A LATE FAMMENIAN AGE STORM-DOMINATED SUCCESSION AT BERROCAL (Iberian Pyrite Belt – Spain)

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SUMMARY

The Berrocal area is situated in the northern limb of Valverde del Camino anticlinal in the Spanish sector of the Iberian Pyrite Belt and exposes the upper part of the Phyllite-Quartzite Group. Recent studies on palynostratigraphy and sedimentology of the Berrocal section indicates that the stratigraphic succession is late Famennian age (VH miospore biozone) and was accumulated on the offshore zone of a siliciclastic shelf dominated by storm events.

Keywords: Late Famennian, palynomorphs, tempestites, Pyrite Belt, South Portuguese Zone

INTRODUCTION

The Berrocal area is located in the northern limb of Valverde del Camino anticlinal (Fig. 1) that belongs to Spanish sector of the Iberian Pyrite Belt (IPB), one of the richest and most prolific volcanic-hosted massive sulphide metallogenic provinces in the world. The IPB makes part of the South Portuguese Zone, a SW branch of the European Hercynian Orogen. The stratigraphic column of the IPB is characterized by an extremely reduced geologic record, from late Devonian to Carboniferous, and is commonly divided into three major units (Oliveira, 1990): the Phyllite Quartzite (PQ) Group, comprising the IPB´s basal detritic formation (Upper Devonian); the Volcano Sedimentary Complex, an assemblage of alternating felsic and mafic volcanic rocks within a detritic sedimentary sequence, hosting massive sulphide deposits (Late Famennian to mid Late Viséan), and the Upper Carboniferous Baixo Alentejo Flysch Group (mid Late Visean to Bashkirian).

The PQ group commonly lies in the core of anticlines (such as Valverde del Camino) and has been described as more than 1000m-thick monotonous sequence of shales and sandstones, deposited in epicontinental sea environment (Oliveira, 1990). The homogeneous feature of the sequence changes near the top by the increase of the sand/lutite ratio and appearance of sedimentary facies such as fan-deltas, near-shore bars, mega-debris flows and some limestone lenses, suggesting a collapse and fragmentation of the stable continental platform (Moreno et al., 1996).

The core of the Valverde del Camino anticline represents the largest exposed area of the PQ rocks throughout all IPB, which was folded and thrusted during Variscan Orogeny according to thin-skinned tectonics (Silva, 1990). The Berrocal section along the road cuts HV-5137 and HV-5131 is one of the rare places where the top succession of the local PQ sequence is well exposed. The upper PQ levels are characterized by the occurrence of intercalations of shales with sandstones. In this area the PQ rocks are conformably overlain by a thick sequence of basic rocks of the Volcano Sedimentary Complex.

SEDIMENTARY FACIES AND ENVIRONMENTAL INTERPRETATION

The stratigraphic information presented here resulted from the detailed logging of road-cuts exposed along roads HV-5137 and HV-5131 (Fig. 2). The sedimentary succession of the PQ group at Berrocal (Fig. 3) is composite with a measured thickness of *ca.* 980 m. The upper part of this succession is 695 m thick and is well exposed along road HV-5137 between points A and B (Fig. 2), whereas the bottom part of the succession, corresponding to a thickness of 275 m, is exposed along road HV-5131 between points C and D. Breaks in the sedimentary succession are frequent, especially in the part between points C and D due to intense faulting and folding. The 150 m break, observed in the upper part of the succession, starting at the depth of 416 m, corresponds to a section of the road with no outcrop, possibly due to intense tectonism.

Four principal lithofacies were recognised: Shale, Siltstone, Quartzite and Greywacke Lithofacies. The Shale Lithofacies consists of grey to black siliceous shales exhibiting parallel laminae and are interbedded with mostly nongraded, laminated grey siltitic beds with an average thickness of 1 – 2 cm. The fine grade and the parallel lamination displayed throughout this lithofacies suggest deposition from suspension in the offshore part (bellow storm wave base) of an epicontinental sea. The Siltstone Lithofacies occurs essentially in the lower part of section outcropping in road HV-5137. It consists of centimetric (1-2 cm thick) beds of nongraded silt interbedded with parallel laminae of mud.

Particularly important in the Berrocal stratigraphic succession is the Quartzite Lithofacies. This lithofacies occurs throughout the succession either as single beds or as tabular bodies, with several metres thick, formed by tens to hundreds of amalgamated beds. The thickness of the quartzite beds ranges from 3 cm to 20 cm, having an average of 10 cm. This lithofacies is composed of very fine to medium sand grade. The main internal sedimentary structure exhibited by the quartzite beds is hummocky cross stratification (HCS) (figure 4). Wave ripple cross stratification (WCS) is a very rare feature in these beds and suggest that deposition occurred essentially bellow fairweather wave base. Palaeocurrents measured from WCS of 30 beds, in the interval between 120 – 135 m, indicate direction of sediment transport from E, SE, SW and W. Amalgamated quartzite beds are the dominant lithofacies in several parts of the succession (e.g. between 110 and 145 m) and are considered to represent frequent episodes of storm deposition above storm-wave base (Dott & Bourgeois, 1982), typically on the lower shoreface or offshore transition zone, close to the fairweather wave base. The single beds of quartzite with HCS, which occur throughout the section, reflect the alternation of slow fairweather mud/silt deposition with storm-emplaced sands on a siliciclastic shelf between the fairweather and storm-wave bases (Dott and Bourgeois, 1982; Walker and Plint, 1992).

The Greywacke Lithofacies consists of parallel beds of sand-sized clasts, mostly quartz, and a clay-sized matrix. Bed thicknesses range from 10 cm to up 1 m, averaging about 30 cm. The beds are usually normal graded and in the ones with well-developed sedimentary structures, these are comparable to the Bouma sequence. The range of sedimentary structures described above is typical of deposition by turbidity currents. Two beds consisting of matrix-supported conglomerates, located towards the top and base of the section, were also observed, although due to its minor distribution were not described as a new lithofacies. The internal sedimentary structures suggest that they are mass flows deposited, possibly, during periods of tectonic instability.

Sediments represented in the Berrocal stratigraphic succession accumulated, generally, on the offshore zone of siliciclastic shelf below the fairweather wave base dominated by storm events. The amalgamated quartzite beds with HCS represent the shallower sediments, possible deposited by frequent storm events on the lower shoreface zone. Conversely, the greywacke beds are considered to be the sediments that accumulated in deeper waters. Intervals of the succession with quartzite beds showing HCS interbedded with siltstone and/or mudrock beds are considered to be sediments that accumulated on the offshore zone between fairweather and storm wave bases.

PALYNOSTRATIGRAPHY

The palynostratigraphic study is based on 21 rock samples collected along the road HV-5137 (Figure 1). Standard palynological laboratory procedures were employed in the extraction and concentration of the palynomorphs (Wood et al., 1996). The slides were examined with transmitted light, with a BX40 Olympus microscope equipped with an Olympus C5050 digital camera. All samples, residues and slides are stored in the Geological Survey of Portugal/INETI, S. Mamede Infesta, Portugal. The spore biozonal scheme used follows the standard Western Europe Miospore Zonation (Higgs et al., 1988; Higgs et al., 2000 and Maziane et al., 2002).

The dark shales of the PQ in the Berrocal section, along the road cut studied HV-5137, revealed moderately to well preserved miospore assemblages assigned to the VH Biozone of late Famennian age. The assemblages include *Grandispora echinata* that indicates the base of the biozone, together with *Ancyrospora sp*, *Apiculiretusispora* sp., *Auroraspora macra*, *Cristicavatispora dispersa*, *Diducites versabilis*, *D. poljessicus*, *Emphanisporites annulatus*, *Grandispora cornuta, G. famenensis*, *G. gracilis*, *Plicatispora* sp., *Punctatisporites* spp., *Retusotriletes planus*, *R. triangulatus*, *R. rugulatus*, *Rugospora explicata, R. radiata* and *Teichertospora iberica.* Rare acritarchs, prasinophytes and chitinozoans are present. Miospore tetrads are also very frequent. Palynomorph assemblages recovered are poorly sorted and larger taxa frequently occurs broken, suggesting torrential events, which substantiates the depositional environment.

The miospore assemblages recovered in shales interbedded in Quartzite Lithofacies, samples 18 and 24/25, respectively at *ca.* 280 and 970 m depth (Fig. 3), show some correspondence, marked by the presence of common miospore tetrads and chitinozoans in the assemblage. This palynostratigraphic evidence may suggest that this part of the stratigraphic sequence is tectonically repeated.

Comparison of the Berrocal section with palynostratigraphic records acquired from the South Portuguese Zone (Gonzalez, 2005; Oliveira et al., 2004; 2005; 2006; Pereira et al., 2006) indicates a number of similarities:

- PQ Formation in Berrocal Section is dated miospore biozone VH of Late Famennian age, with characteristic assemblages that contains a number of taxa, only documented in the SPZ (e g. *Cristicavatispora dispersa, Rugospora explicata* and *Teichertospora iberica*). These taxa are also common presence at the late Famennian assemblages of the Phyllite Quartzite Group in Portugal (Neves Corvo mine) and in Spain (Jarama River and Rio Tinto old Railway) in the Horta da Torre, Santa Iria and Represa Fms of the Pulo do Lobo Domain.
- miospore biozone VH of Late Famennian age was also recovered in the Volcano Sedimentary Complex of the Pyrite Belt in Portugal.

CONCLUSIONS

The following conclusions were reached from this study:

- PQ Formation in the Berrocal section is late Famennian age based on palynomorphs.
- The Berrocal stratigraphic succession accumulated, generally, on the offshore zone of siliciclastic shelf below the fairweather wave base dominated by storm events.

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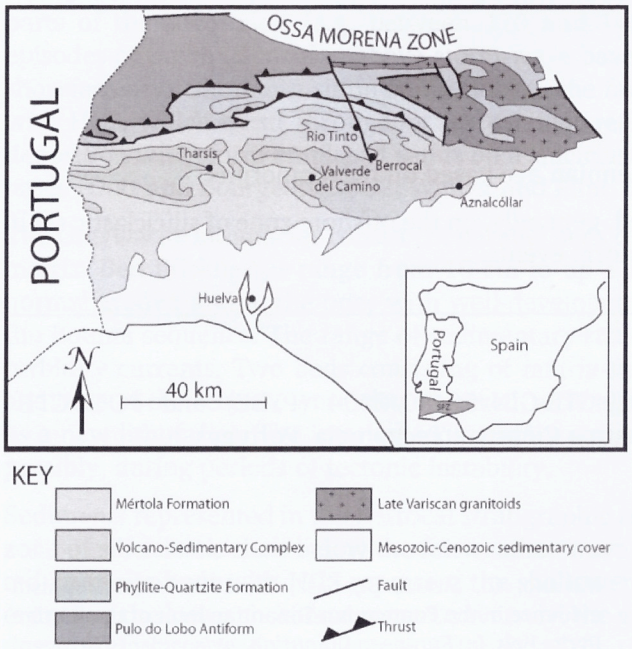

Fig. 1 Geological sketch map of the Berrocal section, Iberian Pyrite Bekt, Spain (Adapt. Oliveira et al., 1990).

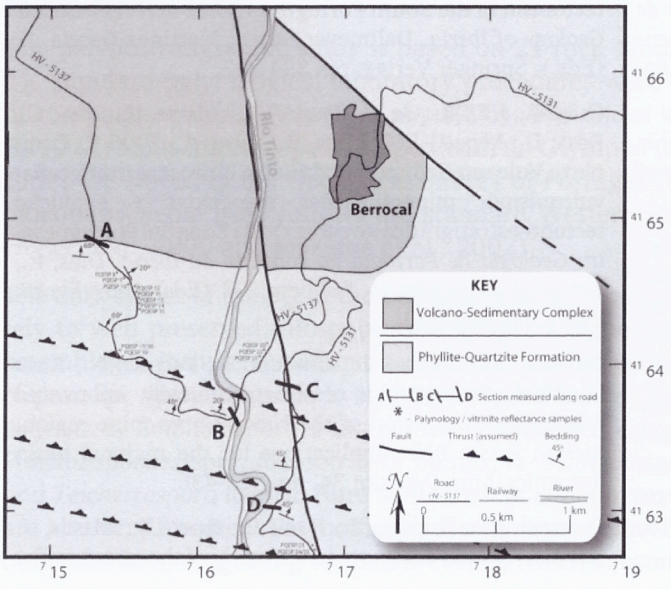

Fig. 2 Sample location and studied sections, along the HV-5137 and HV - 5131 roads in Berrocal region.

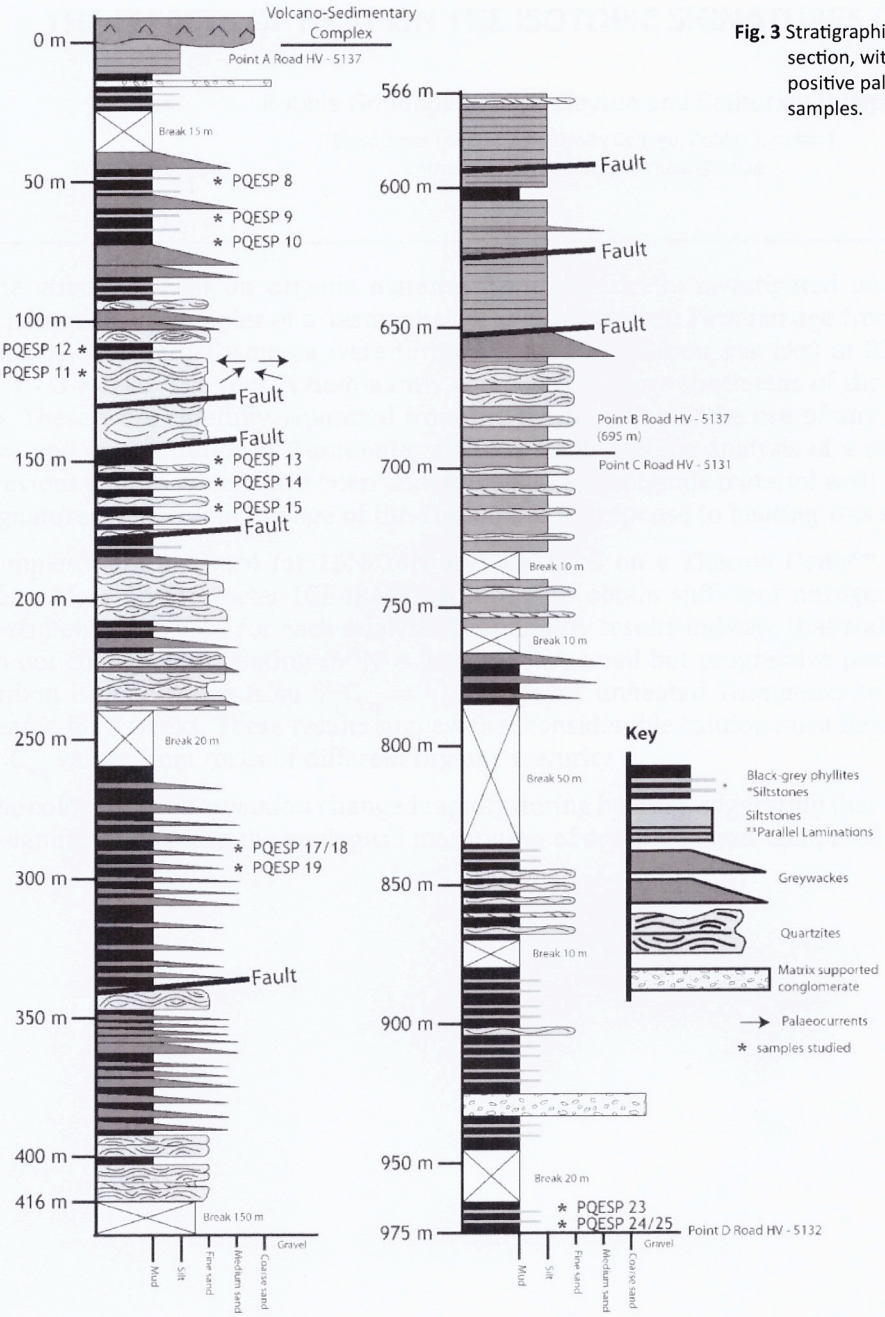

Fig. 3 Stratigraphic log of Berrocal section, with position of positive palynostratigraphic samples.

Fig. 4 Hummocky cross stratification in several quartzite beds. Quartzite lithofacies, approximatelly 125 m depth.