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Devonian and Carboniferous palynostratigraphy of the South Portuguese Zone, Portugal – An overview.

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Keywords: Devonian, Carboniferous, Palynostratigraphy, South Portuguese Zone.

Abstract: The South Portuguese Zone (SPZ) represents the southern branch of the Iberian Variscides and comprehends the following geologic domains: the Pulo do Lobo Antiform, the Iberian Pyrite Belt, the Baixo Alentejo Flysch Group and the Southwest Portugal (Aljezur and Bordeira Anticlines). An overview of all the results recently achieved in palynostratigraphic research of selected sections all over the SPZ is presented. A chronostratigraphic correlation of the stratigraphic units recognized across the ZPZ and its geodynamic and palaeogeographic implications is attempted.

Palavras-chave: Devónico, Carbonífero, Palinostratigrafia, Zona Sul Portuguesa.

Resumo: A Zona Sul Portuguesa (ZSP) representa o ramo sul do Orógeno Varisco Ibérico e compreende os seguintes domínios, de norte para sul: o Antiforma do Pulo do Lobo, a Faixa Piritosa Ibérica, o Grupo do Flysch do Baixo Alentejo e o Sector Sudoeste (Anticlinais da Bordeira e Aljezur). No presente trabalho apresenta-se uma síntese dos conhecimentos palinoestratigráficos obtidos em secções seleccionadas dos vários domínios da ZSP. Os dados obtidos permitem estabelecer correlações cronoestratigráficas em toda a Zona Sul Portuguesa, contribuindo assim para o melhor conhecimento da sua evolução paleogeográfica e geodinâmica.

1. INTRODUCTION

The South Portuguese Zone (SPZ) represents the southern branch of the Iberian Variscides (Figure 1). It is almost entirely composed of Upper Palaeozoic sedimentary rocks of late Devonian to the Moscovian (Late Carboniferous) age. The following geological domains are recognized in the SPZ (Oliveira, 1990): the Pulo do Lobo Antiform, the Iberian Pyrite Belt, the Baixo Alentejo Flysch Group and the Southwest Portugal (Bordeira and Aljezur Anticlines).

The boundary between the Pulo do Lobo Antiform and the Ossa Morena Zone, a major shear zone, is in several places underlined by the Beja-Acebuches Ophiolite, a remnant of an oceanic realm closure. The Pulo do Lobo Antiform is currently interpreted as a Variscan palaeo-accretionary prism (Oliveira, 1990). The Iberian Pyrite Belt (IPB) was part of a late Devonian shallow siliciclastic sea that underwent crustal extention during the late Devonian (Strunian) and the lower Carboniferous giving rise to an impressive bimodal volcanism. Related with this volcanism near 90 massive sulphide deposits were formed. The Baixo Alentejo Flysch Group (BAFG) is composed of southwestward prograding sandy turbidites of Late Viséan to Moscovian age that filled a foreland basin. Finally, the Southwest Portugal Sector (SWPS) still part of the siliciclastic sea during the late Devonian, evolved to a distal carbonate/shale platform that only during the Moscovian became part of the Variscan orogeny.

The rock succession of the SPZ attracted researchers, particularly exploration companies, because of its famous IPB polymetallic massive sulphides ore deposits (e.g., the world class Neves Corvo deposit). Geological research was mainly concentrated on lithostratigraphy, petrology and geochemistry. More recently, biostratigraphy, sedi-

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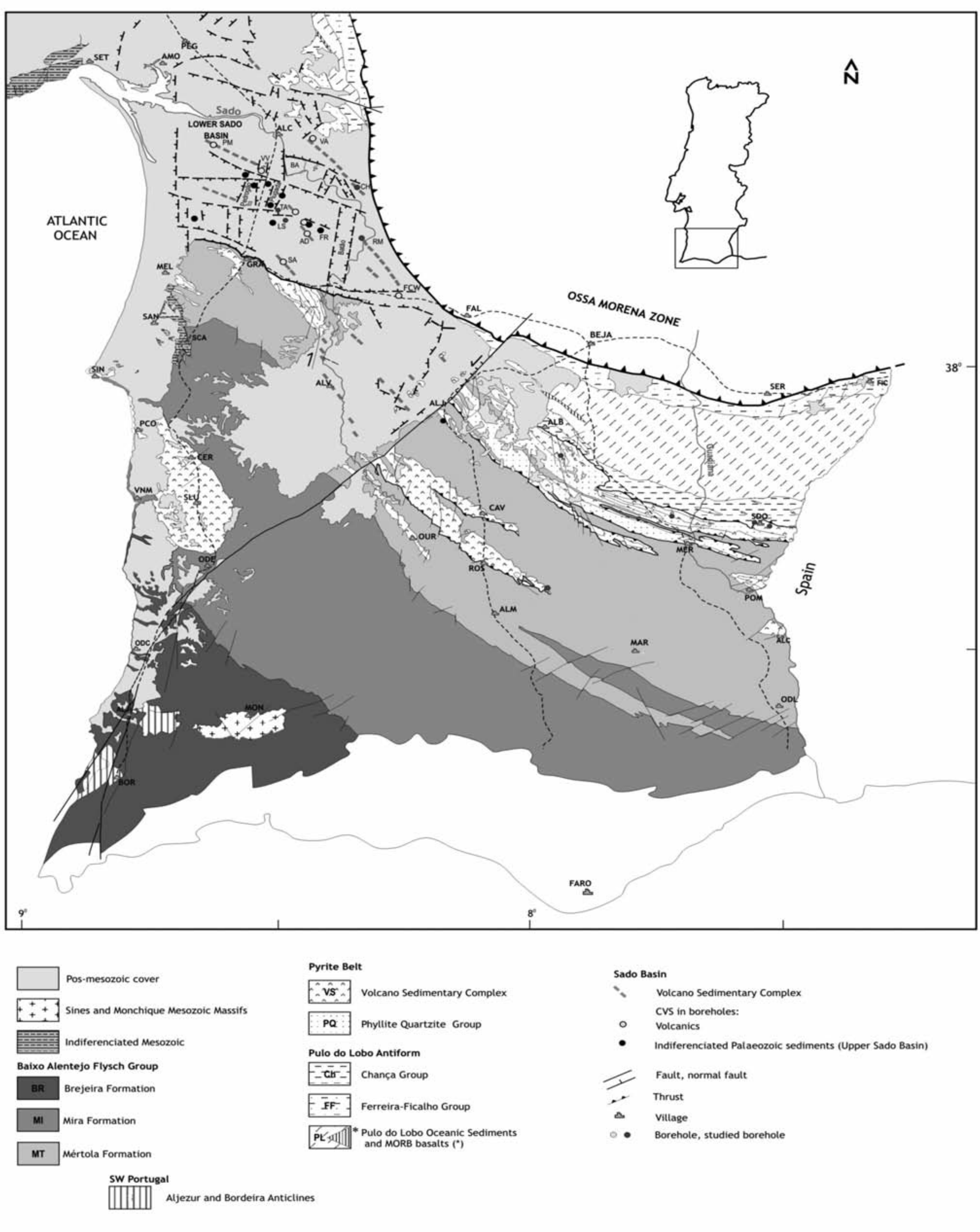

Fig. 1 – Geological sketch map of the South Portuguese Zone (adapted after Oliveira, 1990; Geological Map of Portugal 1/500 000, Oliveira *et al.* 1996).

mentary geology, physical volcanism and sediment geochemistry deserved more attention and are now current fields of research.

Palynological studies of the SPZ extend back to 1980s. Palynostratigraphy was for the first time tested in several units of the SPZ as part of a mapping programme carried out by the Portuguese Geological Survey (Oliveira *et al.*, 1986; Cunha & Oliveira, 1989). At that time palynostratigraphic work was also undertaken in the Spanish sector of the Pulo do Lobo Antiform (Giese *et al.*, 1988; Lake, 1991). In the following years more focussed projects on the biostratigraphy were developed.

Palynostratigraphy represents the best tool to date the SPZ lithostratigraphic units, allowing reliable stratigraphic correlations across the basins and giving support to structural, palaeogeographic and geodynamic interpretations. This paper presents an overview of all results recently achieved in palynostratigraphic research of selected sections all over the SPZ. The palynology data has allowed the establishment of the general chronostratigraphic correlation chart for all the domains of the SPZ (Figure 2).

2. METHODS

The studied samples were collected in complete outcrop sections, boreholes and occasionally spot samples. In the IPB, where a large number of boreholes are available, drilled by mining and exploration companies and by the Portuguese Geological Survey. Samples were preferably collected from cores and in a few cases samples were also collected from the mine addits (e.g., Neves Corvo and Aljustrel). In the SW Sector samples were mainly collected along the costal sections of the area.

Biostratigraphic research is based on palynomorphs and standard palynological laboratory procedures were employed in the extraction and concentration of the palynomorphs from the host sediments (Wood *et al.*, 1996). The slides were examined with transmitted light, per BX40 Olympus microscope equipped with an Olympus C5050 digital camera facility. All samples, residues and slides are stored in the Geological Survey of Portugal (LNEG – LGM). The miospore biozonal scheme used follows the standard Western Europe Miospore Zonations (after: Clayton *et al.*, 1977; Clayton 1996; Clayton *et al.*, 2003; Higgs *et al.*, 1988; Higgs *et al.*, 2000; Maziane *et al.*, 2002; Owens, 1996; Owens *et al.*, 2004; Streel *et al.*, 1987; Streel, 1996). The choice of alternative schemes was stated by the presence of very consistent local miospore assemblages in South Portugal. The defined zonal taxa used for the latest Devonian and Carboniferous of the South Portuguese Zone are presented in Figure 2. Stratigraphically important and typical taxa are illustrated in Plates I and II.

3. GEOLOGICAL SETTING AND PALYNOSTRATIGRAPHIC FRAMEWORK OF SPZ

This section deals with the stratigraphic palynology of all sections, boreholes and spot samples studied by the authors. Description of the new palynological data is presented here. In case of previously published data only a brief review is presented.

3.1. Pulo do Lobo Antiform

The Pulo do Lobo Domain is an antiformal structure located in the northern part of the SPZ, wher it is in direct contact with the Ossa Morena Zone (OMZ). In the core of the structure crops out the Pulo do Lobo Fm. and is composed of phyllites, quartzites, minor felsic volcanics and amphibolites (former basalts) with MORB-type geochemical affinity at the lower part (Munhá, 1983; Eden, 1991; Quesada *et al*., 1994).

In the north limb of the structure, the Ferreira-Ficalho Group (Figure 3) includes from base to top the following units (Carvalho *et al*., 1976; Oliveira *et al*., 1986; Giese *et al*., 1988; Oliveira, 1990; Eden, 1991; Quesada *et al*., 1994): the Ribeira de Limas Fm. is composed of phyllites, quartzwakes and minor intercalations of tuffites with a tectonic deformation similar to that of the Pulo do Lobo Fm.; the Santa Iria Fm. is made up of greywackes, siltstones and shales, forming a flysch-like succession; and the Horta da Torre Fm. is composed of dark shales, impure sandstones, siltstones and quartzite beds with strong bioturbation. The Santa Iria and Horta da Torre Fms. are affected by a main folding phase with associated cleavage. The group thickness is unknow, but estimated at 500 m.

The south limb of the structure is represented by the Chança Group (Figure 3), which comprises the following units (Pfefferkorn, 1968; Silva, 1989; Cunha & Oliveira, 1989; Oliveira, 1990; Silva *et al*., 1990): the

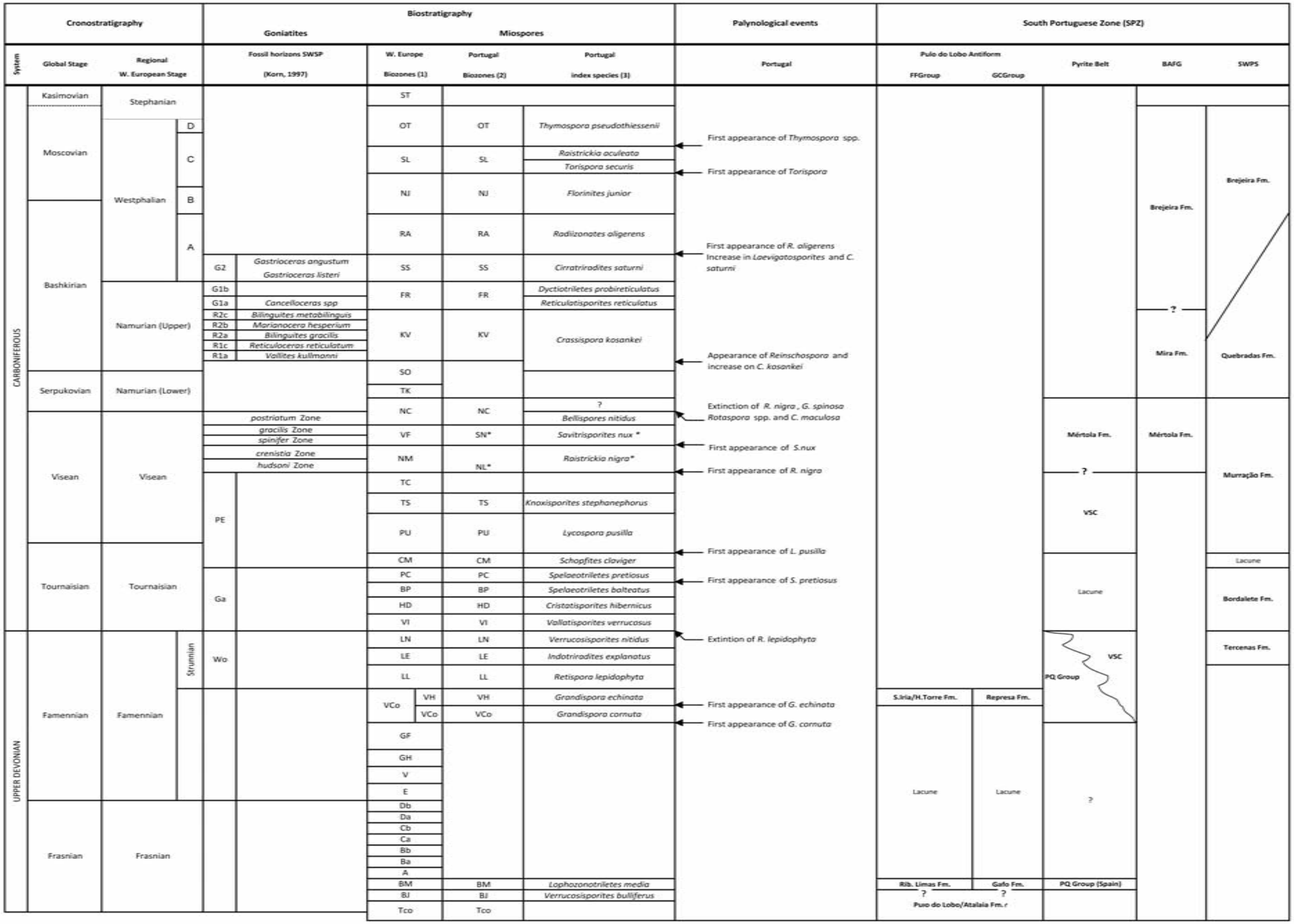

Fig. 2 – Latest Devonian and Carboniferous of SPZ. (1. Western European Miospore Zonation (CLAYTON *et al.*, 1977; CLAYTON 1996; CLAYTON *et al.*, 2003, HIGGS *et al.*, 1988; HIGGS *et al.*, 2000; MAZIANE *et al.*, 1999; OWENS, 1996; OWENS *et al.*, 2004; STREEL *et al.*, 1987; STREEL, 1996); 2. South Portugal miospore Zonation (PEREIRA, 1999); 3. Defined guide taxa used for the latest Devonian and Carboniferous of the South Portuguese Zone (PEREIRA *et al.*, 2007; Present work)).

Atalaia Fm. composed mostly of phyllites and quartzites, sharing with the Pulo do Lobo Fm. the same type of tectonic deformation; the Gafo Fm. made up of a thick pile of greywackes siltstones and shales forming a flysch succession, with intercalations and intrusions of felsic and mafic volcanics showing two main episodes of NW trending folds and related cleavages; and the Represa Fm. which is composed of siliceous siltstones, shales, greywackes and minor intercalations of fine volcanogenic sediments. The group thickness is estimated at 1100 m.

The overall structure has been interpreted as an anticline (Schermerhorn, 1971; Carvalho *et al.*, 1976; Oliveira *et al.*, 2006; Pereira & Oliveira, 2006; Pereira *et al.*, 2006a, b) as an accretionary prism related to a northward dipping subduction (Silva *et al.*, 1990; Quesada *et al.*, 1994, Silva, 1998) and as a suspect terrain (Ribeiro *et al.*, 1990).

3.1.1. Pulo do Lobo palynostratigraphy

The Pulo do Lobo Antiform units were recently investigated for palynostratigraphy (Pereira *et al.*, 2006, Figure 2, 3). No age determinations were achieved for the Pulo do Lobo and Atalaia Fms., probably due to the high grade of metamorphism that affected these units, however the sequence is older than early Frasnian. The

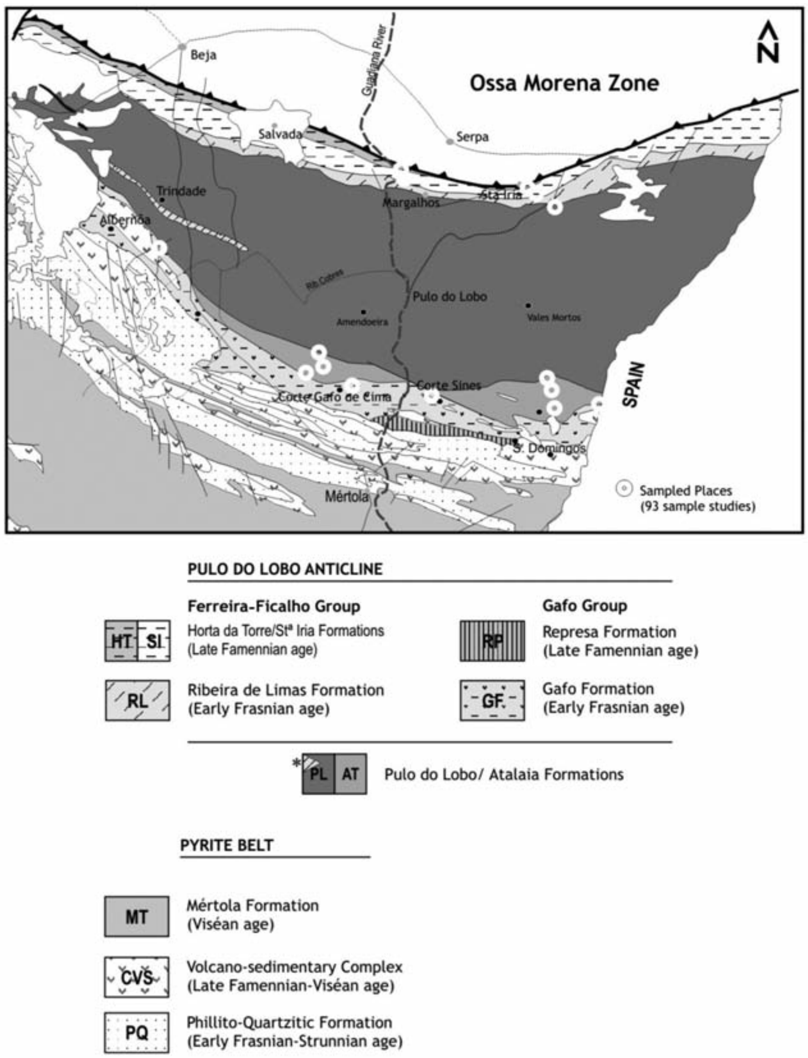

Fig. 3 – The Pulo do Lobo Geology (and studied localities).

Ribeira de Limas and Gafo Fms. revealed the presence of moderately preserved miospore assemblages assigned to the BM Biozone of lower Frasnian age. The assemblage includes *Aneurospora greggsii*, *Chelinospora concinna*, *Cristatisporites triangulatus*, *Cristatisporites* sp. cf. *C. inusitatus, Cymbosporites* sp., *Emphanisporites rotatus*, *Geminospora lemurata*, *Lophozonotriletes* sp., *Verrucosisporites bulliferus, V. premnus* and *V. scurrus*. All samples contain rare acritarchs and prasinophytes.

The Santa Iria, Horta da Torre and Represa Fms. yielded well-preserved assemblages of miospores assigned to the VH Biozone of late Famennian age (Pereira *et al*., 2006 a,b). The assemblages include abundant *Grandispora echinata* which indicates the base of the biozone, together with *Ancyrospora* sp., *Ancyrospora? implicata, 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.* All samples contain very rich assemblages of acritarchs and prasinophytes.

The early Frasnian and late Famennian ages of the Ribeira de Limas/Gafo sequence and Santa Iria-Horta da Torre/Represa sequences indicate they are separated of about 14 My. This fact reinforces previous structural interpretations that suggested the existence of an unconformity between the Santa Iria/Horta da Torre Fms. and the underlying Ribeira de Limas Fm..

The stratigraphic correlations of these units of both limbs of this antiform suggests that these were part of the same sedimentary basin that appears to have been superimposed over an acretionary prism, now preserved in the Pulo do Lobo/Atalaia Fm. (Pereira *et al*., 2006a,b).

3.2. Iberian Pyrite Belt

In general terms, the stratigraphy of the Iberian Pyrite Belt (Figure 4) consists of two major units, the Phyllite Quartzite Group (PQG) and the Volcanic-Sedimentary Complex (VSC). The PQG is dated as late Devonian age by ammonoids, conodonts and palynomorphs (Boogaard, 1967, Fantinet *et al.,* 1976; Cunha & Oliveira, 1989; Oliveira *et al*., 1997; Oliveira *et al*., 2004, Pereira *et al.*, 2004). The PQG forms the detritic basement and is composed mostly of phyllites, quartzites, quartzwackes and shales with intercalations of limestone lenses and nodules at the upper part of this unit, which as a whole were laid down in a marine siliciclastic platform. The thickness is in excess of 200m (base not known). The VSC is dated as late Devonian to late Viséan age principally on palynomorphs and rare conodonts (Oliveira, 1990; Oliveira *et al.*, 1997, Oliveira *et al.*, 2004; Pereira *et al.*, 2004). The VSC incorporates several episodes of intrusive and extrusive volcanism, with dominant rhyolites, dacites, basalts and minor andesites, and intercalations of black shales, siltstones, minor quatzwackes, 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 was laid down in a deep submarine environment.

Regionally the belt is divided into two branches (Oliveira, 1990): the North and the South branch (Figure 4). The North branch extends from Palma (Alcácer do Sal), below the Cenozoic sediments of the Sado Basin (at the west), to Mina de São Domingos mine (at the east) (V. Oliveira *et al.,* 1998a, b; Matos *et al.*, 1998, 2000, 2003). This branch incorporates both autochthon sections, where it is possible to identify the VSC sequence overlain by the Freixial Fm. turbidites, and allochthon sections composed of several tectonic sheets that include PQG sediments and VSC volcanics and sediments. The South branch refers to the rooted anticlines and extends from the Pomarão Anticline (west termination of the Puebla de Guzmán Anticline in Spain) through the Neves Corvo-Rosário Anticline to the Lousal region (Figure 4). Conformably above the VSC is a turbidite succession, known as Mértola Fm. which is the lower unit of the Baixo Alentejo Flysch Group (BAFG).

3.2.1. Iberian Pyrite Belt palynostratigraphy

The selected lithostratigraphic sections investigated for palynostratigraphic purposes are depicted in Figure 4.

In the **North branch** three sections were studied, i.e., **Albernôa, Serra Branca and Mina de São Domingos**. The palynomorph assemblages were recovered mostly from drill cores, complemented with outcrop samples. Within the autochthon successions, moderately preserved miospore assemblages were identified in shales interbedded in the lower part of the VSC and doubtly in shales of the PQG (Albernôa). These assemblages are assigned to the VCo and VH Bizones of late Famennian

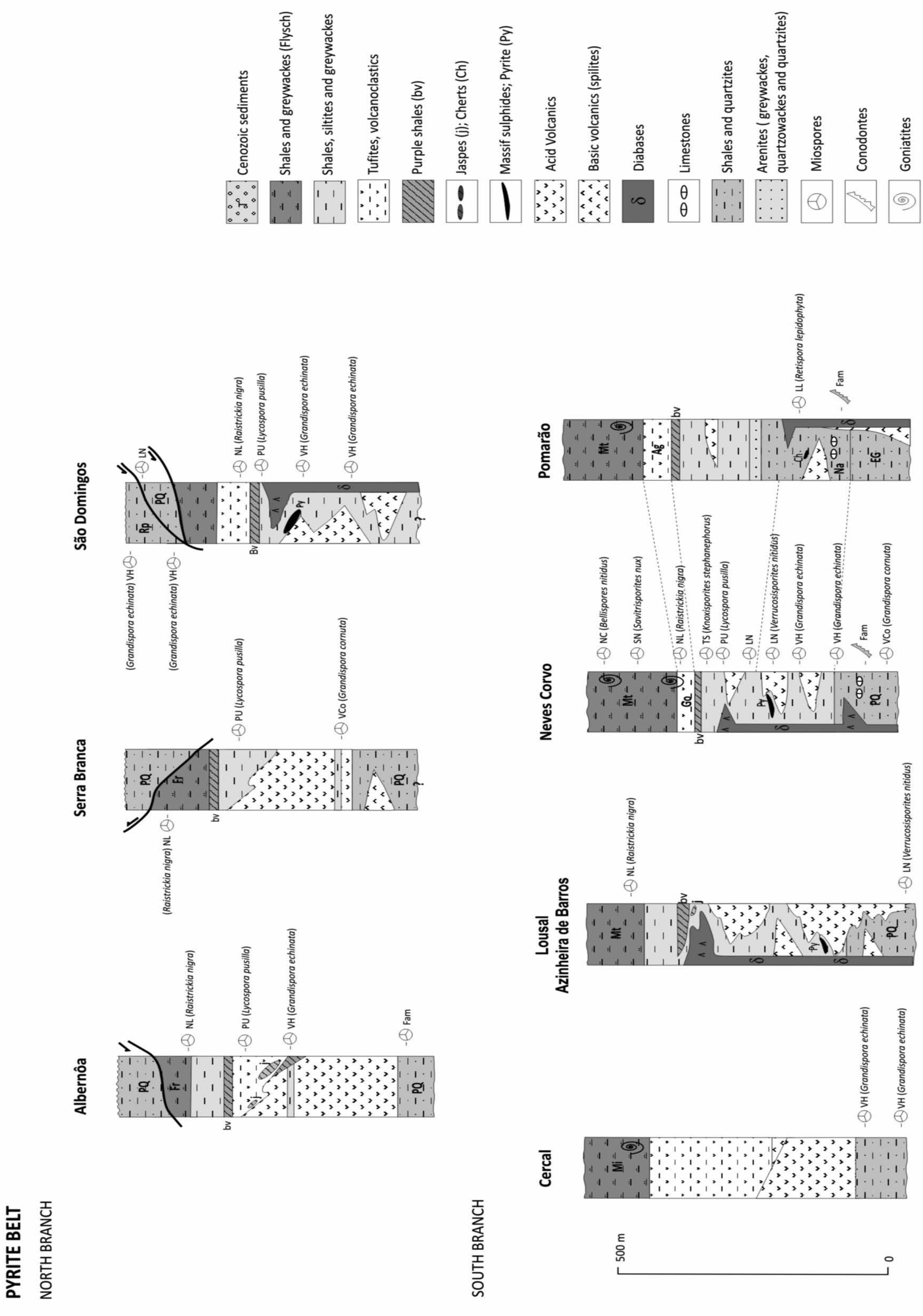

Fig. 4 – Synthetic stratigraphic columns selected from the Pyrite Belt (adapt. OLIVEIRA *et al.*, 2006).

age. The VCo assemblage contain the zonal species *Grandispora cornuta* and *Auroraspora* sp., *Diducites* spp., *Emphanisporites rotatus*, *Geminospora lemurata*, *Punctatisporites* sp., *Retusotriletes planus*, *R. rugulatus* and *Rugospora radiata.* The VH assemblage is defined by the presence of the key specie, *Grandispora echinata* and includes the taxa *Auroraspora* sp., *Diducites poljessicus, D. versabilis*, *Emphanisporites rotatus*, *Geminospora lemurata*, *Grandispora cornuta, Punctatisporites* sp., *Retusotriletes phillipsii, R. planus*, *R. triangulatus*, *Rugospora explicata* and *R. radiata*. All assemblages contain abundant acritarchs and prasinophytes.

Higher in the VSC, palynomorph assemblages obtained from black shales are assigned to the Pu Biozone and comprises the zonal species *Lycospora pusilla* in association with *Auroraspora macra, Convolutispora* sp., *Densosporites* sp., *D. spitsbergensis, D. brevispinosum*, *Dictyotriletes castaneaeformis*, *Discernisporites micromanifestus, Knoxisporites* cf. *triradiatus*, *Vallatisporites pusillites*, *V. galearis, V. verrucosus*.

At the top of the autochthon grey shales, siltstones and thin bedded greywackes of the Freixial Fm. yielded moderately preserved miospores of the NM Biozone of mid late Viséan. The NM biozone assemblage is defined by the presence of the zonal specie *Raistrickia nigra* and abundant taxa such as *Ahrensosporites* sp., *Anaplanisporites* sp., *Crassispora trychera, Densosporites* sp., *D. brevispinosum, D. intermedius, Knoxisporites triradiatus*, *Leiotriletes tumidus, Lycospora pusilla*, *Microreticulatisporites* sp., *Vallatisporites vallatus* and *Waltzispora* sp. In Serra Branca the NM assemblage recovered from the Freixial Fm. also containes taxa such as *Emphanisporites rotatus, Geminospora* sp., *Retispora lepidophyta, Rugospora radiata* and *Vallatisporites verrucosus*, which are interpreted as reworked miospores of late Famennian age.

In the allochthon, shales ascribed to the PQG yielded a moderately to well preserved miospore LN Biozonal assemblage (**Mina de São Domingos section**) that contains *Verrucosisporites nitidus*, the index species in association with the taxa *Crassispora* sp., *Densosporites spitsbergensis, Geminospora lemurata, G. spongiata, Punctatisporites* sp., *Retispora lepidophyta, Rugospora radiata* and *Vallatisporites* sp. with some rare acritarchs and prasinophytes. Shales of the Represa Fm. contain well preserved miospore assemblages assignable to the VH Biozone. The assemblages contain *Grandispora echinata* the key specie, together with the taxa *Ancyrospora* sp., *Ancyrospora*? *implicata*, *Aneurospora greggsii, Apiculiretusispora* sp., *Auroraspora* sp., *A. solisorta*, *Crassispora* sp., *Cristatisporites triangulatus*, *Cristicavatispora dispersa*, *Cymbosporites* sp., *Diducites poljessicus, D. versabilis*, *Emphanisporites annulatus, E. rotatus*, *Geminospora lemurata*, *Grandispora cornuta, Punctatisporites irasus*, *Retusotriletes* sp., *R. crassus, Rugospora explicata, R. radiata* and *Spelaeotriletes* sp.. All samples enclose very rich assemblages of acritarchs and prasinophytes. The fact that the autochthon and the allochthon both have VH assemblages with strong similarities implies that were part of the same palaeogeographic realm.

In the **South branch** research has been concentrated in the **Pomarão anticline, Neves Corvo mine** and **Lousal regions,** and very recently in the **Cercal anticline** (Figure 4).

The most complete palynostratigraphic study undertaken in the Portuguese sector of the Iberian Pyrite Belt was the investigation of the **Neves Corvo mine succession**. All the local rock units were accurately dated, and so concluded a long standing stratigraphic controversy and providing a major contribution to the interpretation of the local tectonic structure and ore genesis (Oliveira *et al.*, 1997; Pereira *et al.*, 2001; Pereira *et al.*, 2004; Oliveira *et al.*, 2004). This study allowed the following main conclusions:

(1) The age of the PQG is late Famennian based on moderately to well preserved miospore assemblages assigned to the VCo and VH Miospore Biozones. The VCo Biozone assemblage includes the type species *Grandispora cornuta* and abundant specimens of *Auroraspora macra*, *Cristatisporites triangulatus*, *Diducites versabilis*, *D. poljessicus*, *Emphanisporites annulatus*, *Geminospora lemurata, Retusotriletes planus*, *R. triangulatus*, *R. rugulatus* and *Rugospora radiata*. Reworked Frasnian miospores (*Cristatisporites* sp., *Contagisporites optivus*, *Aneurospora greggsii*, *Verrucosisporites premnus* and *V. scurrus*) are well represented in the VCo studied assemblages. The VH Biozone is marked by the abundant presence of *Grandispora echinata* together with *Ancyrospora* sp., *Auroraspora macra*, *Cristatisporites triangulatus*, *Grandispora cornuta*, *Emphanisporites annulatus*, *Geminospora lemurata, Retusotriletes planus*, *R. triangulatus*, *Raistrickia variabilis, Rugospora radiata, Spelaeotriletes* sp. and *Vallatisporites pusillites*. Acritarchs and prasinophytes are well represented in the assemblages. Reworked Frasnian miospores are also documented in the VH assemblages;

(2) The age of the VSC ranges from the late Strunian to early late Viséan. The LN, TS and NL Miospore Biozones are identified. The LN Biozone is marked by the presence of well preserved and abundant specimens of *Auroraspora macra, Densosporites spitsbergensis, Geminospora spongiata*, *Grandispora cornuta*, *G. echinata*, *Knoxisporites literatus, Leiotriletes struniensis*, *Retispora lepidophyta, Retusotriletes incohatus*, *Rugospora radiata*, *Tumulispora malevkensis, Vallatisporites pusillites and Vallatisporites verrucosus* together with the index species *Verrucosisporites niditus.* Rare specimens of *Aratrisporites saharaensis* also occur. Acritarchs and prasinophytes are very common in the assemblage. The TS Biozone is defined by the presence of the key species *Knoxisporites triradiatus* and *K. stephanephorus*. Other taxa present include *Anapiculatisporites* sp., *Convolutispora nigrata*, *Densosporites rarispinosus*, *Diatomozonotriletes* sp., *Dictyotriletes propius*, *Hymenozonotriletes caperatus*, *Knoxisporites hederatus*, *Microreticulatisporites concavus*, *Proprisporites* sp., *Spelaeotriletes pretiosus, S. arenaceus, Vallatisporites pusillites* and *V. galearis*. Reworked Tournaisian palynomorphs are present. The NL Biozone, a local biozone defined by the fist occurrence of *Raistrickia nigra* (see the details described in the SSP below). Other taxa include *Convolutispora* sp., *Densosporites rarispinosus, D. annulatus, Diatomozonotriletes* sp., *Knoxisporites hederatus, K. triradiatus, K. stephanephorus, Leiotriletes* sp., *Lycospora pusilla, Microreticulatisporites concavus, Proprisporites* sp. and *Vallatisporites ciliaris*;

(3) The Mértola Fm. flysch sediments yielded poorly to moderately preserved miospores assemblages assignable to the Biozones NL, SN and NC Miospore Biozones of the late Viséan. The NL Biozone includes the guide species *Raistrickia nigra* and also common specimens of *Densosporites rarispinosus*, *D. annulatus*, *Diatomozonotriletes* sp., *Knoxisporites hederatus*, *K. triradiatus*, *K. stephanephorus*, *Leiotriletes* sp., *Lycospora pusilla, Microreticulatisporites concavus* and *Proprisporites laevigatus*. Reworked Viséan and Tournaisian palynomorphs were also determined. The SN Biozone, a local zone, was defined by the presence of abundant *Anaplanisporites baccatus*, *Densosporites intermedius*, *D. brevispinosus*, *Lycospora pusilla*, *Knoxisporites triradiatus, K. stephanephorus*; *Raistrickia nigra*, *Savitrisporites nux* and rare *Rotaspora fracta*, *Diatomozonotriletes* sp. and *Triquitrites marginatus*. The NC Biozone is characterized by the first occurrence of *Bellispores nitidus* together with abundant species of *Crassispora maculosa*, *Convolutispora venusta*, *Diatomozonotriletes* sp., *Dictyotriletes* sp., *Leiotriletes tumidus*, *Rotaspora fracta* and *Savitrisporites nux*. In the entire studied NC assemblages reworked Strunian and Tournaisian miospores are common. The Mértola Fm. also yielded the goniatites *Goniatites hudsoni* and *G? globostriatus* of late Viséan A age and *Arnsbergites arnsbergensis*, *Arnsbergites falcatus* and *Hibernicoceras*, which indicate the late Viséan B confirming the results provided by the palynomorphs in the Neves Corvo mine region (Oliveira *et al.*, 2004);

(4) Three stratigraphic hiatuses are recognized, embracing the early to middle Strunian, the Tournaisian and the early Viséan. These hiatuses appear related to a southwestward progressive unconformity;

(5) Precision of the biostratigraphic dating of the massive sulphide orebodies that are intercalated in latest Famennian (late Strunian) black shales. These age determinations proved that all of the lithostratigraphic units are involved in a pile of tectonic sheets (Figure 4).

The **Pomarão anticline** exposes a complete lithostratigraphic section of the Portugueses Pyrite Belt (Figure 4). Here, only shales of the lower part of the sequence (Nascedios Member of the PQG) yielded miospores assigned the LL Biozone of late Strunian age (Oliveira *et al.*, 2006). Assemblage comprises moderately preserved specimens of *Auroraspora* sp., *Diducites* sp., *Emphanisporites rotatus, Knoxisporites literatus, Retispora lepidophyta* and *Retusotriletes* sp., rare acritarchs and prasinophytes are also present. The overlying VSC is composed of three volcanic episodes and interbedded sediments. Until now no biostratigraphic age was obtained for VSC succession.

In the **Lousal/Azinheira de Barros/Mina da Caveira** region the Pyrite Belt develops complex antiformal structures. The age of the lithostratigraphic units is still poorly constrained. Only shales of the PQG, recovered from a road cut north of Azinheira de Barros village provided a moderately preserved miospore assemblage that contains *Verrucosisporites nitidus*, the index species and the following taxa *Crassispora* sp., *Densosporites spitsbergensis, Geminospora lemurata, G. spongiata, Punctatisporites* sp., *Retispora lepidophyta, Rugospora radiata* and *Vallatisporites* sp. that indicate the LN Biozone. The VSC shows two main volcanic suites: one dominated by felsic volcanics, shales and intrusive diabases; the other composed mostly of basic volcanics and intrusives. The VSC suite is followed by the Mértola Fm. turbidites that yielded a moderately preserved miospore association *Crassispora* sp., *Densosporites* spp., *Lycospora pusilla*, *Microreticulatisporites concavus*, *Proprisporites* sp. and *Waltzispora planiangulata*, in association to the nominal species *Raistrickia nigra*. This assemblage is assigned to the NL local Biozone of mid late Viséan.

Palynostratigraphic research in the **Cercal anticline** (westernmost Iberian Pyrite Belt) is currently being studied. The lithostratigraphic sequence is still poorly constrained in terms of lithology and age, and only very recent and limited data is available. The investigated Elf Aquitaine boreholes, located in the antiform central sector, SW of Salgadinho, revealed the VSC Cercal felsic volcanics, a large sequence (>250m) of dark grey shales, with siltitic intercalations and minor quartzwakes and quartzites. These shales yielded very well preserved specimens of *Grandispora echinata* together with *Ancyrospora* spp., *Apiculiretusispora* sp., *Auroraspora macra*, *Cristicavatispora dispersa*, *Diducites poljessicus*, *D. mucronatus, D. versabilis*, *Emphanisporites annulatus*, *Grandispora cornuta, Punctatisporites* spp., *Retispora macroreticulata*, *Retusotriletes phillipsii, R. planus*, *R. triangulatus*, *R. rugulatus*, *Rugospora explicata* and *R. radiata.* This assemblage indicates the VH Biozone of late Famennian age. All samples studied contain rich assemblages of acritarchs and prasinophytes. This assemblage is similar to those described for the Neves Corvo and Mina de São Domingos mines (Pereira 2006a,b inc. ref.). No Carboniferous palynomorph assemblages have been identified until now. This data confirm the antiform Cercal structure and will be compared with the upper sequences of the VSC, located in the eastern and western antiform sectors.

In the Spanish region of Gerena, in the eastern part of the **Val Verde del Camino Anticline**, the PQG was dated early Frasnian base on a moderate preserved assemblage of miospores that includes *Chelinospora concinna*, *Cristatisporites triangulatus*, *Geminospora lemurata*, *Retusotriletes rugulatus*, *Aneurospora greggsii* and *Verrucosisporites scurrus* (LAKE, 1991; GONZALEZ *et al.*, 2004; GONZALEZ, 2005). These assemblages are analogous to those recovered in the Pulo do Lobo Antiform (Ribeira de Limas and Gafo Fms.) and also the reworked assemblage recovered in the upper part of the PQG in the Neves Corvo mine region.

3.3. The Baixo Alentejo Flysch Group

The Baixo Alentejo Flysch Group (BAFG) comprises mostly gravity flow sediments that form a continuous and southward prograding unit (Figure 1). Sedimentological and palaeontological data of the GFBA indicate it consists of three formations, the Mértola, Mira, and Brejeira Formations (OLIVEIRA *et al.,* 1979; OLIVEIRA, 1983; OLIVEIRA & WAGNER-GENTIS 1983). The stratigraphic palynology of the Baixo Alentejo Flysch Group, although still very incomplete, has been provisionally established. The miospore ages are consistent with ammonoid data recovered from all the BAFG units (KORN, 1997).

Mértola Formation

The Mértola Fm. was studied for palynomorphs in several regions: such as the Neves Corvo mine, Mértola town, Azenhas section in Guadiana River, Bens Farm, and are give a late Viséan age (OLIVEIRA *et al.*, 2007; PEREIRA *et al.*, 2007). Three miospores biozones of late Viséan age are identified: the NL and SN Biozones, defined as local Miospore Biozones (*see the details described in the SWSP below*) based respectively on the first occurrence of the index species *Raistrickia nigra* and *Savitrisporites nux*, and the NC Biozone (recognized only at the Neves Corvo mine region) based on the first appearance of the key species *Bellispores nitidus.*

Mira Formation

The age of Mira Fm. is late Viséan to early Bashkirian, based on the ammonoids *Dombarites*, *Lyrogoniatites* and *Cravenoceras* (OLIVEIRA *et al.,* 1979; KORN, 1997). Palynostratigraphic data are scarce at the present time and are only restricted to black shale samples obtained in the Castro Marim region. These samples yielded late Viséan NC miospore Biozone assemblages that contain the key species *Bellispores nitidus.*

Brejeira Formation

The youngest unit of the BFGA is the Brejeira Fm. The palynostratigraphic study of this unit revealed 6 miospore biozones, ranging from the Bashkirian to late Moscovian (PEREIRA 1997; 1999; Figure 5, 6). These miospore ages are consistent with the local ammonoid biozonation (KORN, 1997).

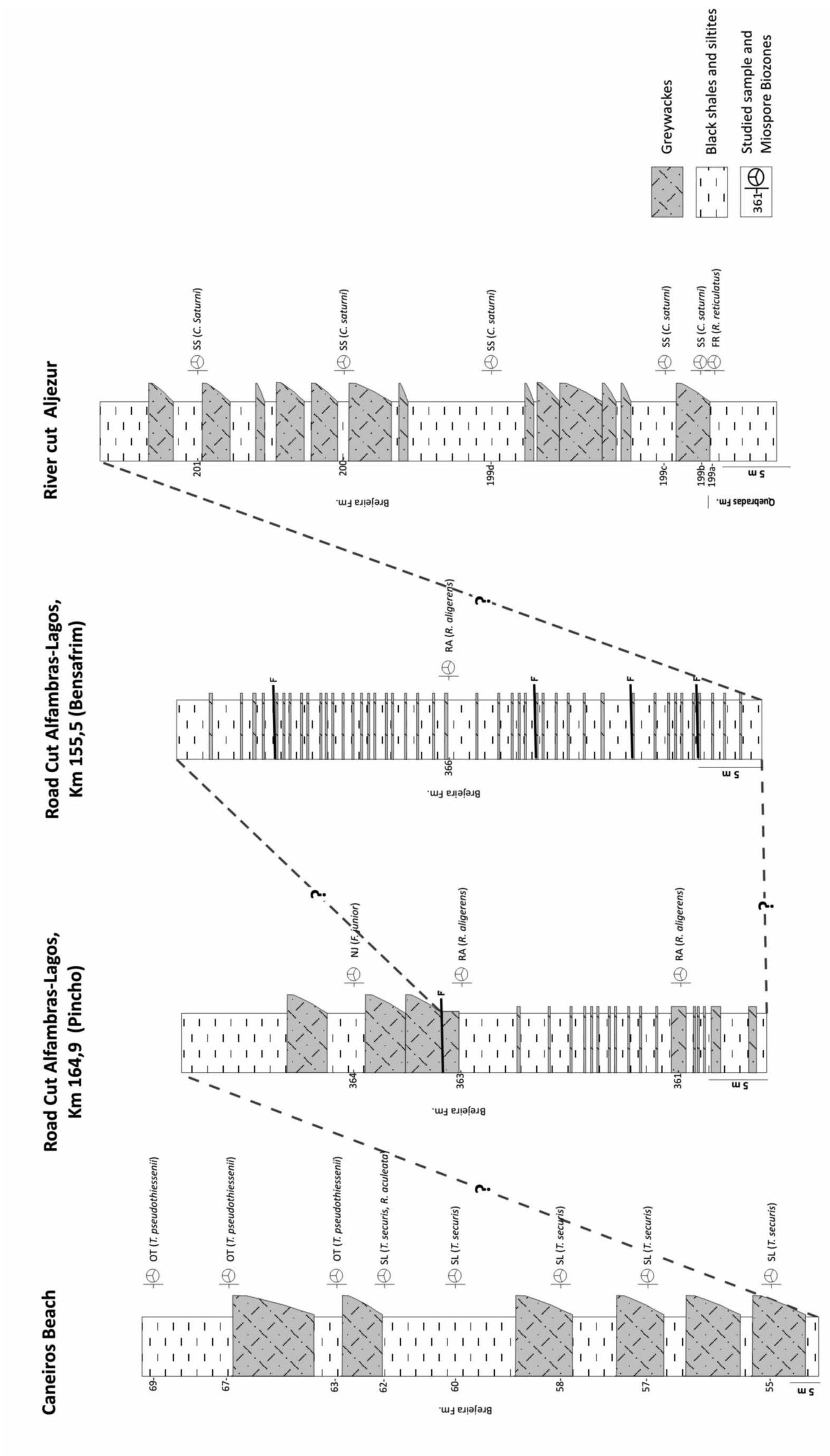

Fig. 5 – Selected stratigraphic section from Brejeira Fm. (Adapt. Pereira, 1999).

The base of the Brejeira Fm., in the north part of its outcrop area indicates the FR miospore Biozone of the mid Bashkirian age, which contains the index specie *Reticulatisporites reticulatus* and the *Dyctiotriletes probireticulatus* in the upper part of the zone. Further south, miospore assemblages are successively assigned to the following: SS Biozone characterized by the index specie *Cirratriradites saturni*; Ra Biozone assemblage containing *Radiizonates aligerens;* Ra/NJ biozonal boundary was only identified in Pincho Road section and is marked by the first occurrence of *Florinites junior*; the SL Biozone was identified based on the first appearance of *Torispora securis*, the presence of *Cadiospora magna* and upper in the series by the incoming of the index taxa *Raistrickia aculeata*; the OT Biozone is marked by the occurrence of *Thymospora psedothiessenii,* and the common presence of *T. obscura* and *T. thiessenii.* This distribution of the palynological assemblages, confirms the southwestward progradation of the turbidites. The Variscan tectonic deformation in this sector is Kasimovian in age.

3.4. Southwest Portugal Sector (SPS) (Bordeira and Aljezur Anticlines)

The stratigraphic succession of this sector was given in OLIVEIRA *et al.* (1985), OLIVEIRA *et al.* (1986), RIBEIRO *et al.* (1987), PEREIRA (1997, 1999) and KORN (1997). Four successive formations were identified in SPS, from

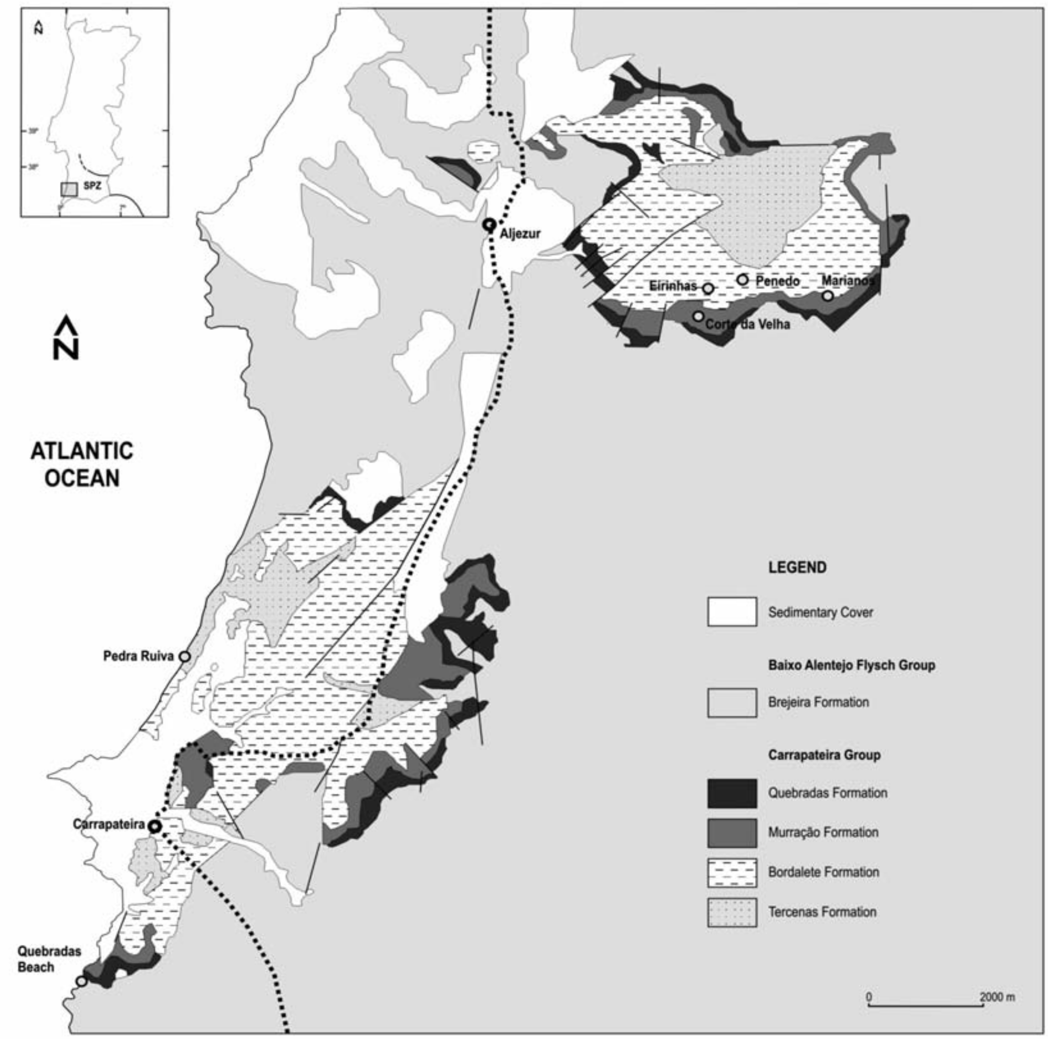

Fig. 6 – Geological Map of Aljezur and Bordeira Antiforms in SWPS (Adapt. SILVA *et al.*, 1990).

base to top, the Tercenas, Bordalete, Murração and Quebradas Formations, of which the latter three are combined to form the Carrapateira Group (Figure 6). Detailed palynostratigraphic research has allowed the establishment of 12 miospore biozones, with 47 late Devonian and more than 200 Carboniferous miospore species documented (Pereira *et al.*, 1994; Pereira *et al.*, 1995; Pereira, 1997; 1999). These palynostratigraphic results correlate well with the local ammonoids biozonation (Korn, 1997).

Tercenas Formation

The Tercenas Fm. (base unknown) comprises dark marine shales with interbedded thin sandy tempestites which grades upward to a 10m thick tidal sandstone body. Rare clymenids, brachiopods and corals suggest a late Famennian to early Tournaisian age for this unit (Oliveira, 1990). The palynological study reveals a diverse well preserved miospore assemblages assignable to the LN miospore Biozone of late Strunian age and VI miospore Biozone of early Tournaisian age (Figure 7). The LN Biozone is characterized by the common presence of *Densosporites spitsbergensis, Dictyotriletes fimbriatus, Knoxisporites concentricus, Retusotriletes crassus, Retispora lepidophyta, Rugospora radiata, Vallatisporites pusillites, Vallatisporites verrucosus*, *Tumulispora rarituberculata* and the key specie *Verrucosisporites nitidus*. All samples suited contain rich assemblages of acritarchs and prasinophytes.

Bordalete Formation

The Bordalete Fm. is a monotonous succession of dark grey to black shales and siltstones, which frequently contain phosphatic nodules. Goniatites are randomly distributed within the Bordalete Fm., and being concentrated at certain horizons and where they belong to only one species, *Becanites algarbiensis* (Pruvost 1914; Korn, 1998). In terms of palynostratigraphy, the Bordalete Fm. allowed the identification of the VI, HD and PC Miospore Biozones of Tournaisian age (Figure 7). The VI miospore Biozone (recognized in the Eirinhas-Rizada-Penedo Road section, Monte do Penedo and Pedra Ruiva sections) is marked by the presence of the index specie *Vallatisporites verrucosus* together with the common presence of *Cyrtospora cristifera, Puctatisporites irrasus*, *Retusotriletes incohatus, Secarisporites* sp. and *Tumulispora malevkensis.* The base of HD biozone, marked by the first incoming of the index taxa *Cristatisporites hibernicus*, identified in the Eirinhas-Rizada-Penedo Road section, is also characterized by the first appearance of the distinctive species *Umbona-tisporites distinctus* and *Neoraistrickia cymosa*. A typical, diverse and very well preserved PC miospore Biozone assemblage was recovered from several sections of the Bordalete Fm. The zone is defined by the presence of the guide specie *Spelaeotriletes pretiosus* together with *Auroraspora macra, K.* cf. *triradiatus, Granulatisporites microgranifer, Neoraistrickia cymosa, N. logani, Raistrickia clavata, Spelaeotriletes balteatus, Vallatisporites microspinosus, V. vallatus, V. verrucosus, Verrucosisporites congestus, V. irregularis* and *V. nitidus* (Figure 7). At the top of this unit the CM miospore Biozone of late Tournaisian age is missing, probably due to the presence of a hiatus. These palynostratigraphic data exclude the existence of a basal hiatus as previously suggested (Oliveira *et al.*, 1985).

Murração Formation

The Murração Fm. is composed of two members. The lower Pedra das Safias Member, has a thickness of 25 metres and is composed of grey shales with rhythmic marly carbonate and dolomitic intercalations. The member has yielded a few fragmentary macrofossils of corals and trilobites, including large but poorly preserved specimens of *Merocanites* sp., indicating an early to middle Viséan age. The upper Vale Figueira Member has a thickness of 32 metres and is best exposed at the Atlantic coast, near Carrapateira village. Strongly weathered successions of the formation also occur in the area of Aljezur and Bordeira. However in the Quebradas beach section, the Vale Figueira Member is well exposed and in non-weathered conditions. Here, it is composed of dark-grey or black shales, and nodular and sometimes dolomitic limestones. The sucession contains scarce benthic faunas, restricted to certain levels characterized by rare trilobites, brachiopods, echinoderms and rugose corals. The section is also extremely rich in goniatites and bivalves such as *Posidonia becheri* Bronn, 1828, of late Viséan age. The following goniatite zones were identified (Korn, 1997): *hudsoni* Zone (fauna with *Goniatites hudsoni*), *crenistia* Zone (fauna with *Beyrichoceras* sp.),

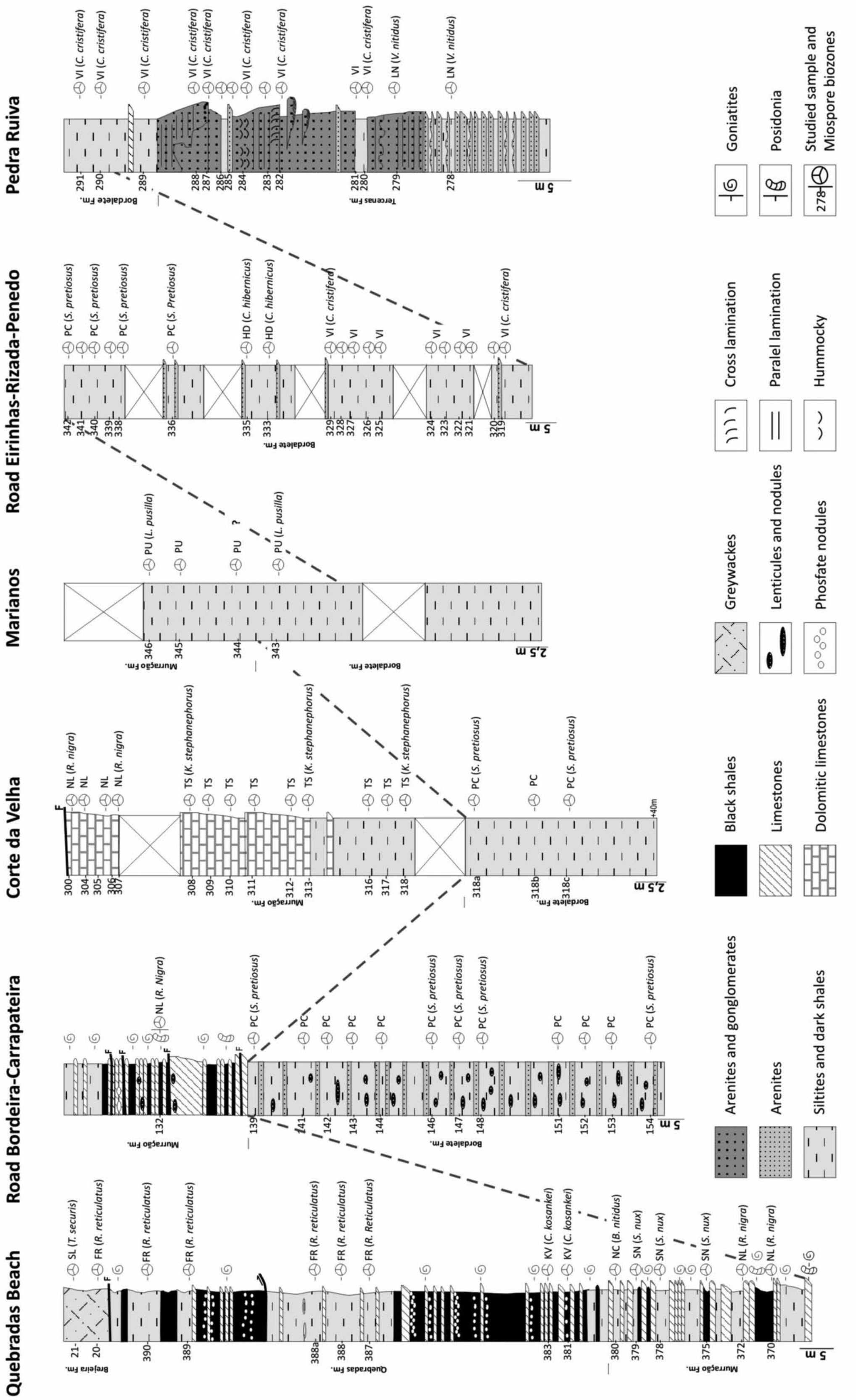

Fig. 7 – Selected stratigraphic sections from Aljezur and Bordeira Anticlines, Southwest Portugal Sector (SWPS).

spirifer Zone (fauna with *Goniaitites spinifer* and *Goniatites fimbriatus*), *gracilis* Zone (fauna with *Hibernicoceras carraunense*) and *postriatum* Zone (fauna with *Lusitanoceras algarviense*). The Murração Fm. has been interpreted as a deep open-marine, pelagic carbonate platform in front (to the south) of the flysch basin (Oliveira *et al.*, 1985; Herbig *et al.,* 1999).

The palynostratigraphic study of the Murração Fm. has recognized 5 miospore biozones of Viséan age (Pereira, 1999; Figure 2, 7). The study of the Pedra das Safias Member proved to be very difficult due to the strong dolomitization. Only in the Aljezur Anticline, in the Marianos and Corte da Velha sections (Figure 7), where the unit has a more shaly character, it has been possible to identify the base of the Pu miospore Biozone, based in the first appearance of *Lycospora pusilla* and the base of TS Biozone*,* by the first appearance of *Knoxisporites triradiatus* and *K. stephanephorus.* These two miospore biozones indicate an early Viséan age for the Pedra das Safias Member.

The Vale Figueira Member, in Praia das Quebradas section (Figure 7) has yielded moderately preserved miospore assemblages assigable to the NL, SN, and NC Biozones of late Viséan age. Two zones were defined as local miospore Biozones, the NL (*Raistrickia nigra – Proprisporites laevigatus*) and SN (*Savitrisporites nux*) based respectively, on the first occurrence of *Raistrickia nigra* and *Savitrisporites nux* guide taxa (Figure 2). These biozones were defined due to the absence of stratigraphically useful taxa such as *Rotaspora* spp., *Tripartites* spp. and *Triquitrites* spp. Nevertheless, the NL biozone can be correlated with the *Raistrickia nigra – Triquitrites marginatus* Miospore Biozone of Western Europe based in the first appearance of *Raistrikia nigra* that occurs at the same level. *Proprisporites laevigatus* appears together with the first *R. nigra* in southwest Portugal, but in Western Europe the first record of this specie is much higher, at the top of NC Biozone of late Viséan to early Serpukhovian (Clayton *et al.*, 1977, Clayton, 1996). The SN local biozone can be correlated with the VF miospore Biozone of Western Europe, based in the first occurrence of *Savitrisporites nux*. In Western Europe, in addition to *S. nux*, the *Tripartites vetustus* Biozone is defined by the first appearance of a group of new species which includes *Tripartites vetustus, Tripartites nonguerikei, Rotaspora fracta* and *R. knoxi*, which are not represented in the late Viséan of southwest Portugal (Clayton *et al.*, 1977; Clayton 1996).

The basal part of the NC Biozone is marked by the presence of the guide species *Bellispores nitidus*, which was recognized in the Quebradas Beach section. The assemblage also contains the species *Crassispora maculosa, Microreticulatus concavus, Propisporites laevigatus, Raistrickia nigra* and *S. nux.*

The palynostratigraphical evidence indicates that the entire Viséan may be represented in the Murração Fm. (Pereira 1997, 1999).

Quebradas Formation

The Quebradas Fm. has a thickness of approximately 70 metres and is mainly composed of black shales with intercalated carbonate and phosphoritic layers, lenses and nodules (Figure 7). This unit is rich in fossils, and several carbonatic horizons contain distinctive ammonoid assemblages (Oliveira *et al.*, 1985; KORN, 1997). In a lower horizon, an indistinctive *Cravenoceratoides* (?) sp. suggests an Arnsbergian age. Higher up, some of the goniatite zones between the R1a to G2 are represented by characteristic goniatites, including *Vallites kullmanni* Korn, 1997, *Reticuloceras reticulatum* (Phillips, 1836), *Reticuloceras coreticulatum* Bisat & Hudson, 1943, *Bilinguites gracilis* (Bisat, 1924), *Bilinguites metabilinguis* (Wright, 1927) *Cancelloceras* cf. *crencellatum* (Bisat, 1924), *Gastrioceras listeri* (Sowerby, 1812) and *Gastrioceras angustum* (Patteisky, 1964).

The moderately preserved miospore assemblages recovered from Quebradas Fm. are assigned to the Bashkirian KV and FR miospore Biozones. The KV Biozone is marked by the presence of *Crassispora kosankei*. The basal pat of the FR Biozone is defined on the first occurrence of *Reticulatisporites reticulatus* together with common specimens of *Crassispora kosankei*, *Raistrickia fulva* and *S. nux* (Figure 2). These results fit well, in terms of age, with the local ammonoid biozonation (Korn, 1997).

CONCLUSIONS

Devonian and Carboniferous palynomorphs are documented from all the geological domains recognized in the SPZ. For the first time, an assessment of all of the palynostratigraphic records obtained in the SPZ are compared (Figure 2). Twenty three miospore biozones are identified in the SPZ comprising the identification of more than 150 Devonian miospores and acritarchs species and more than 200 Carboniferous miospore species (Pereira *et al.*, 2007). Selection of the index species used for the SPZ is based upon the consistent occurrence of each taxon in several sections and boreholes.

A number of palynological events recognized in the Western Europe were identified in the SPZ. These events, generally defined as the appearance or disappearance of a single genus or whole complexes of forms, providing important indicators in the establishment of global zonations (Clayton, 1985; Clayton, 1996; Clayton *et al.*, 2003; Owens, 1996; owens at al., 2004; Streel, 1996). One event has local importance at the scale of SPZ (in Portugal and Spain) and two events are locally distinct and are correlated with goniatites control points in the BAGF and SPS (see figures 2 and 7).

The most important events identified in the Western Europe and recognized in SPZ are:

(1) The first appearance of *Grandispora cornuta*, together with other taxa that typically occur at this level in SPZ, that includes *Retusotriletes phillipsii*, *Diducites versabilis* and *Rugospora radiata*. This event, with the same type assemblage is recognized in Western Europe and marks the basal part of the VCo Biozone of late Famennian age (Maziane *et al.*, 1999);

(2) First appearance of *Grandispora echinata.* Assemblages in the SPZ also typically contain consistently *Ancyrospora* sp., *Cristicavatispora dispersa, Rugospora explicata* and *Teichertospora iberica* at this level. It is worth noting that this assemblage is currently only documented in the SPZ and could represent a local event. In addition, the appearance of *Grandispora echinata* occurs immediately before the first inception of *Retispora lepidophyta* in SPZ and Western Europe, at the late Famennian age;

(3) Extinction of *Retispora lepidophyta*. In Western Europe this event is approximately at the Devonian/Carboniferous boundary (Paproth & Streel, 1972; Higgs & Streel, 1984);

(4) First appearance of *Spelaeotriletes pretiosus*, marking the middle Tournaisian age, in Western Europe;

(5) First appearance of *Lycospora pusilla*. In Western Europe it is approximately coincident with the Tournaisian/Viséan boundary;

(6) First appearance of *Raistrickia nigra*, together with other taxa that typically occur at this level in the SPZ is *Propisporites laevigatus* and *Densosporites* spp.. This event marks the mid late Viséan in SPZ. This data is confirmed with goniatites;

(7) First appearance of *Savitrisporites nux*. This local event is equivalent to the Western Europe first appearance of *Tripartites vetustus* Schemel. In the SPZ, the other taxa that typically occur with the *S. nux* are *Rotaspora* spp. and *Grandispora spinosa* of late Viséan age;

(8) Extinction of the characteristic Viséan miospore species, *Raistrickia nigra*, *Grandispora spinosa*, *Rotaspora* spp. and *Crassispora maculosa*, analogous to the Viséan/Serpukovian bondary of the Western Europe;

(9) Appearance of the distinctive Bashkirian genus *Reinschospora* and increase on *Crassispora kosankei*, representative of the early Bashkirian assemblages, similar to the Western Europe;

(10) First appearance of *Radiizonates aligerens*, a type event for the late Westphalian A, in Western Europe. It is also characterized by the increase of *Laevigatosporites* and *Cirratriradites saturni*;

(11) First appearance of *Torispora* genus, marking the basal Westphalian C, as documented for Western Europe;

(12) First appearance of *Thymospora* spp. which in Western Europe marks the basal part of the Westphalian D.

The synopsis of the SPZ palynostratigraphy obtained from all the geological domains recognized allow the following conclusions (Figure 2):

1. Early Frasnian miospores assemblages were recovered from the PQG of the IPB, in Valverde del Camino Anticline, SW Spain (Lake, 1991; Gonzalez *et al.*, 2004; Gonzalez, 2005) and appear as reworked assemblages at the top of this same Group. These Frasnian assemblages are also comparable to those found in the Ribeira de Limas and Gafo Fms. of the Pulo do Lobo Antiform (Pereira *et al.*, 2006).

2. Late Famennian assemblages in SPZ have a consistent presence of the miospore species *Ancyrospora* sp., *Cristicavatispora dispersa, Rugospora explicata* and *Teichertospora iberica*. These assemblages were recovered from the PQG and the VSC (IPB) (Gonzalez *et al.*, 2004; Pereira *et al.*, 2004; 2007) and from the upper units of the Pulo do Lobo Antiform (Horta da Torre, Santa Iria and Represa Fms; Pereira *et al.*, 2006a, b).

3. Analogous late Strunian miospore assemblages were recovered from the IPB, the upper part of the PQG (Cunha and Oliveira, 1989; Oliveira *et al.*, 2004; Oliveira *et al.*, 2005; Matos *et al.*, 2006), and the VSC in Spain (Gonzalez, 2005) and also from the Tercenas Fm. in Southwest Portugal (Bordeira and Aljezur Anticlines).

4. Similarities in Upper Devonian miospore assemblages, strongly suggest that the Pulo do Lobo, the IPB basin and the Tercenas Fm. (Southwest Portugal), were part of the same palaeogeographic realm during the late Devonian.

5. Records of Tournaisian palynomorphs from the Bordalete Fm. in Southwest Portugal and reworked Tournaisian associations in the VSC of the IPB show the presence of the same taxa.

6. The VSC of the IPB yield miospores of late Famennian to mid/late Viséan age (Oliveira *et al.*, 1986; Oliveira *et al.*, 2004; 2005; 2006; Pereira *et al.*, 2006; 2007). Mid/late Viséan assemblages appear to be very consistent along the SPZ as the same assemblages are recorded from the BAFG.

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REFERENCES

Boogaard, M. (1967) – *Geology of Pomarão region (Southern Portugal).* Thesis. Graffisch Centrum Deltro. Rotterdam.

Carvalho, D., Correia, M. & Inverno, C. (1976) – Contribuição para o conhecimento geológico do Grupo Ferreira-Ficalho. Suas relações com a Faixa Piritosa e o Grupo do Pulo do Lobo. *Mem. Not. Mus. Lab. Min. Fac. Cienc. Coimbra*, **82**, pp. 145-169.

Clayton, G. (1985) – Dinantian Miospores and intercontinental correlation. *C.R. 10e, International Congress Stratigraphy Geology Carboniferous,* Madrid 1983, **1**, pp. 9-23.

—— (1996) – Mississippian Miospores. *In*: *Palynology: Principles and applications.* Jansonius J. & McGregor D.C, (eds.), Am. Assoc. Strat. Palynol. Found, Vol. **2**, pp. 589-596.

Clayton, G., Coquel, R., Doubinger, J., Gueinn K. J., Loboziak, S., Owens, B. & Streel, M. (1977) – Carboniferous Miospores of Western Europe: illustration and zonation. *Meded. Rijks Geol. Dienst* **29**, pp. 1-71.

Clayton, G., McClean, D. & Owens, B. (2003) – Carboniferous palinostratigraphy: recent developments in Europe (Abstract 103). *International Congress on Carboniferous and Permian Stratigraphy*, Utrecht, August 2003.

Cunha T. & Oliveira J. T. (1989) – Upper Devonian Palynomorphs from the Represa and Phyllite- Quartzite Formation, Mina de São Domingos region, Southwest Portugal. Tectonostratigraphic implications. *Bull. Société Belge Géol.*, **98** (3/4), pp. 295-309.

Eden, C. P. (1991) – *Tectonostratigraphic analysis of the Northern Extent of the Oceanic Exotic Terrane, Northwestern Huelva Province, Spain*. PhD thesis. Univ. Southampton, 281 pp.

Fantinet, D., Dressen, R., Dusar, M. & Termier, G. (1976) – Faunes famenniennes de certains horizons calcaires dans la formation quatzitophylladique aux environs de Mértola (Portugal méridional). *Comunicações Serviços Geológicos de Portugal*, 60: pp.121-138.

Giese, V., Reitz, E. & Walter, R. (1988) – Contributions to the stratigraphy of the Pulo do Lobo succession in Southwest Spain. *Comunicações Serviços Geológicos de Portugal,* **74**, pp.79-84.

González, F., Moreno, C., López, M. J., Dino, R. & Antonioli, L. (2004) – Palinoestratigrafia del Grupo PQ del Sector más oriental de la Faja Pirítica Ibérica, SO de España. *Rev. Esp. Micropaleont.*, **36**, 2, pp. 279-304.

Gonzalez, F. (2005) – *Las pizarras negras del límite Devónico/carbonífero de la Faja Pirítica Ibérica (S.O. de España). Estúdio bioestratigráfico e implicaciones sobre la paleogeografía de la cuenca y el origen de las mineralizaciones de sulfuros.* Tesis Doctoral. Facultad de Ciencias Experimentales, Departamento de Geologia, Área de Estratigrafia, Universidad de Huelva, 200 pp.

Higgs, K., Clayton, G. & Keegan, B. J. (1988) – Stratigraphic and systematic palynology of the Tournaisian rocks of Ireland. *Geol. Surv. Irel. Spec. Pap.* **7**, pp. 1-93.

Higgs, K. & Streel, M. (1984) – Spore stratigraphy at the Devonian--Carboniferous boundary in the Northern "Rheinisches Schieferebirge" Germany. *Cour.Forsch.-Inst. Senckenberg*, **67**: pp. 157-180.

Higgs, K.T., Avkhimovitch V. I., Loboziak, S., Maziane-Serraj, N., Stempien-Salek, M. & Streel, M. (2000) – Systematic study and stratigraphic correlation of the *Grandispora* complex in the Famennian of northwest and eastern Europe. *Review of Palaeobotany and Palynology*, **112**: pp. 207–228.

Korn, D. (1997) – The Palaeozoic ammonoids of the South Portuguese Zone. *Mem Inst Geol Min Portugal*, **33**: pp. 1-131.

Lake, P. A. (1991) – *The Biostratigraphy and Structure of the Pulo do Lobo Domain within Huelva Province, Southwest Spain.* PhD Thesis, Univ. of Southampton, pp. 1-324.

Matos, J., Oliveira, V. & Barriga, F. (1998) – Contribuição para o conhecimento geológico e metalogenético da Jazida de Lagoa Salgada, Faixa Piritosa Ibérica – Bacia Terciária do Sado. Actas V Cong. Nacional de Geologia, *Comunicações IGM*, **84**, 2, pp.11-14, Lisboa.

Matos, J., Barriga, F., Oliveira, V., Relvas, J. & Conceição, P. (2000) – The structure and hydrothermal alteration of the Lagoa Salgada orebody (Iberian Pyrite Belt – Sado Tertiary Basin). Volcanic Environments and Massive Sulfide Deposits – *SEG/CODES Int. Conf. Abstract, Tasmania*, pp. 119-121.

Matos, J., Barriga, F. & Oliveira, V. (2003) – Alunite veins versus supergene kaolinite/halloysite alteration in the Lagoa Salgada, Algares and S. João (Aljustrel) and S. Domingos massive sulphide deposits, Iberian Pyrite Belt, Portugal. *Ciências da Terra (UNL)* 5, pp. B56-B59.

Matos, J. X., Pereira, Z., Oliveira, V. & Oliveira, J. T. (2006) – The geological setting of the S. Domingos pyrite orebody, Iberian Pyrite Belt. *In*: *VII Congresso Nacional de Geologia,* Mirão, J. & Balbino, A. (eds), Vol **1**, pp. 283-286.

Maziane, N., Higgs, K.T. & Streel, M. (1999) – Revision of late famennian miospore zonation scheme in eastern Belgium. *Journal of Micropalaeontology*, **18**, pp. 17-25.

Munhá, J. M. (1983) – Low grade metamorphism in the Iberian Pyrite Belt Pyrite: *Comunicações Serviços Geológicos de Portugal***,** **69**, 1, pp. 3-35.

Oliveira, J. (1983) – The marine carboniferous of South Portugal: a stratigraphic and sedimentological approach. *In*: The Carboniferous of Portugal. Lemos de Sousa, M. J. & Oliveira, J. T. (eds.,). *Memórias Serviços Geológicos de Portugal* **29**, pp. 3-38.

Oliveira, J. T. (1990) – Stratigraphy and syn-sedimentary tectonism in the South Portuguese Zone. In: *Pre-Mesozoic Geology of Iberia*. Dallmeyer, R. D. & Martinez Garcia, E. (eds.). Springer Verlag. pp. 334-347.

Oliveira, J. & Wagner genthis, C. (1983) – The Mértola and Mira formations boundary between Doguedo and Almada do Ouro, marine Carboniferous of South Portugal. *In: Contributions to the Carboniferous Geology and Palaeontology of the Iberian Peninsula*. Lemos de Sousa, M.J. (ed.,), pp. 1-39.

Oliveira J. T., Carvalho P., Pereira Z., Pacheco N., Fernandes J. P. & Korn D. (1997) – The stratigraphy of the Neves Corvo Mine Region. *SEG Guide Book Series* **27**, pp. 86-87.

Oliveira, J. T., Cunha, T. A., Streel, M. & Vanguestaine, M. (1986) – Dating the Horta da Torre Formation, a new lithostratigraphic unit of the Ferreira-Ficalho Group, South Portuguese Zone: Geological consequences. *Comunicações Serviços Geológicos de Portugal,* **72**, 1/2, pp. 129-135, 363-368.

Oliveira, J., Horn, M., Paproth, E. (1979) – Preliminary note on the stratigraphy of the Baixo-Alentejo Flysch Group, Carboniferous of Portugal, and on the palaeogeographic development compared to corresponding units in NorthWest Germany. *Comunicações dos Serviços Geológicos de Portugal* **65**, pp. 151-168.

Oliveira, J., Horn, M., Kullmann, J. & Paproth, E. (1985) – The stratigraphy of the Upper Devonian and Carboniferous sediments of Southwest Portugal. *C.R. 10e, International Congress Stratigraphy Geology Carboniferous,* Madrid 1983, **1**, pp. 1-17.

Oliveira, J. T., Pereira Z., Carvalho P., Pacheco N. & Korn D. (2004) – Stratigraphy of the tectonically imbricated lithological succession of the Neves-Corvo Mine region, Iberian Pyrite Belt. Implications for the regional basin dynamics. *Mineralium Deposita* 34, pp. 422-436.

Oliveira, J. T., Pereira, Z., Rosa, C., Rosa, D. & Matos, J. (2005) – Recent advances in the study of the stratigraphy and the magmatism of the Iberian Pyrite Belt, Portugal. *In: The southern Variscan belt*. Carosi, R., Dias, R., Iacopini, D. & Rosenbaum, G., (eds.,). Journal of the Virtual Explorer, Electronic Edition, **19**, 9, pp. 1441-8142.

Oliveira, J. T., Pereira, Z., Fernandes, P. & Matos, J., (2007) – Palynostratigraphic contributions to the understanding Ossa Morena and South Portuguese Zone geology, Portugal. *CIMPLISBON'07, Field trip Book*, pp. 1-46.

Oliveira, J. T., Relvas, J., Pereira, Z., Matos, J., Rosa, C., Rosa, D., Munhá, J. M., Jorge, R. & Pinto, A. (2006) – O Complexo Vulcano-Sedimentar da Faixa Piritosa: estratigrafia, vulcanismo, mineralizações associadas e evolução tectono-estratigráfica no contexto da Zona Sul Portuguesa. *In*: *Geologia de Portugal no contexto da Ibéria.* Dias, R., Araújo, A., Terrinha, P. & Kullberg, J.C. (eds). Univ. Évora, Évora, pp. 207-243.

Oliveira, V., Matos, J., Bengala, M., Silva, N., Sousa, P. & Torres, L. (1998a) – Geology and geophysics as successful tools in the discovery of the Lagoa Salgada Orebody (Sado Tertiary Basin-Iberian Pyrite Belt), Grândola, Portugal, *Mineralium Deposita* **33**, pp. 170-187.

Oliveira, V., Matos, J., Bengala, M. & Sousa, P. (1998b). Principais alinhamentos vulcânicos a norte da Falha de Grândola, sob formações da Bacia Terciária do Sado e sua potencialidade mineira no contexto da Faixa Piritosa Ibérica. Actas V Cong. Nacional de Geologia, *Comunicações do IGM* , T. **84** F. 2, pp. 15-18.

Owens, B. (1996) – Upper Carboniferous Spores and Pollen. *In*: *Palynology: Principles and applications.* Jansonius J. & McGregor D.C. (eds.), Am. Assoc. Strat. Palynol. Found, Vol. **2**, pp. 597-606.

Owens, B., McLean. D. & Bodman, D. (2004) – A revised palynozonation of British Namurian deposits and comparisons with eastern Europe. *Micropalaeontology*, vol 50, **1**, pp. 89-103.

Paproth, E. & Streel, M. (1972) – Corrélations biostratigraphiques prés de la limite Dévonien/Carbonifère entre les facies littoraux ardennais et les facies bathyaux rhenans. Colloque sur la Stratigraphie du Carbonifère. *Congress et Colloques Univ. Liège*, **55**: pp. 365-398.

Pereira, Z. (1997) – *Palinologia e petrologia orgânica do Sector SW da Zona Sul Portuguesa.* PhD Thesis. Fac. Ciências da Universidade do Porto, 268 pp.

—— (1999) – Palinoestratigrafia do Sector Sudoeste da Zona Sul Portuguesa. *Comunicações IGM, Portugal* **86**, pp. 25-57.

Pereira, Z. & Oliveira, J. T. (1995) – Estudo palinológico da Formação da Brejeira, sector Sudoeste da Zona Sul Portuguesa. *In: IV Congresso Nacional de Geologia, Porto, 1995*. Sodré Borges F.& Marques, M.M. (eds.,). Resumos Alargados, Memórias do Museu Laboratório Mineralógico Geológico da Faculdade de Ciências, Porto, **4**, pp. 111-115.

—— (2006) – Recent advances on the Upper Devonian palynostratigraphy of the Pulo do Lobo Domain, South Portuguese Zone, Portugal. *In: Palaeozoic Palynology in Space and Time*. Bek, J., Brocke, R. Daskova & J. Fatka, O. (eds). Inst. Geology, Academy of Sciences, Prague. Czech Republique, pp. 42-43.

Pereira, Z., Clayton, G. & Oliveira, J. T. (1994) – Palynostratigraphy of the Devonian-Carboniferous Boundary in Southwest Portugal. *Annales de la Société Géologique de Belgique*, 117, 1, pp. 189-199.

Pereira, Z., Fernandes, P. & Oliveira, J. T. (2006)a – Palinoestratigrafia do Domínio Pulo do Lobo, Zona Sul Portuguesa. Resumos alargados. *In*: *VII Congresso Nacional de Geologia,* Mirão, J. & Balbino, A. (eds), Vol 2, pp. 649-652.

—— (2006)b – Upper Devonian palynostratigraphy and organic matter maturation of the Pulo do Lobo Domain, South Portuguese Zone, Portugal. *Comunicações Geológicas (in press*).

Pereira, Z., Pacheco, N. & Oliveira, J. T. (2004) – A case of applied palynology: dating the lithological succession of the Neves--Corvo mine, Iberian Pyrite Belt, Portugal. *In: Proceedings of the XVth ICCP Stratigraphy.* Wong, Th. E. (ed.). R. D. Academy Arts and Sciences, pp. 345-354.

Pereira, Z., Matos, J., Fernandes, P. & Oliveira, J. T. (2007) – Devonian and Carboniferous palynostratigraphy of the South Portuguese Zone, Portugal – An overview. *In: Abstracts CIMPLISBON'07*. Pereira, Z., Oliveira, J.T. & Wicander, R. (eds)., pp. 111-114.

Pfefferkorn, H. W., (1968) – *Geologie des Gebietes zwischen Serpa und Mértola (Baixo Alentejo), Portugal*. PhD Thesis. Munster. Forsch. Geol. Palaont., 9, pp. 2-143.

Pruvost, P. (1914) – Observations sur les terraines Dévoniens et Carbonifères du Portugal et sur leur faune. *Comunicações Serviços Geológicos de Portugal,* **10**: 1-21.

Quesada, C., Fonseca, P., Munhá, J., Oliveira, J. T. & Ribeiro, A. (1994) – The Beja-Acebuches Ophiolite: Geological caracterization and geodynamic significance. *Boletim Geológico Mineiro*, **105**, pp. 3-49.

Ribeiro, A. (1983) – Structure of the Carrapateira Nappe in the Bordeira Area, SW Portugal *In*: *The Carboniferous of Portugal.* Lemos de Sousa, M. J. & Oliveira, J. T. (eds.,). Serviços Geológicos de Portugal, **29**: pp. 91-97.

Ribeiro, A., Oliveira, J. T., Ramalho, M., Ribeiro, M. L. & Silva, J. B. (1987) – Carta Geológica de Portugal na escala de 1/50 000. Notícia Explicativa da Folha 48-D, Bordeira. 79 pp. Serviços Geológicos de Portugal. Lisboa.

Ribeiro, A., Quesada, C. & Dallmayer, R. D. (1990) – Geodynamic evolution of the Iberian Massif. In: *Pre-Mesozoic Geology of Iberia*. Dallmeyer, R. D. & Martinez Garcia, E. (eds.). Springer Verlag. pp. 399-409

Schermerhorn, L. G. (1971) – An outline stratigraphy of the Iberian Pyrite Belt. *Boletim Geológico Mineiro, España*, **82**, 3-4, pp. 239-268.

Silva, J. B. (1989) – *Estrutura de uma geotransversal da Faixa Piritosa: Vale do Guadiana.* Tese de Doutoramento. Fac. Ciências Lisboa. 201 pp.

—— (1998) – Enquadramento geodinâmico da Faixa Piritosa na Zona Sul Portuguesa. *In: Livro Guia, V Congresso Nacional de Geologia.* Oliveira, J.T. & Dias, R.P., (eds.,). Excursão **2**, 79-89.

Silva J. B., Oliveira J.T. & Ribeiro A. (1990) – South Portuguese Zone. Structural outline. In: *Pre-Mesozoic Geology of Iberia*. Dallmeyer, R. D. & Martinez Garcia, E. (eds.). Springer Verlag., pp. 348-362.

Streel, M., Higgs, K., Loboziak, S., Riegel, W., Steemans, Ph. (1987) – Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenne-Rhenish regions. *Review of Palaeobotany and Palynology*, **50**, pp. 211-229.

Streel, M. (1996) – Middle and Upper Devonian miospores. *In*: *Palynology: Principles and applications.* Jansonius J. & McGregor D.C, (eds.), Am. Assoc. Strat. Palynol. Found, Vol. **2**, pp. 575-587.

Wood, G. D., Gabriel, A. M. & Lawson, J. C. (1996) – Palynological techniques-processing and microscopy. *In*: *Palynology: Principles and applications.* Jansonius J. & McGregor D.C, (eds.), Am. Assoc. Strat. Palynol. Found, Vol **1**, pp. 29-50.

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PLATES

PLATE I

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

1 – *Verrucosisporites bulliferus* RICHARDSON & MCGREGOR, 1986, Ribeira de Limas Formation, Sample 3-1, 1190-218.

2 – *Cristatisporites triangulatus* (Allen) MCGREGOR & CAMFIELD, 1982, Gafo Formation, Sample 13-2, 1315-165.

3 – *Cristatisporites* sp. cf. *C. inusitatus* (Allen) MCGREGOR & CAMFIELD, 1982, Ribeira de Limas Formation, Sample 3-3, 1260-228.

4 – *Aneurospora greggsii* (McGregor) STREEL IN BECKER, BLESS, STREEL & THOREZ, 1974, Gafo Formation, Sample 13-3, 1290-100.

5 – *Chelinospora concinna* ALLEN, 1965, Ribeira de Limas Formation, Sample 1-1, 1320-205.

6 – *Teichertospora iberica* GONZALEZ, PLAYFORD & MORENO, 2005, Horta da Torre Formation, Sample 7-2b-1450-185.

7 – *Grandispora echinata* HACQUEBARD emend. UTTING, 1987, Horta da Torre Formation, Sample 8-2, 1015-246.

8 – *Grandispora cornuta* HIGGS, 1975; MP3 Borehole, Represa Formation, Sample 36,60-1, 1305-225.

9 – *Cristicavatispora dispersa* GONZÁLEZ, PLAYFORD & MORENO, 2005; Open pit Mina de São Domingos mine, Represa Formation, Sample EM4-1, 1225-185.

10 – *Ancyrospora* sp., Horta da Torre Formation, Sample 8-1, 1440-120.

11 – *Rugospora explicata* GONZALEZ, PLAYFORD &MORENO, 2005, Horta da Torre Formation, Sample 7-3, 1505-200, INETI 0712.

12 – *Rugospora flexuosa* (Jushko) STREEL, 1974, Horta da Torre Formation, Sample 7-1a, 1390-105, INETI 0713.

13 – *Retispora lepidophyta* (Kedo) PLAYFORD, 1976; Tercenas Formation, Sample 105,1, 1350-210.

14 – *Indotrirradites explanatus* (Luber) KEDO, 1963; Tercenas Formation, Sample 106,b,2, 1391-165.

15 – *Verrucosisporites nitidus* (Naumova) PLAYFORD, 1964; Tercenas Formation, Sample 338,1, 1110-110.

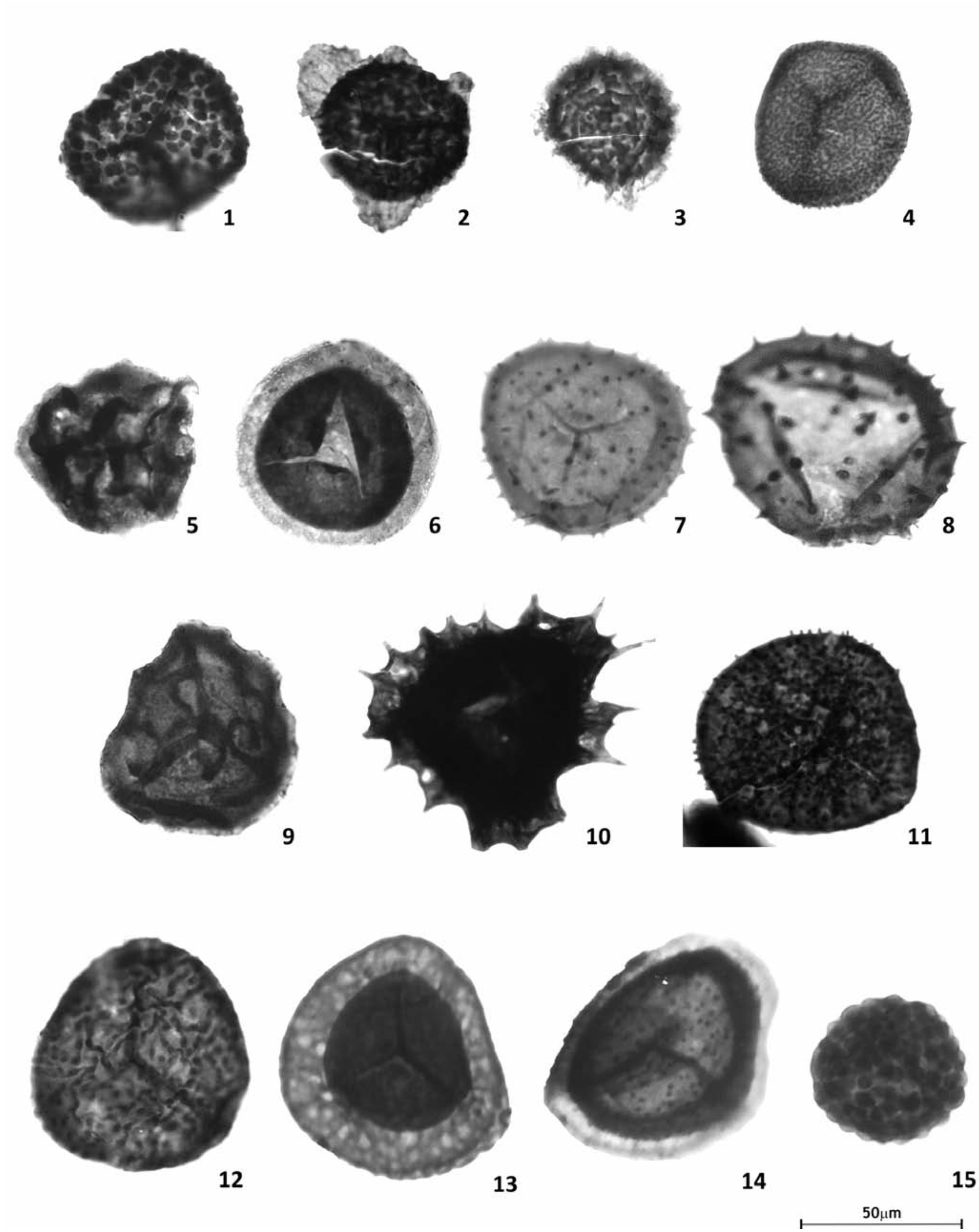
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PLATE II

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

1 – *Cyrtospora cristifer*a (Luber) emend. VAN DER ZWAN, 1979; Bordalete Formation, Sample 147,c,3, 1155-120.

2 – *Cyrtospora cristifer*a (Luber) emend. VAN DER ZWAN, 1979; Bordalete Formation, Sample 147,c,2, 1198-120, equatorial.

3 – *Umbonatisporites distinctus* CLAYTON, 1971; Bordalete Formation, Sample 336,3, 1245-148.

4 – *Granulatisporites microgranifer* IBRAHIM, 1933; Bordalete Formation, Sample 226,1, 1053-215.

5 – *Tumulispora rarituberculata* (Luber) PLAYFORD, 1991; Bordalete Formation, Sample 324,1, 1465-138

6 – *Spelaeotriletes balteatus* (Playford) HIGGS, 1975; Bordalete Formation, Sample 147,4, 1345-195.

7 – *Spelaeotriletes pretiosus* (Playford) NEVES & BELT, 1970; Bordalete Formation, Sample 247,4, 1354-65.

8 – *Lycospora pusilla* (Ibrahim) SCHOPF, WILSON & BENTALL, 1944; Murração Formation, Sample 280,1,1220-175.

9 – *Lycospora pusilla* (Ibrahim) SCHOPF, WILSON & BENTALL, 1944; MDS1 Borehole, VSC, Sample 255, 30-1, 1155-75.

10 – *Densosporites* sp.; MDS1 Borehole, VSC, Sample 255, 30-1, 1095-135.

11 – *Raistrickia nigra* LOVE, 1960; Murração Formation, Sample 379,1, 1455-73.

12 – *Knoxisporites stephanephorus* LOVE, 1960; Murração Formation, Sample 379.1 – 082-240.

13 – *Knoxisporites triradiatus* HOFFMEISTER, STAPLIN & MALLOY *sensu* SULLIVAN, 1964; Murração Formation, Sample 147,2, 1145-120.

14 – *Raistrickia nigra* LOVE, 1960; MDS1 Borehole, VSC, Sample 359, 40-1, 1380-180.

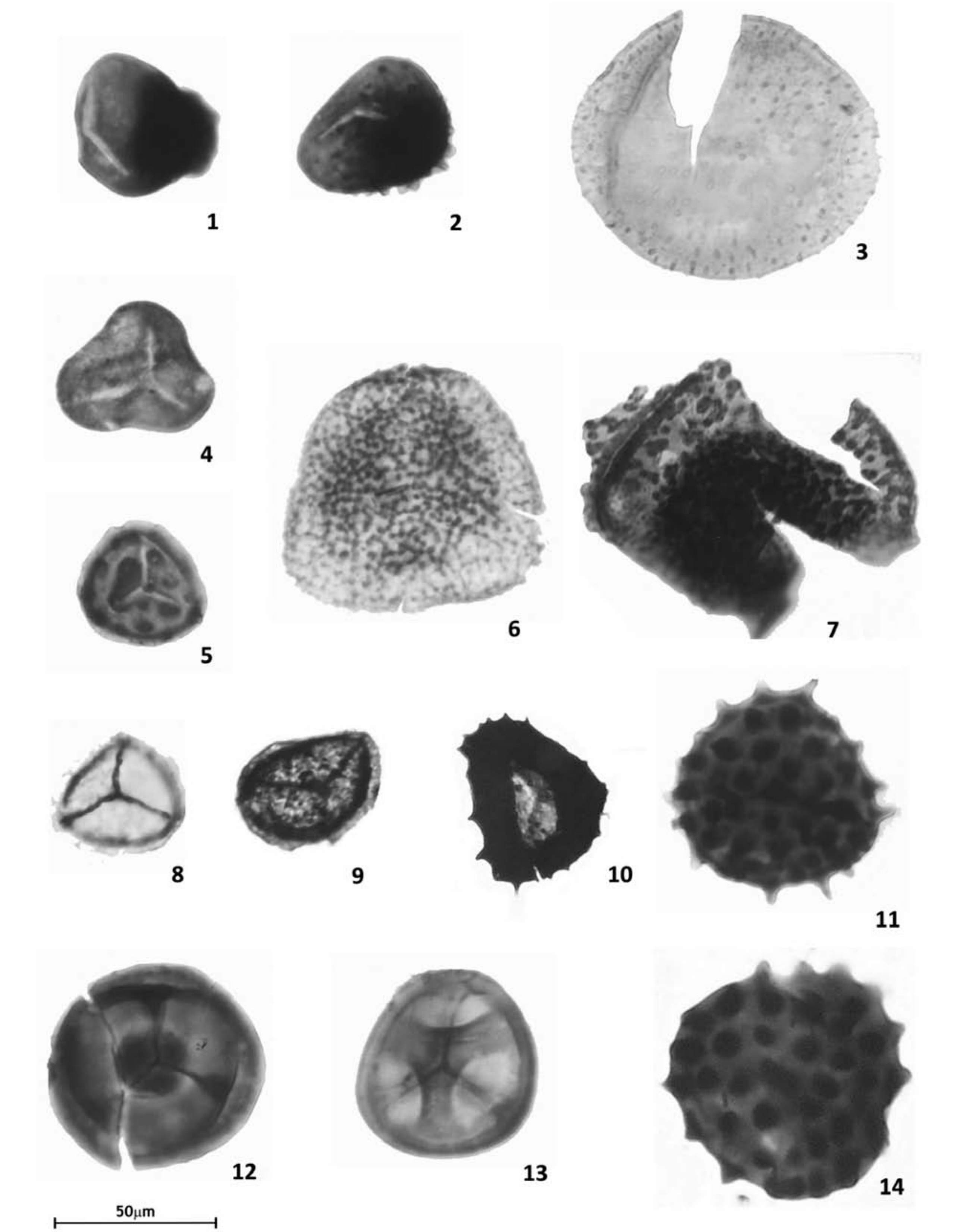
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Plate III

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

1 – *Savitrisporites nux* (Butterworth & Williams) Smith & Butterworth, 1967; Murração Formation, Sample 387,2, 1160-255.

2 – *Bellispores nitidus* (Horst) Sullivan, 1964; Murração Formation, Sample 229.2 – 1368-210.

3 – *Crassispora kosankei* Potonié & Kremp emend Bharadwaj, 1957; Quebradas Formation, Sample 387,2, 1230-95.

4 – *Reticulatisporites reticulatus* (Ibrahim) Ibrahim, 1933; Quebradas Formation, Sample 195,1, 1364-35.

5 – *Raistrickia fulva* Artuz, 1957; Quebradas Formation, Sample 200,1, 1430-205.

6 – *Cirratriradites saturni* (Ibrahim) Schopf, Wilson & Bentall, 1944; Brejeira Formation, Sample 266,1, 1260-87.

7 – *Dictyotriletes probireticulatus* (Ibrahim) Butterworth & mahdi, 1981; Brejeira Formation, Sample 238,b,1, 1350-110.

8 – *Radiizonates aligerens* (Knox) Staplin & Jansonius, 1964; Brejeira Formation, Sample 242,5, 1240-210.

9 – *Florinites junior* Potonié & Kremp, 1954; Brejeira Formation, Sample 229,3, 1145-100.

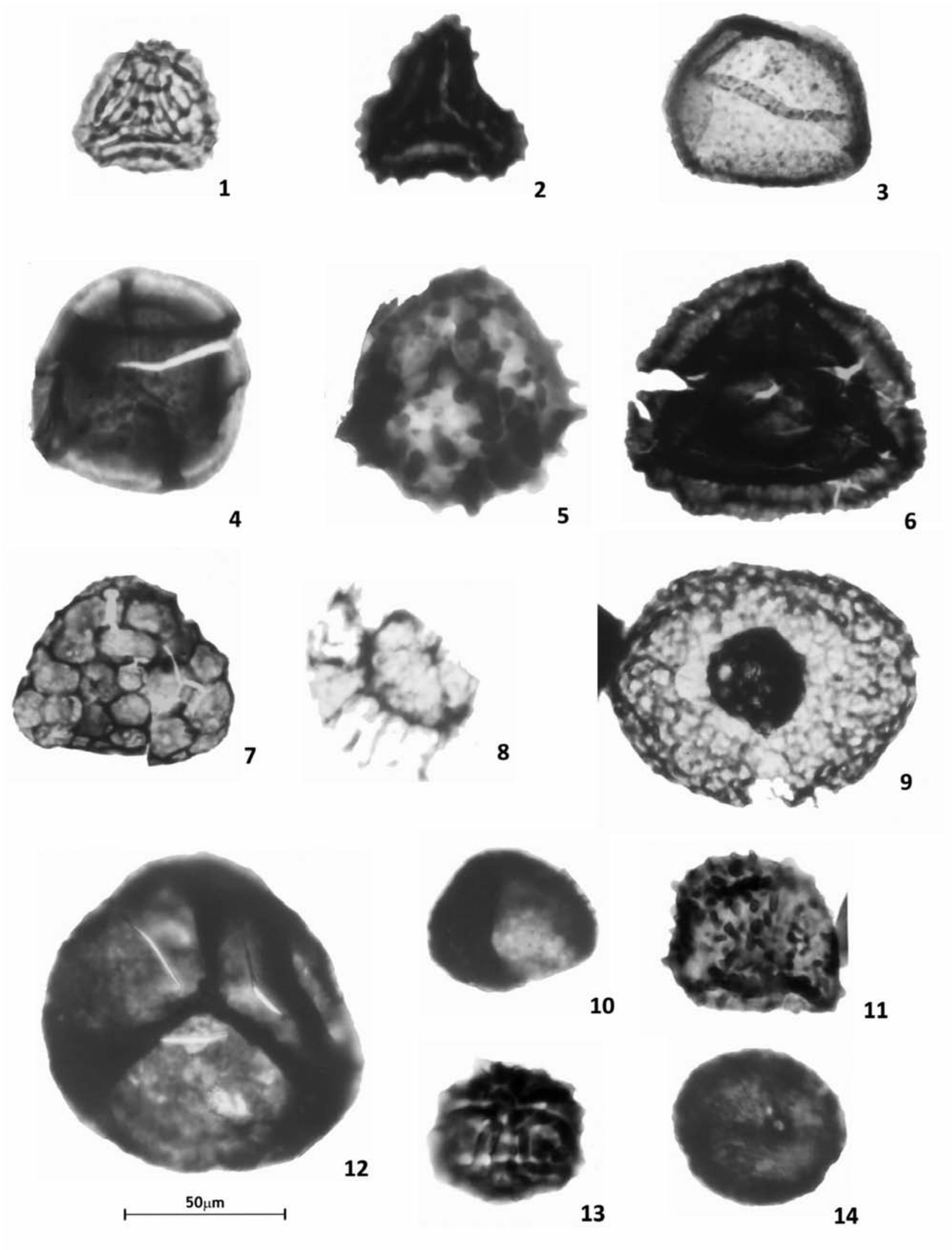
10 – *Torispora securis* Balme, 1952; Brejeira Formation, Sample 63,1, 1135-185.

11 – *Raistrickia aculeata* Kosanke, 1950; Brejeira Formation, Sample 63.1 – 1385-200.

12 – *Cadiospora magna* Kosanke, 1950; Brejeira Formation, Sample 62,1,1254-175.

13 – *Thymospora pseudothiessenii* (Kosanke) Wilson & Venkatachala, 1963; Brejeira Formation, Sample 63,1, 1220-185.

14 – *Thymospora obscura* (Kosanke) Wilson & Venkatachala, 1963; Brejeira Formation, Sample 63,4, 1045-65.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