

Iberian Pyrite Belt Geosites - valorisation of the geodiversity based in the Geological parks model

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ABSTRACT: Located in the South Portuguese Zone, the Iberian Pyrite Belt (IPB) is worldwide famous by its large number of massive sulphide deposits, some with giant dimension (Neves Corvo and Rio Tinto). IPB geodiversity is exposed in the mining areas and in the river valleys cross-sections (e.g. Guadiana, Chança, Rio Tinto, Odiel). Considering the excellent natural conditions of the Alentejo and Andalusia provinces, the current paper promote the discussion of the IPB geological, mining and cultural heritage valorization, based in the development of Geological parks model.

KEYWORDS: Iberian Pyrite Belt, geosites, geological and mining heritage.

1. INTRODUCTION

The Iberian Pyrite Belt (IPB) is an important European mining province shared by the Alentejo and Algarve (Portugal) and Andalusia (Spain) regions. Geographically the Portuguese part of the IPB is exposed from the Alentejo coast all the way to the Guadiana River that marks the Spanish border. The IPB is included in the South Portuguese Zone (SPZ), one of the major geological domains of the Variscan Iberian Massif. It consists of two major stratigraphic units, the Phyllite Quartzite Group (PQG) and the Volcano Sedimentary Complex (VSC). The PQG forms the IPB basal detritic sedimentary unit and consists mostly of phyllites, quartzites and quartzwackes with a thickness in excess of 200 m (base not known). It is dated as lower Givetian to late Strunian age (Middle to Upper Devonian), by ammonoids, conodonts and palynomorphs (Oliveira *et al.*, 2006; Pereira *et al.*, 2008, with references therein). The VSC incorporates several episodes of volcanism, with dominant rhyolites, dacites, basalts and minor andesites, and intercalations of black shales, siltstones, minor quartzwackes, siliceous shales, jaspers and cherts and a purple shale member at the upper part of the complex. The thickness is variable, from few tens of meters to more than 1000m. The VSC is dated as Upper Devonian to Upper Viséan age based on palynomorphs and rare conodonts (Oliveira *et al.*, 2006; Pereira *et al.*, 2008, with references therein). Overlaying the VSC are the turbidites of the Baixo Alentejo Flysch Group (BAFG) that consists of mostly gravity flow sediments that form a continuous southward prograding turbiditic successions, that includes from base to top, the Mértola, Mira and Brejeira Formations. Associated with the VSC felsic volcanic and/or black shales are the giant massive deposits that characterise the IPB as a world famous metallogenetic base metal province.

This paper presents a synthesis of the potential of the IPB geosites and mining areas which constitutes a large geological and mining heritage to be discovered and preserved.

2. IBERIAN PYRITE BELT MINING AND NATURAL LANDSCAPE

The IPB has an exclusive natural heritage characterised by environmental, geological, biological distinctiveness, as well as outstanding seaside coastal landscapes and an inland flat morphology, the typical landscape of Alentejo, and the smooth Andalusia mountains. Both regions present significant and particular human culture, related to agriculture, mining archeology, traditions, music and gastronomy, for example, developed throughout the present history.

They also present a significant valuable geodiversity, not only due to the variety of the sedimentary and volcanic stratigraphic sequences, very well represented in Portugal by classical cross-sections along the Guadiana, Chança and Sado river valleys and in the Pomarão, Ourique, Castro Verde and Cercal antiformal structures. The massive sulphide deposits, associated stockworks and hydrothermal systems are exposed in the open pits of the Lousal, Caveira, Montinho, São Domingos and Chança mines (both in post mining phase) and in the active mines of Neves Corvo and Aljustrel, both considered world class VHMS deposits (Oliveira *et al.*, 2006; Pereira *et al.*, 2008; Matos *et al.*, 2008, 2010). Along several centuries, the IPB mining province has been the aim of intense extractive activities for Cu, Zn, Pb, Sn, Mn, Fe and Ba ores. More than 90 massive sulphide deposits are known in Portugal and Spain, most of them exhausted but some are presently mined or unexploited. From these activities resulted a significant mining heritage especially that related with the Roman period and from the 19th century to the present time. This mining activity changed the landscape and the culture of this region, leaving a rare industrial archaeology heritage that includes exploitation open pits, ore processing industrial systems, railway trails, river harbours for the ore transport (e.g. Pomarão and La Laja at Guadiana river and Rio Tinto and Tharsis at Odiel river), mining villages and a mining cultural memory of the populations (Matos *et al.*, 2008; Gómez & Martinez 2009).

3. IPB PORTUGUESE MINING AND GEOLOGICAL HERITAGE PROJECTS

The Portuguese Geological Survey (LNEG) in cooperation with Direcção Geral de Energia e Geologia, local municipalities and foundations is involved in several actions of promotion, valorisation and conservation of this exclusive IPB heritage. LNEG houses and promotes the detailed investigation of more than 200km of boreholes that constitutes an incomparable legacy, acquired from the old exploitation mining companies (new CEGMA project, submitted to QREN 2011). LNEG is the promoter of an IPB partnership network named PYRITE ROUTE (RUMYS Iberoamerican CYTED Project) and many other actions, trail circuits and panels at Aljustrel, S. Domingos and Ferrarias (Cova dos Mouros Mining Park), the Beja Geological Garden and collaborate actively with the Lousal Life Science Center (Matos *et al.*, 2008, 2010). LNEG it is also a partner of the ATLANTERRA PROJECT (Interreg IVB, Atlantic Space) that will promote digitalization of the mining archives and consequent better access for educational, historical and genealogical interests, production of geo-mining trails supported by interpretation panels, key points with geocache system location, several actions as for example “Algares Geological Garden”, “Lousal open pit trails” and “Space Atlantic mining documents”. This thematic cluster is strategically included in the Alentejo touristic policy (Matos *et al.*, 2010).

4. THE MAIN IPB GEOSITES

The IPB geology is well exposed in several cross-sections along rivers, roads and quarries. In the main mining areas open pits and galleries permit the observation of in situ ore deposits (massive sulphides, Cu, Pb-Ba, Sb veins and Mn-Fe oxides). Mine tailings also permit the identification of ore mineralogy and host rocks. Having in mind PROGEO discussions and recommendations about mining and geological heritage (Brilha, 2005), in this paper the geological features of each mine is evaluated, considering the mining scenario as an excellent way to access to the local stratigraphy and to the understanding of the geological process related with ore metalogeny (hydrothermal systems) and their later evolution during deformation and late supergene alteration and erosion. Current mining activities allow geological studies at near 800m depth in the Neves Corvo mine galleries and up to ~1700 m depth considering exploration boreholes (maximum length of 1888 m at Cotovio AGC/Lundin borehole). Table 1 shows the main mining areas and selected geological cross-sections

that are evaluated in terms of geological heritage (see details in Matos & Oliveira 2003, Matos *et al.* 2003, 2006, 2008; Oliveira & Matos 2004a, 2004b; Relvas *et al.* 2005; Oliveira *et al.* 2007).

Table 1. Significant geosites in the Iberian Pyrite Belt Portuguese sector:

| Geosites Theme | Min. heritage | | Geological heritage | | | | | | | GI |
|----------------------------|---------------|----|---------------------|-----|-----|-----|----|---|---|-----|
| | MI | MV | O | Fly | VSC | PQG | FO | T | L | |
| Mining areas: | | | | | | | | | | |
| Neves Corvo | 1 | 4 | 1 | 2 | 1 | 2 | 2 | 1 | 3 | 1,W |
| S. Domingos (Py) | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1,E |
| Aljustrel (Py) | 1 | 1 | 1 | 2 | 1 | 4 | 3 | 1 | 1 | 1,W |
| Lousal (Py) | 1 | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 1 | 1,E |
| Caveira (Py) | 1 | 3 | 2 | 4 | 2 | 2 | 2 | 2 | 1 | 1,N |
| Chança (Py) | 3 | 4 | 1 | 4 | 2 | 4 | 4 | 3 | 2 | 2,N |
| Brançanes (Cu) | 2 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 3 | 2,N |
| Ferrarias (Cu) | 3 | 4 | 3 | 1 | 4 | 4 | 2 | 3 | 2 | 3,N |
| Cercal (Mn) | 2 | 4 | 1 | 4 | 2 | 3 | 3 | 2 | 2 | 2,N |
| Ferragudo (Mn) | 2 | 4 | 2 | 4 | 3 | 4 | 4 | 3 | 3 | 3,N |
| Cross-sections: | | | | | | | | | | |
| Guadiana/Mértola-Pulo Lobo | - | 2 | 4 | 1 | 1 | 1 | 2 | 1 | 1 | 1,E |
| Pomarão | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 1 | 2 | 1,E |
| Castro Verde/Rosário | - | 4 | 4 | 3 | 1 | 2 | 2 | 2 | 3 | 2,N |
| Cercal/S. Luís | - | 4 | 3 | 3 | 1 | 2 | 2 | 2 | 2 | 2,N |
| São Marcos Atabueira | - | 3 | 4 | 1 | 4 | 4 | 4 | 1 | | 2,N |
| Vaqueiros | - | 4 | 3 | 1 | 4 | 4 | 1 | 2 | 3 | 2,N |

Mining heritage: MI – mining infrastructures; MV – mining villages; **Geological heritage:** O – ore deposits and hydrothermal systems; Fly – Baixo Alentejo Flysch; VSC – Volcano-Sedimentary Comp.; PQG – Phyllite-Quartzite Gr.; FO – fossils and microfossils; T – tectonic structures; L – landscape; **Geological Interest:** 1 – Very important; 2 – Important; 3 – Moderate; 4 – Low/non applicable. **GI Scale:** W – world class; E – European; N – National.

Other South Portuguese Zone (SPZ) geological domains and units must be considered in order to complete the IPB frame within the context of the regional geology. This is the case of the Pulo do Lobo waterfalls, where the oldest SPZ sedimentary unit is exposed, and the Guadiana River exhumed terraces, the so-called “corredoura”. *Posidonia becheri*, ammonoids and palynomorphs fossiliferous well documented outcrops of Carboniferous age are common in the Mértola Formation of the Baixo Alentejo Flysch Group (Korn, 1997; Oliveira, 1988; Pereira *et al.* 2008). Several palynostratigraphic studies are also being carried out for exploration companies, to identify key horizons favourable to the presence of VMS mineralization.

5. DISCUSSION: THE IPB GEOLOGICAL HERITAGE VALORIZATION BASED IN THE GEOLOGICAL PARKS MODEL

The IPB is a unique European metalogenetic province, with a great density of geosites related with Devonian and Carboniferous sequences. LNEG collaborates with a network of local partners like the Lousal Life Science Center, Aljustrel Museum and the municipalities of Grandola, Aljustrel, Mértola, Castro Verde and Almodovar. The aim of this network is the promotion of the IPB mining and geological heritage, considering projects like geological parks and geological gardens. The sustainable promotion and valorization of the IPB heritage must be considered and developed according to proposals incorporating a network of several geological parks infrastructures, or numerous interpretation centers, that could integrate a future national Geopark model. Considering the geodiversity and geosite distribution in the IPB Portuguese sector, several regions present excellent heritage value (the Guadiana and Chança Valleys, the São Domingos and Chança mines, all included in Guadiana Natural Park; the Aljustrel, Lousal and Caveira mining areas, and the Cercal anticline). Other thematic areas can complement geology and mining, supporting the Geopark model concept, for instance the natural landscape and ecologic agriculture, biodiversity,

archeology and the Alentejo's human culture (rich gastronomy, ethnography and music).

Other ideas to be considered in the near future are the twinning with the Spanish sector, in order to integrate the IPB territory shared by the two Iberian countries. This could promote the economical incentives of the scientific tourism, in a common strategy policy. Key areas to consider are São Domingos, Aljustrel and Lousal in Portugal and Rio Tinto, Tharsis, Peña de Hierro, Concepción, Confessionários, San Telmo and La Zarza in Spain, all with local infrastructures related with geological and mining heritage (Matos *et al.*, 2008; Gómez & Martínez 2009). The proposals must involve Portuguese and Spanish experts who must consider similar project development in both IPB sectors. This could be a sustainable strategy for studying the possibility of a future Iberian Geopark proposal, having conscience that the management of this enormous region, needs further work and investments. Successful proposals must consider the strategies of valorization with integrated and multidisciplinary approach to the geological and mining heritage.

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