REPORT ON THE PALYNOSTRATIGRAPHIC STUDY OF THE BOREHOLES S. MARTINHO (SM11-01) and AZINHEIRA DOS BARROS (ADB02) - IBERIAN PYRITE BELT

MAEPA/AVRUPA

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INTRODUCTION

The Iberian Pyrite Belt (IPB) S. Martinho and Azinheira dos Barros sectors, located in the NW IPB region, were investigated by exploration boreholes performed by MAEPA/AVRUPA.

Palynostratigraphic studies were planned to be performed on the Paleozoic sediments, in order to complete the borehole study and to present information concerning the local stratigraphic sequence. The main purpose of the current investigation is to provide a detailed study of the age determinations of the two main IPB units, the Volcano Sedimentary Complex (VSC) and the Phyllite Quartzite Group (PQG). The methodology used is the biostratigraphic research based on the study of palynomorphs that include miospores and acritarchs. This information will provide new understandings on the stratigraphical model, in the local and regional geological context of the IPB.

A research contract was performed between LNEG and MAEPA/AVRUPA. This information is the final report of the study initiated with a sampling program carried out in the 11th June 2012.

GEOLOGICAL SETTING

The S. Martinho borehole is located 2,5 km WNW of Monte da Volta and was drilled in an identified Bouguer anomaly (Matos et al., 2009)

The S. Martinho SM11-01 borehole succession mainly consists of a series of sedimentary rocks of the PQG and VSC. The contacts between the two geological units are tectonic, represented by reverse faults. The VSC is represented by grey and purple shales interbedded with green siliceous shales. The PQG is represented by black strongly deformed shales with thin-bedded siltites and shales with centimetric quartzites and locally quartzwackes.

The Azinheira dos Barros geology is dominated by flysch sequence of the Mértola Formation and VSC sequence represented by basic volcanic rocks and a sedimentary

unit defined by grey shales and black shales, locally with disseminated pyrite. The sequence was sampled at the borehole ADB02.

MATERIALS AND METHODS

A total of fourteen samples of green and grey to black shales recovered in the borehole SM11-01 and sixteen samples collected in the borehole ADB02, were investigated for palynostratigraphy. Sample details and the main results achieved are listed in Table 1 and 2.

Standard LNEG palynological laboratory procedures were employed in the extraction and concentration of the palynomorphs. 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 LNEG S. Mamede Infesta.

The spore biozonal scheme used follows the standard Western Europe Miospore Zonation (after: Clayton et al., 1977; Streel et al., 1987; Higgs et al., 1988; MAziane et al., 1999; Pereira et al., 2007; 2008).

The presence of typical local miospore assemblages in the Devonian/Carboniferous of Portugal led to the use of the modified biozonal scheme proposed by Pereira et al., 2007; 2008.The defined zonal taxa used are presented in Figure 1.

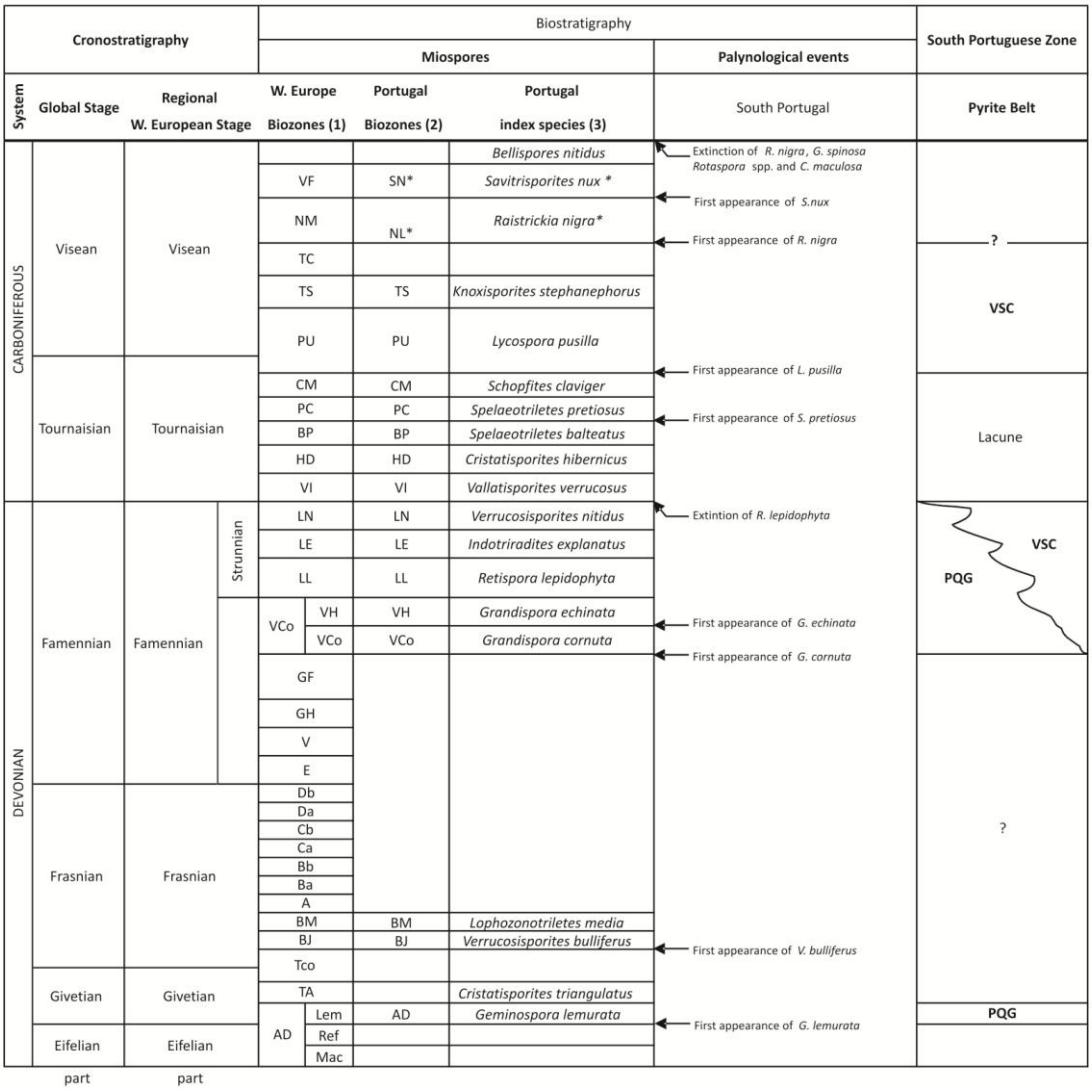

Figure 1. Devonian and Carboniferous Zonal Scheme Proposed for the Iberian Pyrite Belt, and South Portuguese Zone (1. Western European Miospore Zonation (CLAYTON et al., 1977; STREEL et al., 1987; HIGGS et al., 1988, MAZIANE et al., 1999); 2. South Portugal Miospore Zonation (PEREIRA, 1999); 3. Defined index species used for the latest Devonian and Carboniferous of the Iberian Pyrite Belt and South Portuguese Zone (PEREIRA et al., 2007, 2008).

PALYNOLOGY

When possible borehole logs were prepared (see Figure 2, for SM11-01). Ranges of selected palynomorphs taxa recovered and the zonal schemes used are presented in Figure 3 and 5. Stratigraphically important and typical taxa are illustrated in Plates I-III.

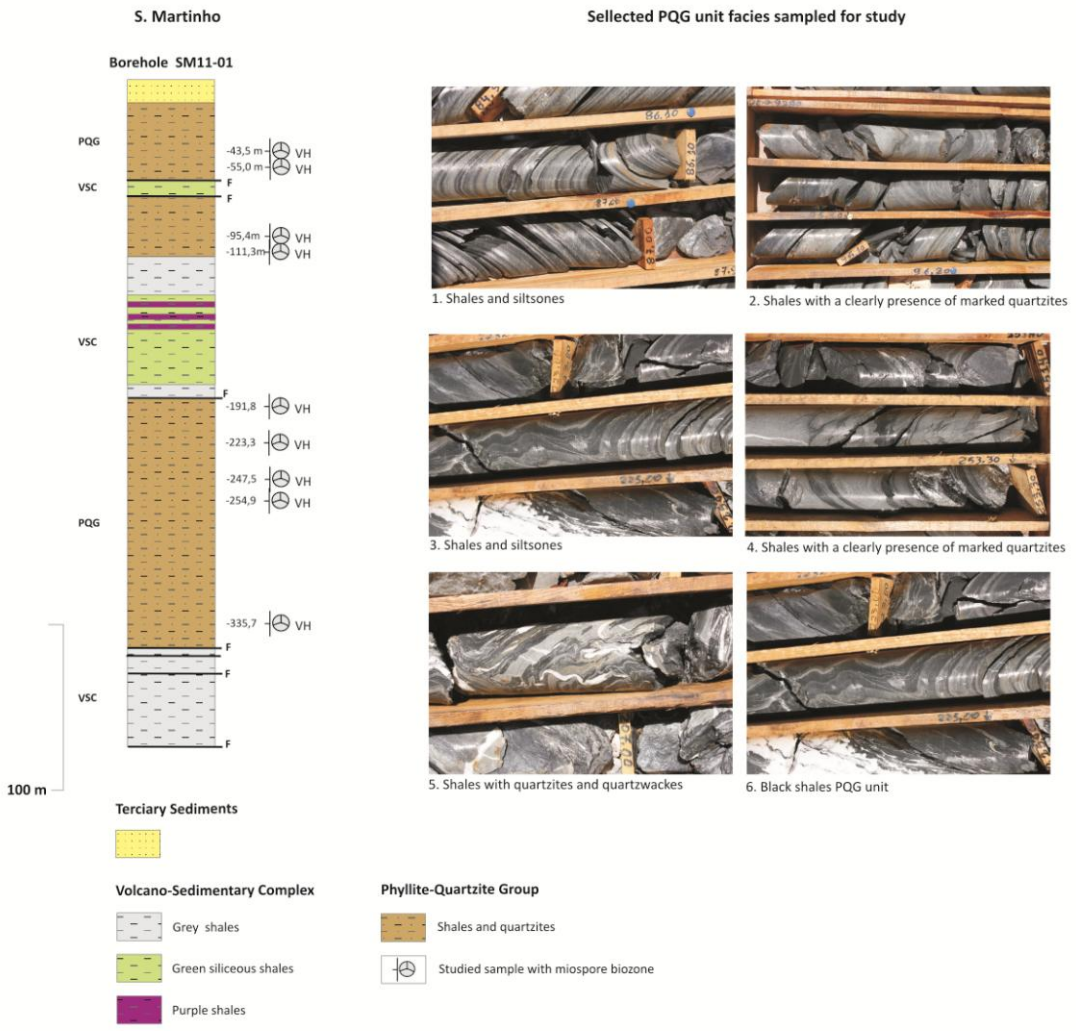

Figure 2. Log from borehole SM11-01 from S. Martinho region, with positive samples and the main results obtained. Photographs of the borehole illustrate the facies sampled.

S. MARTINHO SECTOR
Palynostratigraphy of the Borehole SM11-01

The detailed study of the borehole SM 11-01 is presented in Figure 2 were a complex geological sequence was observed, represented by three layers of Phyllite-Quartzite Group unit (PQG) sediments (shales and quartzites) intercalated with Volcano-Sedimentary Complex (VSC) sediments (grey shales, purple shales and grey to black shales). No volcanic rocks were intersected in the borehole.

Palynostratigraphy research carried on in the S. Martinho borehole **SM11-01**, allows the following main results (see figure 2 and 5):

- All the PQ units intersected were dated Late Famennian (Figure 2 and 5).
- None of the VSC sediments sampled present organic matter and no results were obtained.

- In detail the following PQ intersections were studied:

1. **Interval 10,3-60,5m** - Shales and quartzites, dated Late Famennian based on a moderately to well preserved assemblage of miospores and acritarchs, assigned to the VH Biozone, Late Famennian age;

Shales assigned to the PQG, at the upper part of the borehole were studied previously (Report, 2011). The composite sample from the superficial levels at 55,0m and the sample 60,50 m, corresponding to the black to grey shales assigned to the PQG (figure 3), yielded a moderately to well preserved miospore assemblage assigned to VH Miospore Biozone of the late Famenian (Upper Devonian) age.

Figure3. Borehole SM11-01 (composite sample 55m), shale fragments tested for palynostratigraphy studies PQG unit.

2. **Interval 68,0-114,5 m** - Shales with a clearly presence of marked quartzites beds below the 93 m (figure 4), assigned to the PQG unit. Samples tested at this interval, allow to recover a moderately to well preserved assemblage of miospores and acritarchs, assigned to the VH Biozone, late Famennian age.

Figure 4. Shales with quartzites beds PQG unit.

3. **Interval 191,0-345,1 m** - Shales with quartzites and quartzwackes dated Late Famennian based on a moderately preserved assemblage of miospores and acritarchs, assigned to the VH Biozone, late Famennian age.

Miospores assemblages recovered, presents a moderately to well preserved specimens, that include the guide species *Apiculiretusispora* cf. *verrucosa and Vallatisporites hystricosus* are assigned to the VH biozone of late Famennian age. Other taxa present and identified, complete the assemblages *Ancyrospora* sp., *Ancyrospora andevalensis*, *Apiculiretusispora* sp., *A.* cf. *verrucosa, Auroraspora macra*, *Auroraspora* sp., *Crassispora* sp., *Cristicavatispora dispersa*, *Diducites spp.*, *Endoculeospora gradzinskii*, *Endosporites* sp., *Grandispora* sp., *Grandispora echinata, G. gracilis*, *Punctatisporites irrasus*, *P. minutus*, *Retusotriletes phillipsii, R. planus*, *R. triangulatus*, *R. rugulatus*, *Rugospora explicata* e *R. flexuosa.* The presence of *Endoculeospora gradzinskii* and *Grandispora echinata,* that occur for the first time the basal part of the VH Biozone, confirms the age (see figure 5 for selected species presented and stratigraphic distribution and Plates I – III).

All studied samples contain rich assemblages of acritarchs including *Gorgonisphaeridium sp., G. ohioense*, *G. plerispinosum*, *Micrhystridium* sp., *Multiplicisphaeridium* sp., *Palacanthus ledanoisii*, *P. tripus*, *Stellinium comptum*, *S. micropolygonale*, *Veryhachium* spp. and *Winwaloeusia* sp., and common prasinophytes *Cymatiosphaera* spp., *Leiosphaeridia* sp., *Maranhites* spp., *Pterospermella* sp..

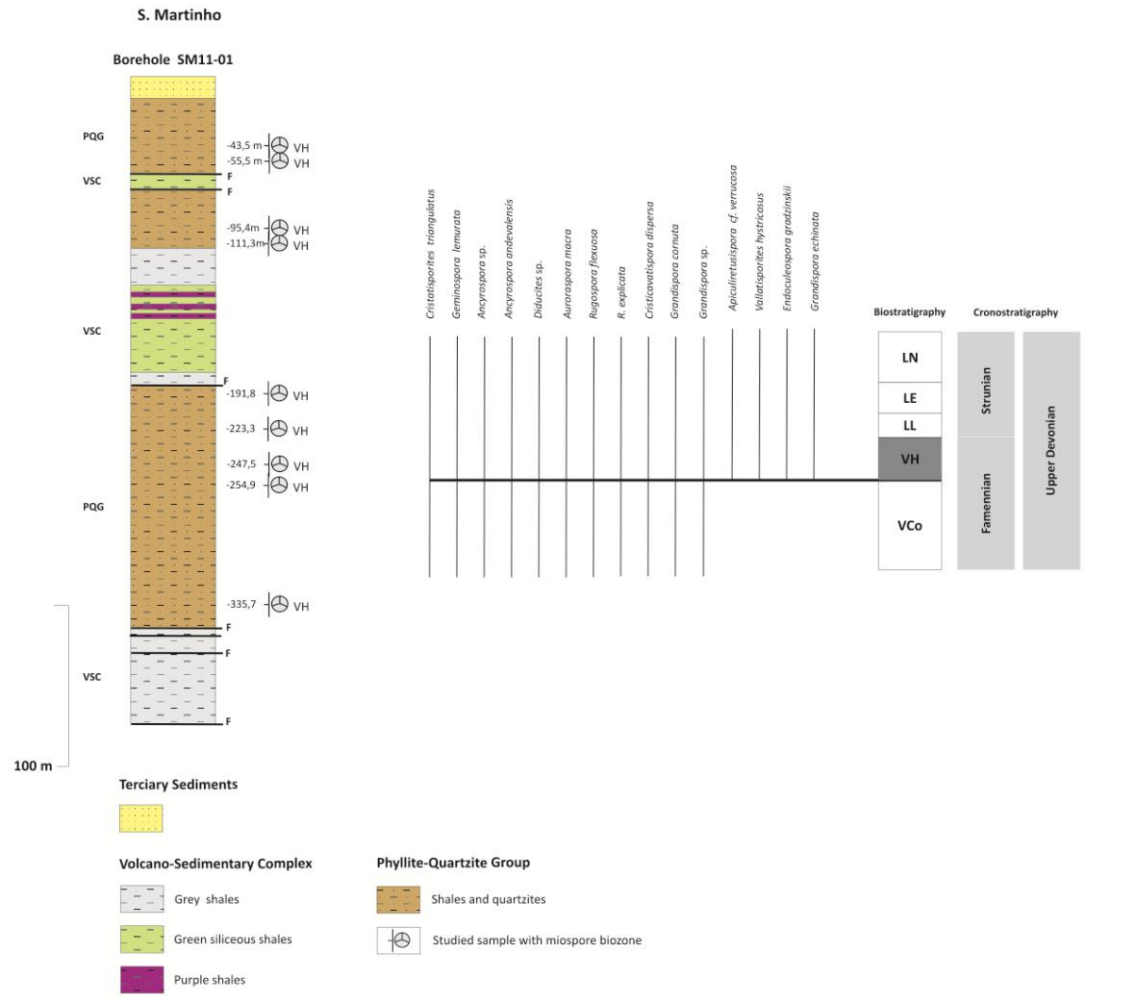

Figure 5. Selected important species assigned to VH Miospore Biozone, Late Famennian, identified in the SM11-01 borehole.

The lowest CVS unit (from 345,1m to 400,7m) presents green and purple shales locally affected by faulting (figure 6). These types of sedimentary facies are common in the upper part of the Volcano-Sedimentary Complex.

Figure 6. Upper VSC facies affected by intense faulting.

Considering the geological setting of the S. Martinho Sector in Iberian Pyrite Belt (see previous LNEG reports) the SM11-01 borehole did not intersected the basal units of the VS Complex were massive sulphide mineralizations commonly occur related with felsic volcanism and black shales of Strunian age. This could suggest, that the basal units of the VSC can be present at S. Martinho, but in more depth.

AZINHEIRA DOS BARROS SECTOR

Palynostratigraphy of the Borehole ADB02

The samples studied in the borehole ADB02 are presented in Table 2. The sequence observed in the borehole starts a flysch sequence of the Mértola Formation, were two samples were studied for palynostratigraphic research. Samples revealed very poor in organic matter content, some bad preserved miospores assemblages assigned to the Visean?, no miospore biozone was determined.

This unit is followed by a VSC sequence represented by basic volcanic rocks and a sedimentary unit defined by grey shales and black shales, locally with disseminated pyrite. This part of the sequence was sampled for palynostratigraphic studies. Only two samples revealed some organic matter and allowed the determination of rare misopores and prasinophytes assigned to the late Devonian. No miospore biozone was determined, due to the limited content in palynomorphs present in the samples.

FINAL REMARKS

The detail palynostratigraphic studies proved by LNEG to MAEPA/AVRUPA will be useful to constrain the geological models and to date the stratigraphic units present at the S. Martinho and Azinheira dos Barros IPB sectors. The presence of the PQG sediments with late Famennian age permit the correlation with other IPB areas.

In the S. Martinho case, the tectonic model defined by LNEG at the Serrinha sector (Matos et al. 2009) is confirmed, considering the presence of PQG intercalated with upper VSC sequences characterized by purple and green shale occurrence (e.g. Neves Corvo area stratigraphic sequence, Pereira et al. 2008).

The palynostratigraphic data allows to establish correlations between units and stratigraphic sequences, particularly valuable to constrain the geological models, structural and geodynamics interpretations, in particular geological settings favorable to the occurrence of massive sulphides deposits.

Considering the recent research carried on by LNEG team for several companies (Lundin/Somincor, Neves Corvo mine; AGC, Aljustrel and now for MAEPA/AVRUPA in the NW sector of the Belt), the palynostratigraphy revealed important to support the regional and local stratigraphic models and to define the prospecting models (Pereira et al., 2004; Oliveira et al, 2006; Matos et al., 2010; Oliveira et al., 2012; Pereira et al., 2012).

LNEG team strongly recommended a follow up of the palynostratigraphic studies to confirm the local geological sequences observed at the region, including outcrop sampling programs. These studies will permit a correct correlation between borehole and outcrop data. Like in other Iberian Pyrite Belt complex sectors the palynostratigraphy research is a very important methodology to characterize the local sequences and polarity and their correlation with other IPB regions where massive sulphide deposits are known.

The research on the Late Devonian age, and in particular on the Late Strunian age is therefore a value in development in the context of IPB. This level becomes an

important key stratigraphic horizon in the Iberian Pyrite Belt and an exploration guide, showing a favorable geological time period of ~2 Ma were the paleogeographic conditions were extremely favorable to hydrothermal fluid circulation and VMS deposits formation (Matos et al., 2011; Pereira et al., 2012).

Aknowlegments

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TABLES

Sector	Borehole	PALINO	Litology	Unit	Palynostratigraphic data and ages obtained	
S. Martinho	**SM11-01**	**43,5**	Grey shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**55,0**	Grey shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**60,5**	Grey shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**95,4**	Shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**111,3**	Grey shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**127,0**	Grey shales	CVS - XBv?	no organic matter present	no information
S. Martinho	**SM11-01**	**177,0**	Grey shales	CVS - XBv?	no organic matter present	no information
S. Martinho	**SM11-01**	**187,4**	Grey shales	CVS?	no organic matter present	no information
S. Martinho	**SM11-01**	**191,8**	Grey shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**223,3**	Grey shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**247,5**	Grey to black shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**254,9**	Grey to black shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**335,7**	Grey to black shales	**PQ**	**Miospore Biozone VH**	**Late Famenian age**
S. Martinho	**SM11-01**	**362,0**	Grey to black shales	CVS - XBv?	no organic matter present	no information

Table 1. Samples studied in borehole SM11-01.

Sector	Borehole	PALINO	Litology	Unit	Palynostratigraphic data and ages obtained	
Azinheira dos Barros	**ADB02**	**253,1**	Black shales	Mértola	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**350,2**	Grey Shales	Mértola	rare miospores present	**Visean?**
Azinheira dos Barros	**ADB02**	**438,0**	Dark grey shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**473,4**	Dark grey shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**505,4**	Dark grey shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**510,8**	Dark grey shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**550,9**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**588,1**	Dark grey shales banded	PQ?	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**598,5**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**608,8**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**618,8**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**623,5**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**662,7**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**673,0**	Black shales	CVS	no organic matter present	no information
Azinheira dos Barros	**ADB02**	**685,7**	Black shales	CVS	rare miospores and prasinophytes present	**Devonian?**
Azinheira dos Barros	**ADB02**	**688,5**	Black shales	CVS	rare miospores present	**Devonian?**

Table 2. Samples studied in borehole ABD02.

PLATE 1

Plate captions list the taxonomic name of the figured selected specimen, followed by the formation, sample number, slide number and microscopic coordinates.

Fig. 1. *Apiculatiretusispora* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1300-55.

Fig. 2. *Verrucosisporites* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1415-28.

Fig. 3. *Cristicavatispora dispersa* Gonzalez, Playford & Moreno, 2005; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1135-58.

Fig. 4. *Geminospora lemurata* Balme emend Playford, 1983; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1325-120.

Fig. 5. *Rugospora flexuosa* (Jushko) Streel, 1974; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1240-200

Fig. 6. *Geminospora lemurata* Balme emend Playford, 1983; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1423-45.

Fig. 7. *Endoculeospora gradzinskii* Turnau, 1975; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1435-65.

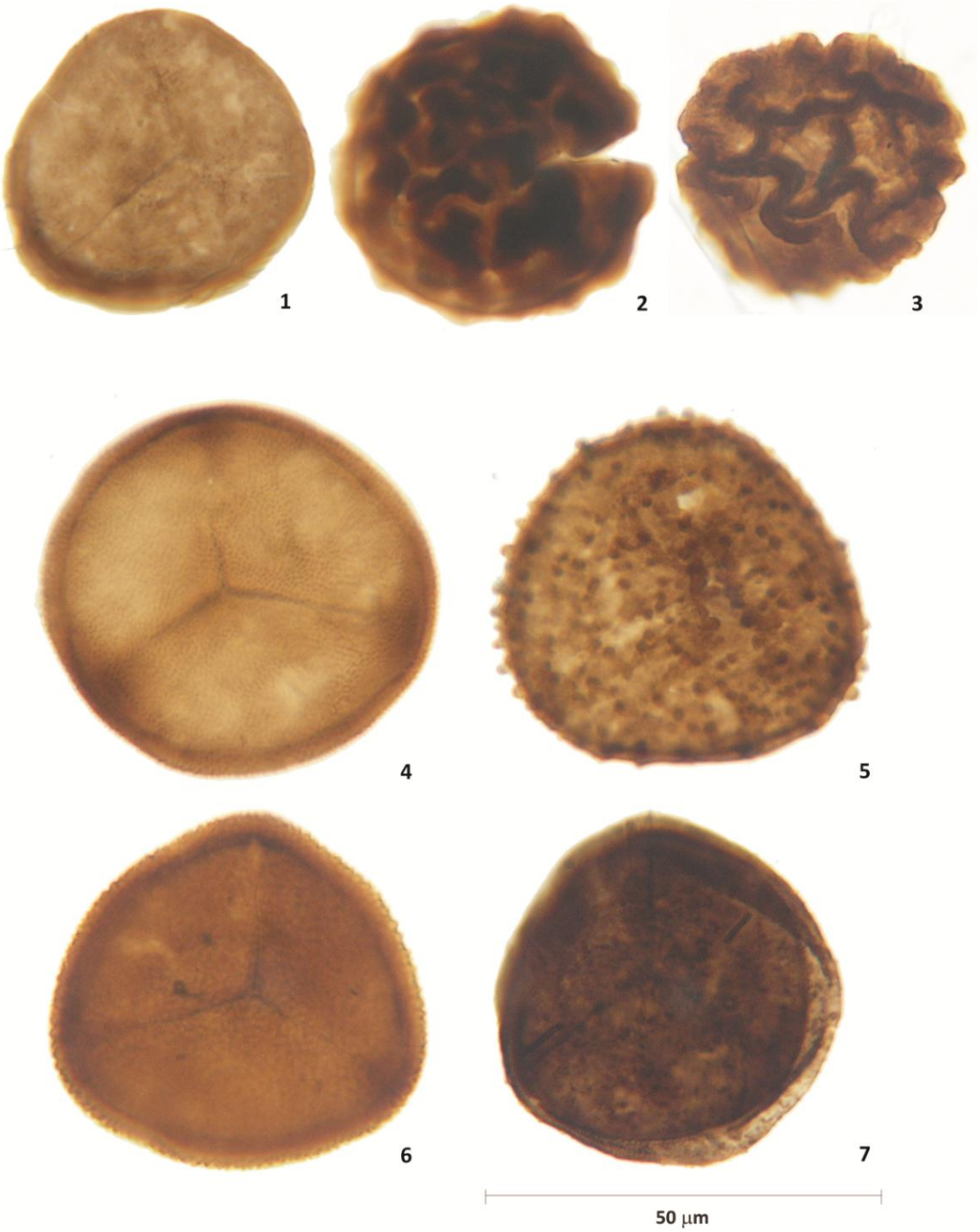
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PLATE 2

Fig. 1. *Grandispora echinata* Hacquebard emend Utting, 1987; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1280-200.

Fig. 2. *Grandispora* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1322-56.

Fig. 3. *Cristatisporites* sp.*;* PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1105-115.

Fig. 4. *Ancyrospora andevalensis* Gonzalez, Playford & Moreno, 2008; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1215-200.

Fig. 5. *Vallatisporites ?hystricosus* (Winslow) Byvsheva, 1985; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1270-130.

Fig. 6. *Auroraspora* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1290-80.

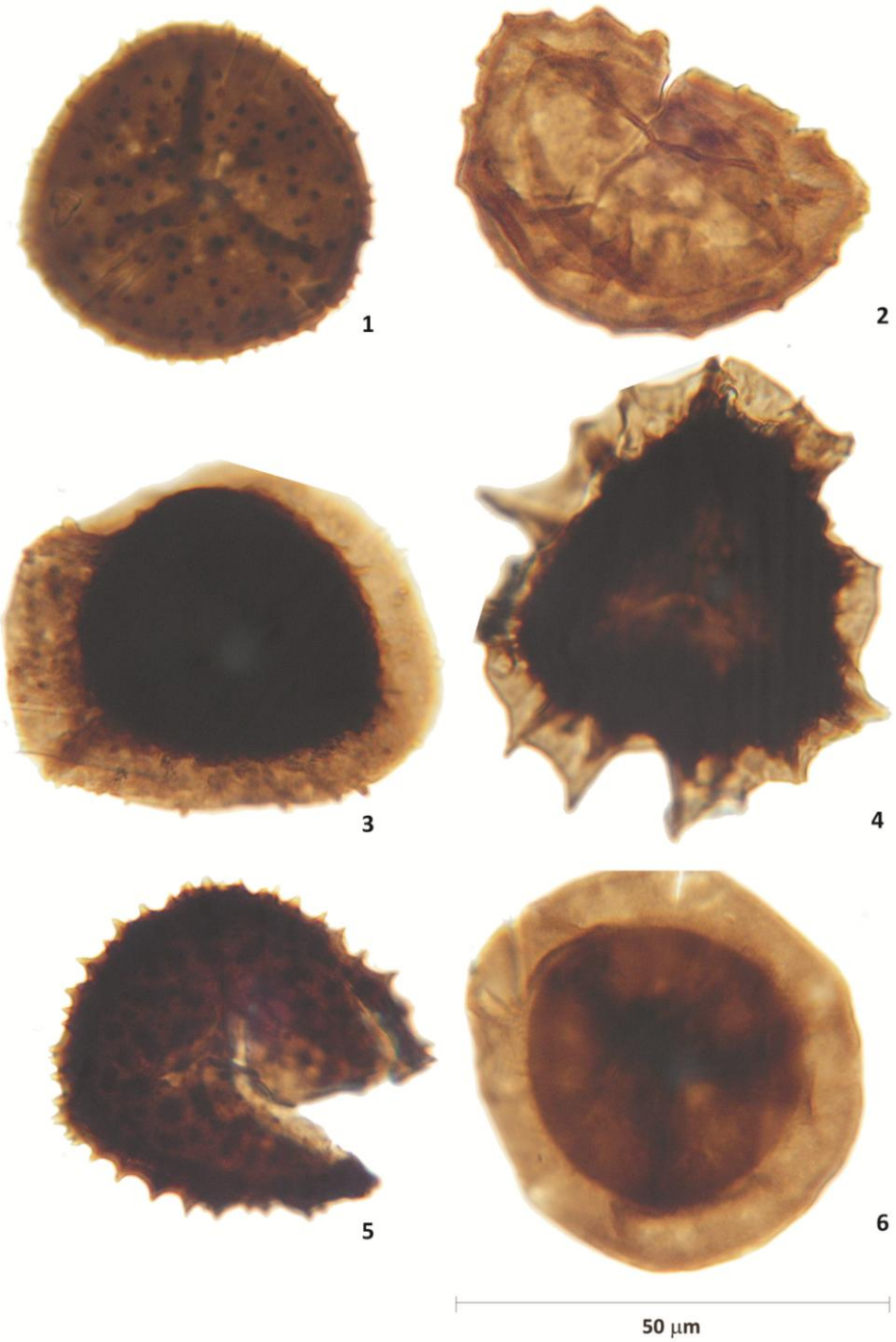
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PLATE 3

Fig. 1. *Gorgonisphaeridium plerispinosum* Wicander, 1974; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1456-25.

Fig. 2. *Gorgonisphaeridium plerispinosum* Wicander, 1974; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1300-65.

Fig. 3. *Gorgonisphaeridium* cf. *ohioense* (Winslow) Wicander, 1974; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1282-175.

Fig. 4. *Multiplicispheridium* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1154-68.

Fig. 5. *Dupliciradiatum* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1215-198.

Fig. 6. *Pterospermella* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1235-110.

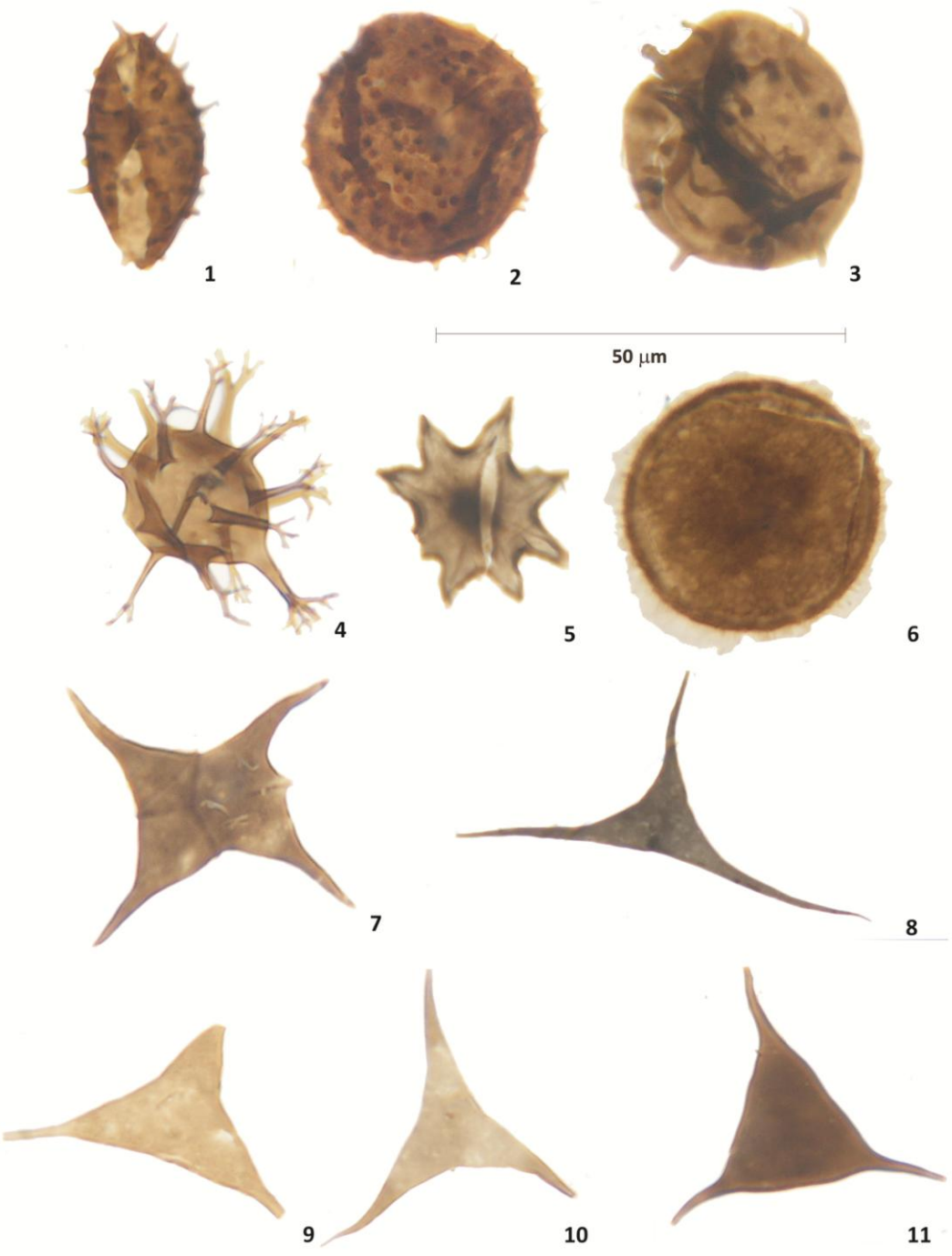
Fig. 7. *Winwaloeusia* sp.; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 2, 1335-190.

Fig. 8. *Veryhachium trispinosum* (Eisenack) Stockmans & Willière, 1962; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1025-100.

Fig. 9. *Veryhachium downiei* Stockmans & Willière, 1962; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1030-105.

Fig. 10. *Palacanthus ledanoisii* (Deunff) Playford, 1977; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1115-118.

Fig. 11. *Veryhachium trispinosum* (Eisenack) Stockmans & Willière, 1962; PQ Formation, borehole SM11-01, sample 43, 5 m, slide 1, 1265-75.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