a left-lateral strike slip fault with uplift of the western block. The Aveleda fault was reactivated as a dextral strike slip fault in late-Variscan episodes (Meireles et al. 2002).

In the MNP, several local surfaces are well defined and clearly identified from different sites, constituting remains of the Iberian Meseta plateau. In general, each surface is defined over distinct lithological units and is tectonically controlled by major faults. This complex geology imprints particular landscape features and plays an important role in the natural heritage of this park. The relation between landscape and geology is the key for a first contact of the general public with the MNP geology.

THE S. BARTOLOMEU PANEL

The use of interpretative panels in geology is common in many places. In the last years, some authors give clues in order to make these panels appropriate for general public (Wilson 1994; Hose 1998; Hose 2000). Interpretation strategies for protected areas must integrate multiple resources. Dias and Brilha (2002) presented different ways to deliver geological information to various target groups in protected areas of NE Portugal.

The S. Bartolomeu panel is mainly addressed to the public with a basic geological background and, in particular, to senior students and teachers. It will be set up on the viewpoint with the same name. This viewpoint was selected because:

i) Allows a complete perspective of the eastern area of the MNP;
ii) Is placed over mafic rocks from the lower continental crust, a good example of the exotic character of the regional geology;
iii) Allows good accessibility;
iv) Presents low vulnerability;
v) Is well known by the local population and mentioned in tourist information.

The S. Bartolomeu panel intends to display the main geological features of this park, based on the following geological features and concepts:

i) Great lithological variety (slates, quartzites, marbles, amphibolites, granulites, peridotites, gneisses, granites, conglomerates, sands, and muds);
ii) Endogenic processes as plate tectonics, magmatism and metamorphism, represented by the Paleozoic lithologies;
iii) Exotic character of various lithologies as a result of Paleozoic dynamic processes;
iv) Tectonics of plate interiors and related stratigraphic units;
v) Geological cycle and orogeny;
vi) Endogenic-exogenic interactions and landforms development;
vii) Geological time and landscape evolution.

This panel (130x100cm) includes different graphic resources and small text boxes (Figure 1). A panoramic photograph illustrates the main geomorphological features - uplifted blocks and surfaces limited by major faults. The caption over this photograph makes these features clear to the public. The simplified geological map represents the main lithologies and tectonics. Another simplified geomorphological map is used to help the identification of several surfaces and fault limits. With this graphical support, the viewer is challenged to recognise the landscape features observed from this viewpoint.

Two photographs illustrate relevant sites suggesting a detailed stop. The text in the panel is presented in three boxes with the following titles:

i) A rich rock diversity;
ii) Reading the landscape;
iii) How did geological processes influence the landscape?

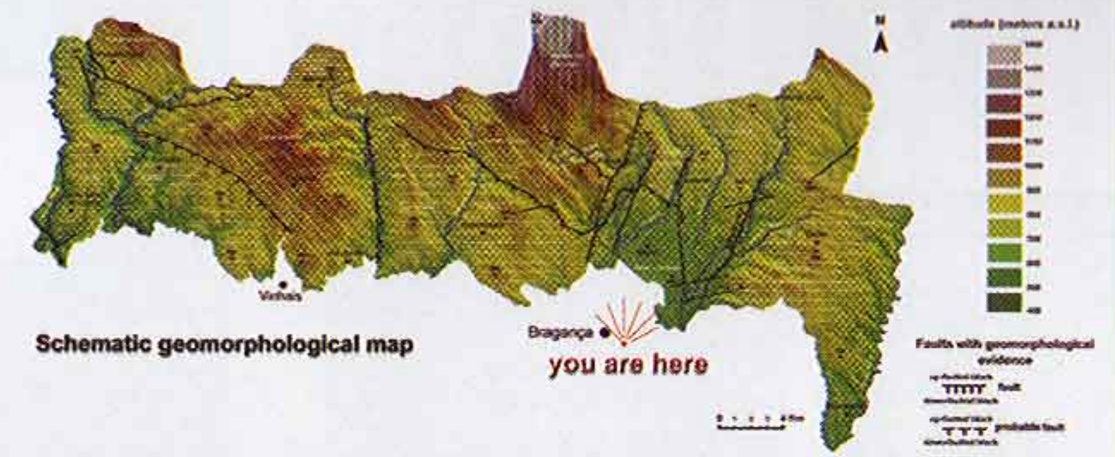
The landscape evolution is presented using a graphical sketch that provides the understanding of the geological processes through the geological time.

Finally, a lateral strip includes complementary information, such as suggestions of trails and sites, indications for further readings and contacts.

Montesinho Natural Park
Geology and Landscape

Montesinho Natural Park

location: northeast of Portugal
foundation: 1979
symbol: chestnut hedgehog - *Castanea sativa*
area: 74 230 ha
population: 9506
headquarters: Bragança
max altitude: Montesinho Mountain (1486 m a.s.l.)
min altitude: Manta river, Sandim (438 m a.s.l.)



A rich rock diversity

The MNP presents an unusual rock diversity (see geological map) as a result of a long and complex Earth evolution.

The metamorphic rocks of the Bragança Massif are remains of the oceanic and continental crust, and of the mantle as well. Among those rocks, formed and displaced several hundred million years ago, the most relevant are:

Amphibolites – dark rocks mainly constituted by iron/magnesium-rich minerals, mostly amphiboles. These rocks were generated from a Paleozoic oceanic crust (see geological time scale).

Granulites – dark rocks with banded structure and constituted by iron/magnesium-rich minerals. These rocks derived from the lowest part of an old continental crust. They can be observed in the outcrops near this site.

Peridotites – rare dark green rocks constituted essentially by olivines and pyroxenes. They were originated deeply in the mantle.

Other common metamorphic rocks were derived from sediments deposited in a Paleozoic ocean, such as:

Slates – fine-grained rocks mainly constituted by lamellar minerals. They present a characteristic feature – slaty cleavage – that makes the rock split into slabs and thin plates.

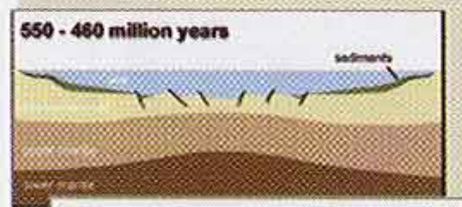
Quartzites – very hard and compact quartz-rich rocks. Their great resistance to the action of atmospheric agents is responsible for some crests.

Granites occur in the Montesinho, Moimenta and Pinheiro Novo massifs. These plutonic rocks crystallized from silicic magmas at about 320-300 million years ago.

Sediments such as clays, sands, and gravels cover the older rocks. They resulted from fluvial activity between 10 to 2 million years ago.

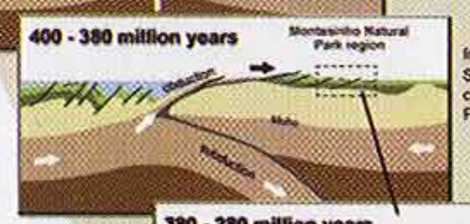
Geodiversity: the result of an ancient plate tectonics

The large diversity of rocks in MNP is related with the opening and closure of an ancient ocean. Different geological processes occurred giving rise to a supercontinent - Pangea.

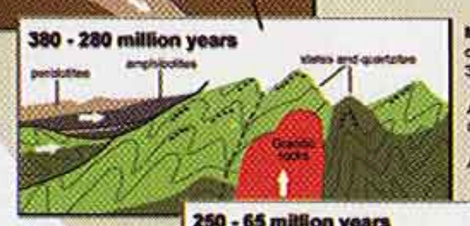


About 550 million years ago, the thinning of a continental crust generated a **marine depression**. Sediments originated from the erosion of continents began to accumulate in this depression.

Continental rupture and rifting occurred in the Silurian (see geological time scale). Sea-floor spreading and oceanic crust generation were active processes. Sedimentation proceeded in the oceanic basin.



In the Middle Devonian, sea-floor spreading stopped and the ocean closure began. Subduction (oceanic crust descending beneath continental crust) followed by continental collision and obduction (overriding of oceanic crust onto the continental crust) occurred. Fragments of the obducted rocks constitute the **Bragança Massif**.



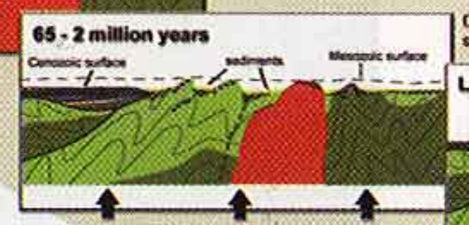
Metamorphism affected rocks due to an increase of pressure and temperature, originating slates, quartzites, and amphibolites, among other rocks. At about 320-300 million years ago, **granitic magmas** were generated and emplaced in the crust.

At about 280 million years ago, the landscape was characterised by a vigorous relief controlled by major fractures.

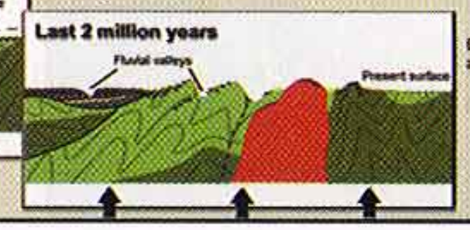
At this time the supercontinent **Pangea** covered a significant part of the Earth surface.

At about 140 million years ago, Pangea broke-up leading to the nowadays distribution of oceans and continents.

In the MNP area, climatic conditions allowed deep rock weathering, erosion and land surfacing.



During the Tertiary, sediments were accumulated in depressions shaped by fluvial systems.



During Quaternary, since 2 million years ago, a new fluvial system is being incised.

Reading the landscape

The landscape of eastern MNP can be observed from this site and interpreted using the above geomorphological sketch. You can see:

- A depression locally known as Baixa Lombada;
- Two uplifted blocks, one on the western side (Montesinho-Espinhoseila) and the other on the eastern side (Alta Lombada);
- Three plain surfaces defined at different altitudes on the western block (Montesinho, Soutelo and Espinhoseila);
- Sabor, Avelada, Onor and Labiados rivers follow a preferential direction towards south inside Baixa Lombada depression.

How did geological processes influence the landscape?

The landscape is conditioned by geological processes at different times of Earth evolution. Tectonics is the great responsible for landscape features at this viewpoint.

- The uplifted and downlifted blocks have a tectonic origin. They resulted from vertical movement across faults, such as the Portelo and the Labiados faults with north-south orientation.
- These north-south faults also controlled stream orientation and sediment accumulation inside the Baixa Lombada depression during the Tertiary. This is a recent tectonics that occurs during the last 25 million years.
- The three plain surfaces of the western block are limited by old reverse faults (thrusts) related with the Paleozoic ocean closure.
- These three plain surfaces are defined upon rocks with distinct resistance to erosion.

Geological time scale

Eon	Era	Period	Million Years
Phanerozoic	Cenozoic	Quaternary	1.8
		Tertiary	65
	Mesozoic	Cretaceous	135
		Jurassic	203
		Triassic	250
	Paleozoic	Permian	295
		Carboniferous	355
		Devonian	410
		Silurian	435
		Ordovician	500
		Cambrian	540
Proterozoic			2500
Archean			4600

Further information:

Other panels in geological sites and tracks
Geological Guide of the Montesinho Natural Park
Web pages at www.icn.pt

Granite landform in Serra Serrada, Montesinho mountain

Schist landform in v.g. Montesinho

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Geology and Mining Institute

Figure 1. General view of the S.Bartolomeu interpretative panel, Montesinho Natural Park (NE Portugal).

FINAL CONSIDERATIONS

The geology interpretation inside Portuguese protected areas is just starting. As recognized by several authors, protected areas are very important for environmental education. The lack of geological information in Portuguese parks is very negative in the effort of raising public awareness of geology. This paper deals with the production of an interpretative panel as an initiative integrated in a wider interpretative strategy for an area with high geological complexity - the Montesinho Natural Park (NE Portugal). This strategy will make available new tools to MNP managers that can be used to promote holistic conservation strategies in this protected area. Additionally, the school population will also benefit with the implementation of these interpretation products, converting the MNP into a true out-door classroom.

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