CIMP Lisbon‘07

Joint Meeting of Spores/Pollen and
Acritarch Subcommissions

Palynostratigraphic contributions to the understanding Ossa Morena and South Portuguese Zone Geology, PORTUGAL

Post meeting Field-trip
27-28 September 2007

INETI, Lisbon, PORTUGAL | 24-28 September 2007

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Edited by J. Tomás Oliveira, Zélia Pereira, Paulo Fernandes and João Matos

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FOREWORD

Traditionally the scientific programmes of these meetings are complemented with field trips. Keeping this tradition the Organizing Committee has prepared a two days field trip across the Portuguese part of the Ossa Morena and South Portuguese Zones. Besides the scientific aspects that certainly will be the aim of interesting discussions and changes of view among the participants, there will also be opportunities to appreciate varied landscapes and scenarios, and to contact with the Portuguese culture and people.

The editors of this guide book and field trip leaders are grateful and express their sincere thanks to all those colleagues and institutions that accept to cooperate. Special thanks are due to our INETI colleague J. Manuel Piçarra for his assistance in the geology of Barrancos region.

INETI – Geosciences provided all the facilities during the preparation of the meeting and field guide. PARTEX Oil Services, FCT - Fundação para a Ciência e Tecnologia and OLYMPUS kindly made available financial and technical support.

The research carried out by J. Tomás Oliveira, Zélia Pereira, Paulo Fernandes and João Matos was supported by the FCT projects PYBE (POCTI/CTE-GIN/56450/2004) and PROVENANCE (PCTI/CTE-GEX/60278/2004).

Bem-vindos

The Organizing Committee
September 2007

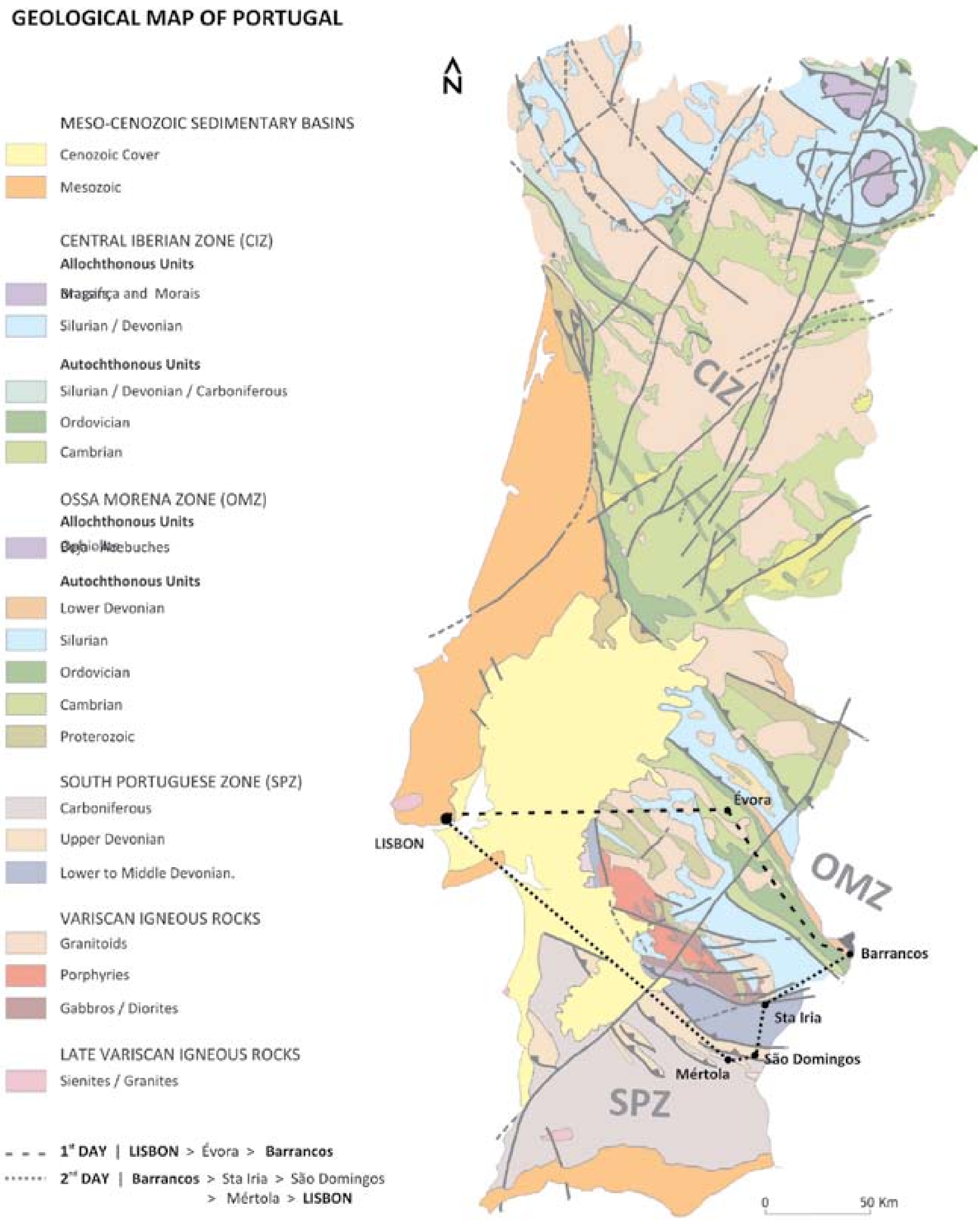


Fig. 1 General location of the proposed itineraries (Geological Map of Portugal, IGM, 1998).

FIELD TRIP PROGRAMME

The field trip is subdivided in two days, the schedule programme and the itineraries to be accomplished are presented in **Fig. 1** and **Tab. 1**.:

1ST DAY | 27 SEPTEMBER
The Barrancos Section

2ND DAY | 28 SEPTEMBER
Palynostratigraphic research in the South Portuguese Zone: the Santa Iria, Mina de São Domingos mine and Azenhas (Guadiana River) Sections

FIELD TRIP DAYS	DATE	REGION	ITINERARY	OVERNIGHT
MEETING POINT IN LISBON	27 SEPTEMBER			
FIRST DAY	27 SEPTEMBER	BARRANCOS	LISBON > ÉVORA > BARRANCOS	BARRANCOS
SECOND DAY	28 SEPTEMBER	PYRITE BELT	BARRANCOS > STA IRIA > S. DOMINGOS > MÉRTOLA > LISBON	LISBON

Tab. 1 General schedule of the field trip.

THE FIELD TRIP PALYNOLOGICAL BACKGROUND

The field trip is foccused on the Ossa Morena Zone (OMZ) and South Portuguese Zone (SPZ) geology, with emphasis on recent palynostratigraphic research.

The history of palynological studies of the SPZ extends back to the 1980s. In 1986, T. Cunha (in Oliveira et al., 1986) recorded for the first time in South Iberia a fairly well preserved palynomorph assemblage of mid Famennian age in the north limb of Pulo do Lobo Antiform. Giese et al., (1988) identified upper Devonian palynomorphs in the Almonaster la Real region, Spain, still in units of the northern limb of the Pulo do Lobo Antiform, Cunha and Oliveira (1989) determined upper Devonian palynomorphs in two lithostratigraphic units of the Mina de São Domingos region, Pyrite Belt and Lake (1991), in an unpublished PhD thesis, studied the palynology of both limbs of the Pulo do Lobo Antiform succession.

A detailed study in Southwest Portugal allowed the establishment of 17 miospore biozones, with 47 late Devonian and more than 200 Carboniferous miospore species (Pereira et al., 1994, Pereira et al., 1995, Pereira 1997, 1999). These palynostratigraphic results proved to fit well, in terms of age, the local ammonoids biozonation.

In the Pyrite Belt, very successful contributions came from the palynostratrigraphic study of the Neves Corvo mine region (Oliveira et al., 1997; Pereira et al., 2001; Pereira et al., 2004; Oliveira et al., 2004) and more recently from the study of the Albernoa, Serra Branca and Mina de São Domingos antiforms (Oliveira et al., 2005; 2006; Matos et al., 2006)

As demonstrated, palynostratigraphy represents at the present time, the best tool to date the SPZ lithostratigraphic units.

Palynostratigraphic studies in the Ossa Morena Zone (OMZ) proved to be more difficult due to metamorphism. Recent progress came from the palynological investigation in the Portuguese part of the OMZ, in particular, the Barrancos Section and more recently the Toca da Moura and Cabrela Complexes (Pereira and Oliveira, 2001a; 2001b; 2003a; 2003b; Pereira et al., 2004; Pereira et al., 2006).

The field trip aims the examination and discussion of selected Devonian and Carboniferous sections in the Portuguese part of the OMZ and SPZ and their palynological content. The choice of these sections followed criteria related with time, access and quality of the exposures.

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 miospore biozonal scheme used follows the standard Western Europe Miospore Zonation (after: Clayton et al., 1977; Clayton, 1996; Higgs *et al.*, 1988; Higgs *et al.*, 2002; Maziane et al., 2000; Streel *et al.*, 1987).

It is hopped that this trip will be a pleasant occasion to discuss and compare sedimentary environments, palynomorph assemblages and paleobiological events. Most important, however, are comments and changes of view with reference to the geological comparison with other areas, in order to better understand regional geodynamic evolution and the paleogeographic development of the Iberia during the Palaeozoic ages.

FIRST DAY, 27th September 2007

The Barrancos Section

Leaders: J. Tomás Oliveira, Zélia Pereira - INETI

Special collaboration: J. Manuel Piçarra - INETI

ROAD LOG

The field trip starts from Lisbon at 8:00 hours, following the road to Évora town (1 hour turistic stop), Reguengos de Monsaraz, Monsaraz (15 minutes turistic stop), Mourão and Barrancos.

Évora city, with its historic center and the unique atmosphere was declared a World Heritage Site by the UNESCO in 1986. The city, enclosed within Roman, medieval and 17th-century walls, has been important since Roman times, as can be seen by the ruins of its emblematic Temple of Diana, built in the 2nd or 3rd century AD. The animated main square, Praça do Giraldo, has Moorish arcades, a fountain dating from 1571 and is a popular meeting-place. The city has more than 20 churches and monasteries, among them the Cathedral, built between 1186 and 1204, with its Gothic entrance and many other treasures of sacred art, and the 15th-century São Francisco church which is famous for its fascinating but rather sinister Chapel of Bones. The University firstly installed by the jesuits in 1559, was closed in the 18th century and re-opened in the sixties of the last century. Its elegant cloister, a Baroque chapel and magnificent azulejos (painted tiles) are noticeable.

Monsaraz is an old village situated on top of a hill from which nice scenaries can be seen across, in particular the recent lake of Alqueva dam. The village is surrounded by a 16th century wall and was used as a fortress since the middle age. The village is also known due several megalithic monuments in its neighborhoods.

Barrancos small town is almost surrounded by Spanish territory. It has a unique culture with singular features such as dialect, architecture (Noudar castle) and the festivities during August, reminiscent of Castilian occupation until the 18th century.

Overnight in Barrancos (hotel *Agarrocha*).

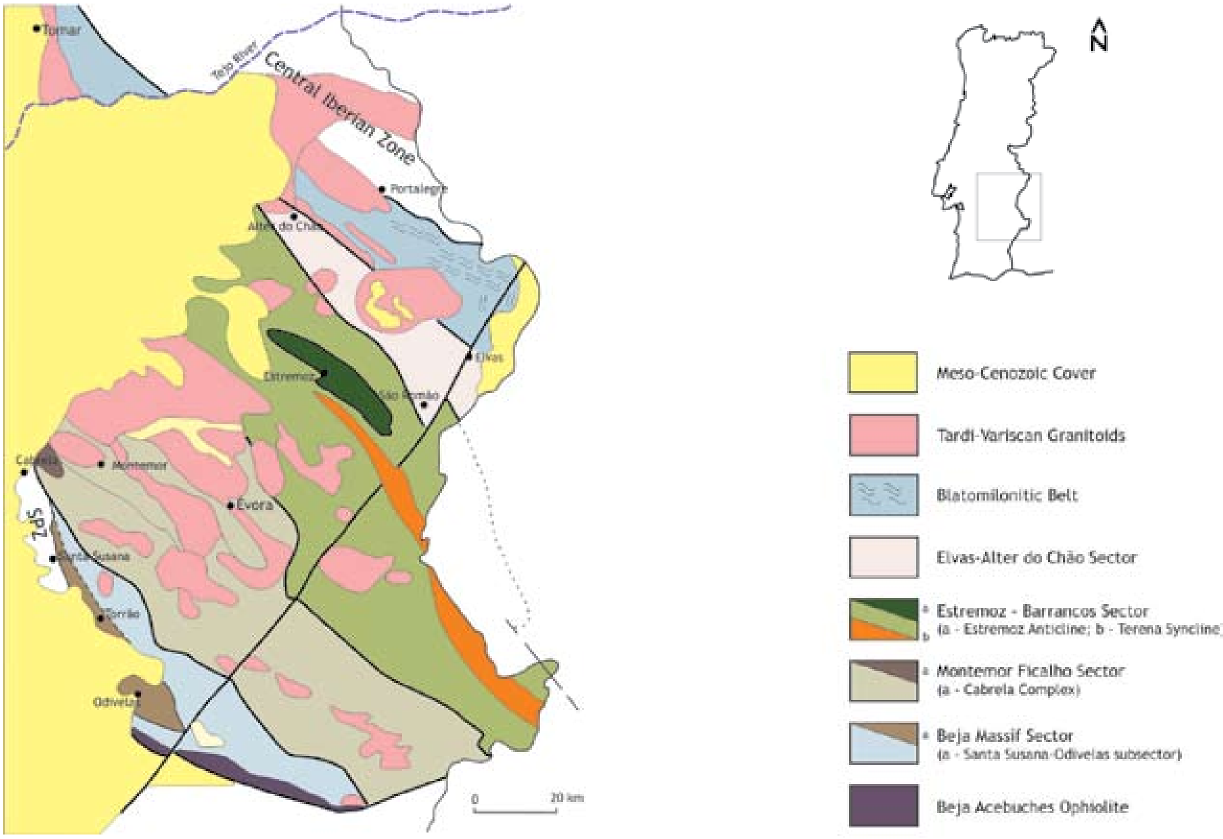


Fig. 1 Main sectors of the Ossa Morena Zone (Adapt. Oliveira et al., 1991)

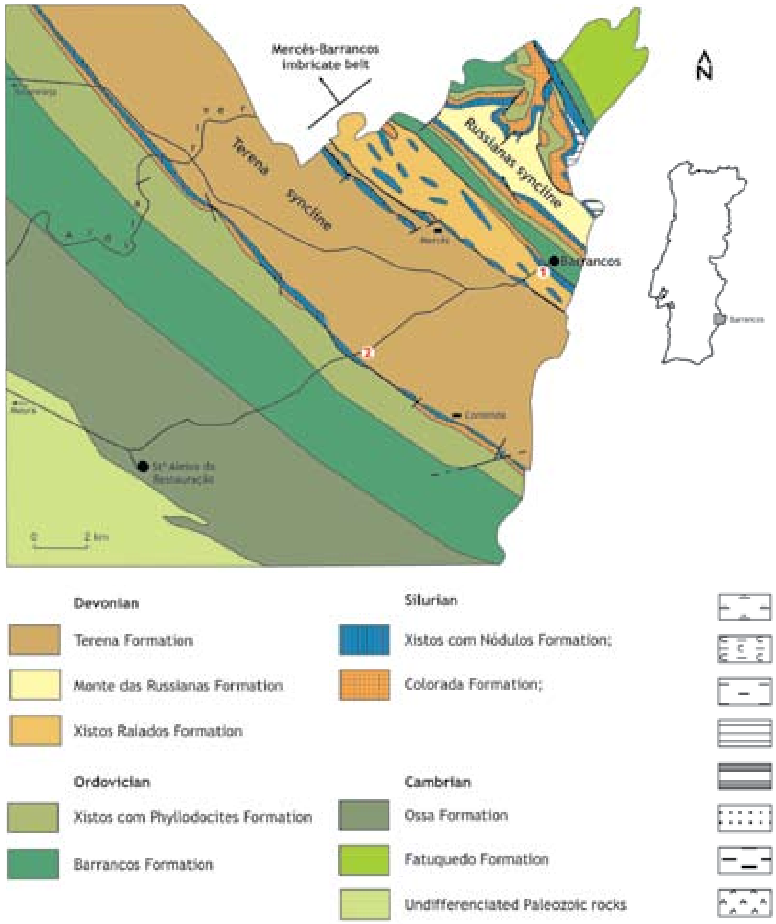
PALYNOSTRATIGRAPHY OF THE LOWER DEVONIAN SUCCESSION, BARRANCOS REGION, OSSA MORENA ZONE

Geological introduction

The Ossa Morena Zone (OMZ) has been subdivided into different tectonostratigraphic units, also called “sectors” or “domains” (Carvalho et al., 1971; Delgado et al., 1977; Apalategui et al., 1990; Oliveira et al., 1991) where the Paleozoic stratigraphic sequences are different in thickness, lithology and tectonic deformation (Fig. 1) Barrancos region is included in the Barrancos--Hinojales Domain (Apalategui et al., 1990) or in the Estremoz-Barrancos sector (Oliveira et al., 1991). Fig. 2 shows a simplified geological map of the Barancos region. Here, the stratigraphic succession (Fig. 3) represents the most complete segment of the Cambrian, Ordovician, Silurian and early Devonian of the Portuguese part of the OMZ (Perdigão, 1972-73; Perdigão et al., 1982; Piçarra et al., 1995; 1998; 1999; Gutiérrez-Marco et al., 1996; 1998; Robardet et al., 1998, Pereira et al., 1999; Le Menn et al., 2002).

The Cambrian comprises mostly shales and sandstones with intercalations of basic volcanics towards its lower part. The Ordovician is composed of pink and green shales (Barrancos Fm.) and gray shales and siltstones (Xistos com *Phyllodocites* Fm.). The Silurian starts with a sandstone unit (Colorada Fm.) followed by a condensed sequence o black shales and lydites (Xistos com Nódulos Fm.) which in turn grades upward to thin bedded shales and silstones (Xistos Raiados Fm.). The Silurian--Devonian boundary in within the upper part of this later formation. The Monte das Russianas Fm. is a lateral equivalent of the Xistos Raiados Fm., and is also composed of shales and siltstones but with thin bedded intercalations of early Devonian fossiliferous limestones. The Terena Fm. is a turbiditic succession of early Devonian age that is interpreted as a deep equivalent of the shallow water Monte das Russianas Fm.

All the stratigraphic units are arranged in three main NW-SE trending Variscan structures, i.e. the Terena syncline, the Barrancos anticline and the Russianas syncline (Fig. 2).



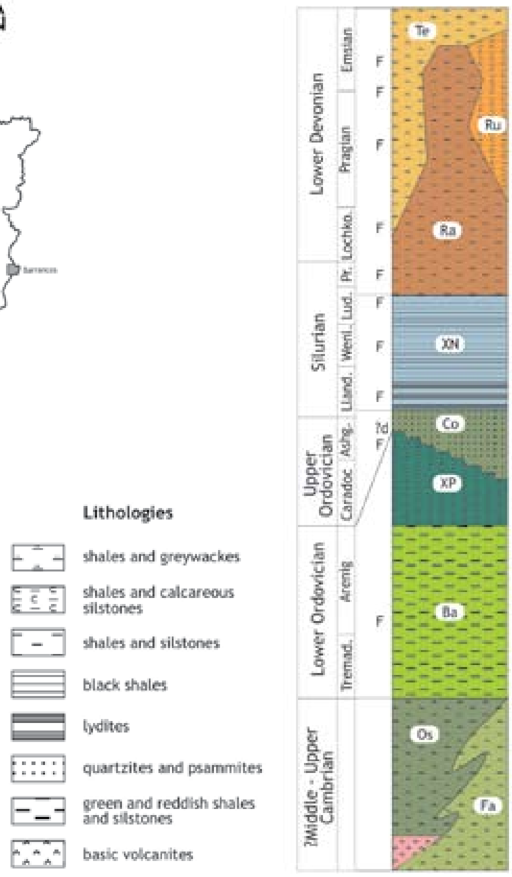


Fig. 2 Simplified geological map of the Barrancos region (Piçarra et al., 1995; 1998; 1999), showing the position of the field trip stops.

Fig. 3 Global stratigraphic column recognised in Barrancos. **F** - Faults; **d** - Discordance (Adapt. Piçarra, 2000).

Palynostratigraphy

The lithostratigraphic units that yielded palynomorphs are the upper part of the "Xistos Raiados" Fm., the "Monte das Russianas" Fm. and the Terena Fm. Fig. 4 shows the age of these units in terms of miospore zonation *sensu* Richardson and McGregor, 1986 and Streel et al., 1997. Fig. 5, elucidates the ranges of selected taxa recovered in Barrancos region. Stratigraphically important and typical taxa are illustrated in PLATE I.

"Xistos Raiados" Formation

This unit was considered of Wenlock to early Ludlow age (Perdigão et al., 1982). However, more recent investigation dated the unit of upper Ludlow to upper Praghian, based on graptolites (Piçarra, 1997; Piçarra et al. 1998) and miospores (Pereira et al., 1999). The lower part of the "Xistos Raiados" Formation has yielded graptolites of the lower (*Colonograptus parultimus-Colonograptus ultimus* Biozones) and middle (*Monograptus bouceki* Biozone) Pridoli age (Piçarra, 2000).

The remaining alternations of shales and thin sandstones of the "Xistos Raiados" Fm. gave graptolites of the Lochkovian, *Monograptus uniformis* Biozone and miospores of the *Verrucosisporites polygonalis-Dictyotriletes emsiensis* (PE Biozone). The presence of *Dictyotriletes canadiensis* and *D. subgranifer* in the miospore assemblage indicates the upper part of PE Biozone, close to the Praghian/Emsian boundary.

This sucession displays a close identity with that of the Valle syncline (Sevilla province, Spanish part of the Ossa Morena Zone) and also with Sardinia, Bohemia and Thuringia, that once were part of North Gondwana.

"Monte das Russianas" Formation

Up to very recent times, the shales, psammites and calcareous siltstones of the Monte das Russianas Formation were the only rocks considered as Lower Devonian. This stratigraphical attribution was based on the occurrence of trilobites, brachiopods, bivalves, bryiozoans and corals of Praghian-Emsian age (see references in Perdigão et al., 1982).

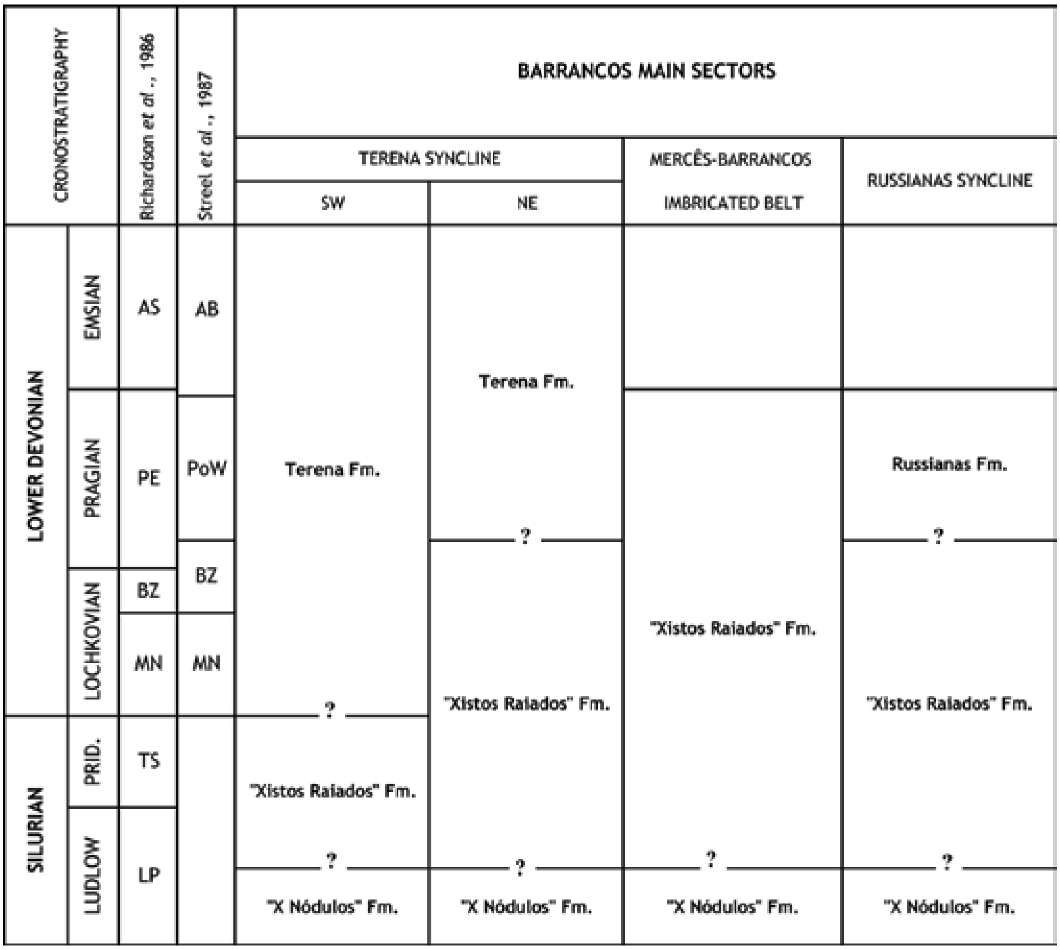


Fig. 4 Age of the Barrancos region units in terms of miospore Zonation (Adapt. Pereira et al., 1999).

More recent palaeontological research provided miospores and crinoids. The crinoids identified indicate a Praghian age and close affinities with Devonian faunes of the Armorican Massif (Le Menn et al., 2002).

The miospore assemblage indicates the PE Biozone (Praghian age). Typical assemblages include: *Apiculiretusispora plicata, Archaeozonotriletes chulus, Brochotriletes sp., Cymbosporites proteus, Dictyotriletes emsiensis, D. subgranifer, Emphanisporites micrornatus, E. multicostatus, E. negletus, E. rotatus, Punctatisporites* sp., *Retusotriletes abundo, R. warringtonii* and *Verrucosisporites polygonalis*. The first occurrence of *Verrucosisporites polygonalis*?, indicates the basal Po Biozone (Streel et al., 1987).

Terena Formation

The Terena Formation is composed of pelites and greywackes, with some conglomerate intercalations. This turbiditic succession occurs in the core of the Terena syncline. It was considered by Teixeira (1951) of early Devonian age, on the basis of plant remains. Subsequently, it was regarded as Upper Devonian and Lower Carboniferous syn-orogenic Variscan flysch (Schermerhorn, 1971; Ribeiro et al., 1979; Perdigão et al., 1982).

The identification of graptolites of the Lochkovian *Monograptus hercynicus* Biozone (Piçarra, 1996; 1997) in the lowermost levels and of miospores in the whole formation (Pereira et al., 1998; 1999) have confirmed the early Devonian age.

The basal part of the Terena Formation turbidites, in both limbs of the syncline provided miospore assemblages assigned to the PE Biozone of Praghian age. Higher in the lithological succession Emsian (*Emphanisporites annulatus-Camarozono-triletes sextantii*) miospores were also found.

These age determinations suggest that the three units interfinger and are partially coheval, no major unconformity having been detected between the Terena Formation and the other units, as previously accepted. The assumption that the Terena Formation seals a first variscan orogenic episode should be questioned.

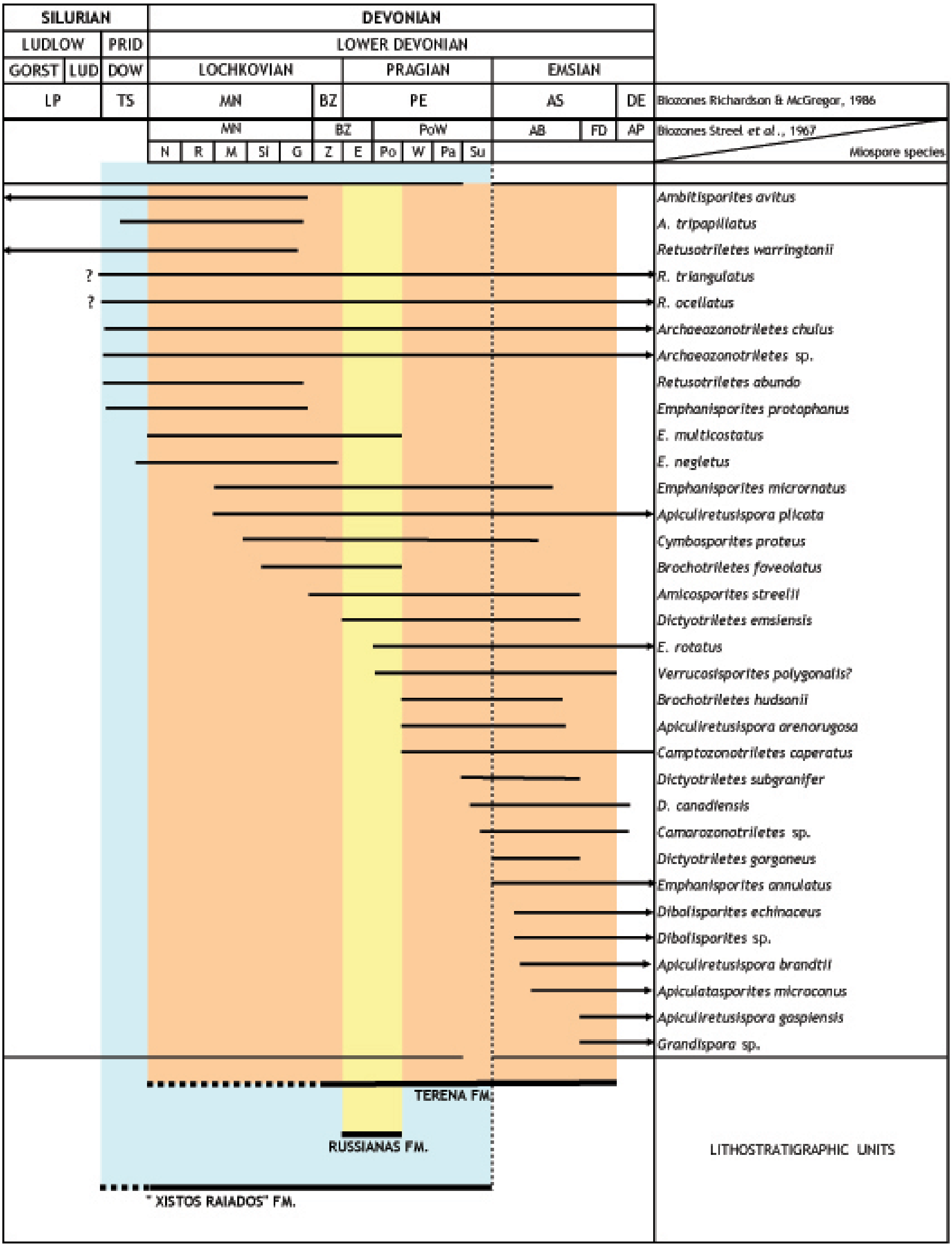


Fig. 5 Ranges of selected taxa recovered in Barrancos region (Adapt., Pereira et al., 1999).

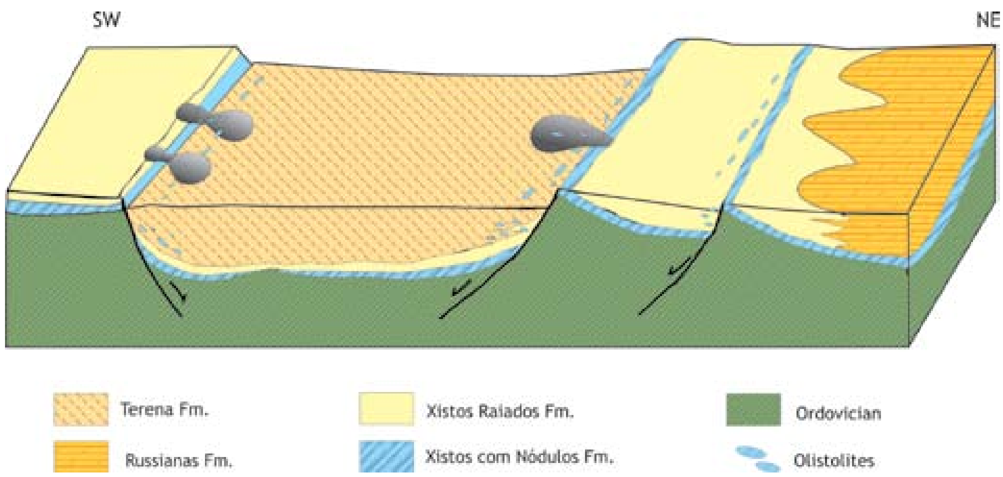


Fig. 6 Tectonostratigraphic interpretation of the Barrancos units.

Conclusions

Previous age determinations mostly based on macrofossils and the more recent palynostratigraphic research show that during the lower Devonian three coheaval sedimentary depositional systems occurred in the Barrancos region. The thin bedded limestones in the Russianas Fm., conjugated with their faunal content with trilobites, brachiopods, bivalves, bryiozoans and corals suggest deposition in a distal platform. The Xistos Raiados Fm. has lithological affinities with the Russianas Fm., the main difference being the absence of limestones and the more widespread occurrence of thin bedded sandstones with graded bedding, ripple cross lamination and bioturbation. It is suggested that the Xistos Raiados lithologies may represent offshore sediments in a region affected by storm events. The Terena Fm. turbidites were probably deposited in a narrow elongated basin bordered by synsedimentary active normal faults. This crustal instability led to synsedimentary gravity sliding of which the olistholites interbedded in the Xistos Raiados and Terena Fms. respresent presently the prove (Fig 6).

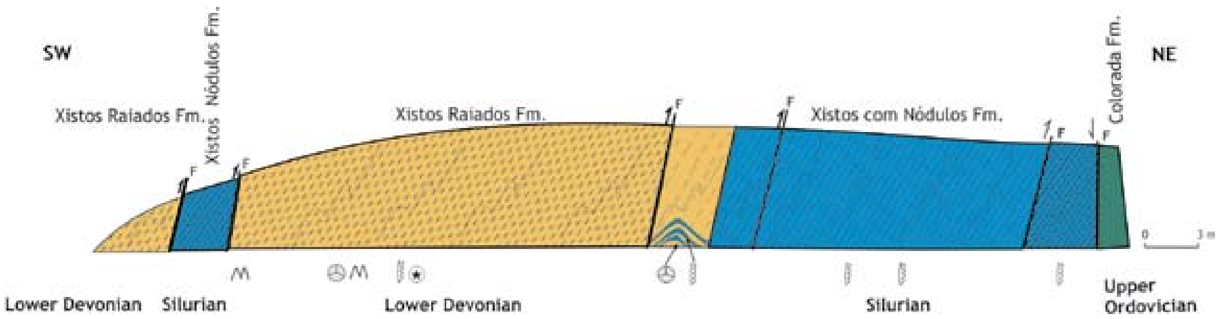


Fig. 7 Scheme of the road cut section at km 103.7 of the road from Santo Aleixo da Restauração to Barrancos, at the entrance of this town (Adapt. Piçarra, 2000).

GEOLOGICAL STOP 1

Early Silurian-Lower Devonian sequence, Barrancos anticline

Location (Point 1 on Fig. 2)**:** Road cut section between kms 103.3 and 103.7 of the road from Santo Aleixo da Restauração to Barrancos, at the entrance of this village.

Description (Fig. 7 and 8)**:**

This stop begins in the road-side trench, at km 103.7. From NE to SW the succession comprises:

· Impure sandstones of the early Silurian Colorada Formation, in tectonic contact (vertical fault) with Llandoverian lydites of the basal part of the "Xistos com Nódulos" Formation.

· A sequence of rather strongly deformed lydites and black shales weathering white and sporadic siliceous nodules (rarer in the upper part). The graptolite faunas indicate an age range from the Landovery to Upper Wenlock.

· At the upper part of the section, dark shales with intercalations of thin bedded siltstones and rare siliceous and ferruginous nodules belong to the "Xistos Raiados" Formation. The beds situated in the lower part of this sequence contain "pebbles" of lydites that have yielded *Retiolites geinitzianus* and *Torquigraptus* ex gr. *tullbergi* of the Upper Telychian, and scyphocrinoid remains.

Miospore assemblages recovered from this part of the section indicate the upper part of the *Verrucosisporites polygonalis-Dictyotriletes emsiensis* (PE) Biozone. Typical elements are present: *Apiculiretusispora plicata*, *Archaeozonotriletes chulus*, *Brochotriletes* sp., *Clivosispora verrucata*, *Dictyotriletes canadiensis, D. emsiensis*, *Emphanisporites microornatus*, and *E. negletus*. *Dictyotriletes canadiensis* recognize the upper part of the PE Biozone.

Another trench, situated to the SW of the preceding section, also shows lydite "pebbles" dispersed within the Xistos Raiados Formation (Fig. 8). These pebbles yielded Llandovery and Wenlock graptolites, *Cardiola*, brachiopods, orthocone nautiloids and scyphocrinoid remains (including a lobolite) i. e. the pebbles are much older than the hosting shales. This part of the section provided a miospore assemblage of the upper part of the PE Biozone, based on the presence of *Archaeozonotriletes* sp.; *Brochotriletes* sp.; *Clivosispora verrucata*, *Dictyotriletes emsiensis*, *D. subgranifer*, *Emphanisporites microornatus*, *Punctatisporites* sp.; *Retusotriletes* sp. *D. subgranifer* marks the base of Su zone (Streel et al., 1987).

The sections now observed are affected by folds, normal and reverse faults, a tectonic situation that is characteristic of the regional geology. Besides these Variscan deformations, the fact that lower Silurian olistholites occur in the lower Devonian shales of the "Xistos Raiados" Formation points to the existence of sin-sedimentary gravity slides, probably in connection with normal faults.

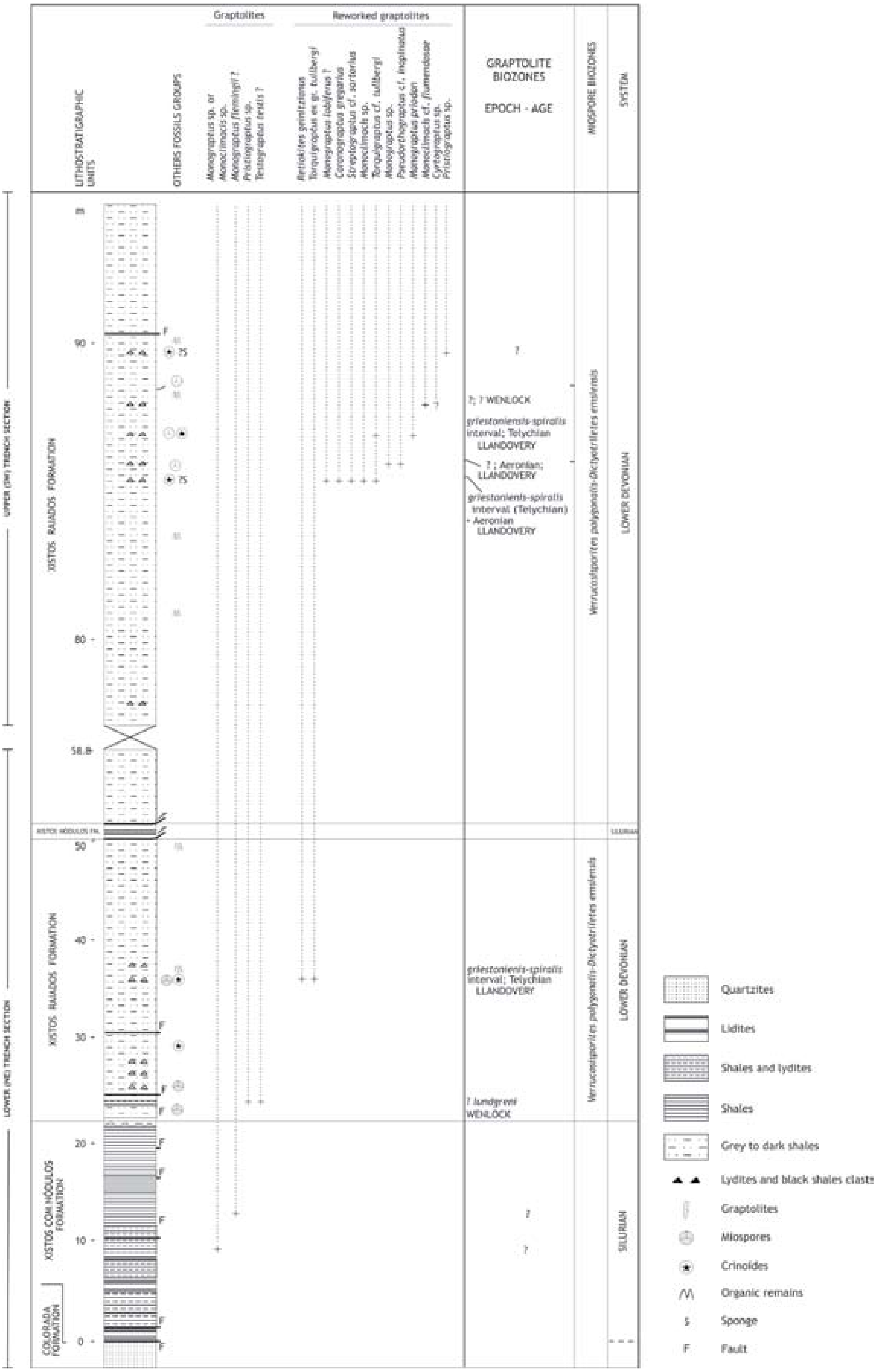


Fig. 8 Composite stratigraphic logs of the road cuts (NE and SW sections), road from Santo Aleixo da Restauração to Barrancos (Adapt. Piçarra, 2000).

GEOLOGICAL STOP 2

The Terena Formation flysch at the western limb of the Terena syncline

Location (Point 2 on Fig. 2)**:** Road cut section at km 94,7 of the main road from Santo Aleixo da Restauração to Barrancos.

Description:

This stop allows a close examination of the lower levels of the Terena Formation. In the west limb of the syncline, the unit comprises thin and thick beds of greywaky turbidites and intercalations of conglomerates in places with crinoid remains. The road trench shows beds of greywackes displaying Bouma`s sedimentary divisions, flute and groove marks, and load cast, which have thin intercalations of shales. The beds dip westward and the sedimentary structures provide way up criteria which clearly shows younging towards east, i.e the beds are overturned. However, the bedding/ cleavage relationship indicates a normzal limb, a geometric situation that suggests a post cleavage tectonic rotation or, alternatively, the transection of the regional fold hinges by the Variscan cleavage generated in a left lateral top to the east shear zone.

Miospores recovered from the thin bedded shales provided an assemblage that contains *Camarozonotriletes sp., Dictyotriltes emsiensis, Emphanisporites micrornatus, E. negletus, E. rotatus, Punctatisporites* sp. *and Retusotriletes* sp., assigned to the PE Biozone of Praghian age.

PLATE I. Miospores from the Barrancos region (Pereira et al., 1999).

Each specimen is referenced by collection number, sample number, slide number, microscope coordinates (MC) and England Finder coordinates (EF).

1. *Ambitisporites* sp. B in Moreau Benoit 1976; IGM 9891; Xistos Raiados Fm., Sample 56,1, slide 1, MC 1115-125, EF N16,4 (x400).

2. *Retusotriletes warrigtonii* Richardson and Lister 1969; IGM 9892; Xistos Raiados Fm., Sample 32, 2, slide 3, MC 1280-115, EF P29,2 (x400).

3. *Archaeozonotriletes chulus* (Cramer) Richardson and Lister 1969; IGM 9893; Xistos Raiados Fm., Sample 32, 2, slide 3, MC 1365-68, EF T34,0 (x400).

4. *Emphanisporites protophanus* Richardson and Ioannides 1973; IGM 9894; Xistos Raiados Fm., Sample 35,2, slide 2, MC 1354-200, EF F31,4 (x400).

5. *Emphanisporites micrornatus* Richardson and Lister 1969; IGM 9895; Xistos Raiados Fm., Sample 32,1, slide 1, MC 1165-182, EF H18,2 (x400).

6. *Amicosporites streelii* Steemans 1989; IGM 9896; Xistos Raiados Fm., Sample 35,2, slide 2, MC 1120-150, EF K13,4 (x400).

7. *Brochotriletes* sp.; IGM 9897; Xistos Raiados Fm., Sample 35,2, slide 2, MC 1085-82, EF U7,0 (x400).

8. *Dictyotriletes subgranifer* McGregor 1973; IGM 9899; Xistos Raiados Fm., Sample 32,2, slide 3, MC 1445-70, EF U46,0 (x400).

9. *Dictyotriletes canadiensis* McGregor 1973; IGM 98102; Xistos Raiados Fm., Sample 35,2, slide 3, MC 1305-200, EF F37,0 (x400).

10. *Dictyotriletes emsiensis* (Allen) McGregor 1973; IGM 9898; Terena Fm., Sample 76,1, slide 1, MC 1082-130, EF N9,3 (x400).

11. *Dictyotriletes gorgoneus* Cramer 1967; IGM 98100; Terena Fm.,Sample 172,1, slide 4, MC 1175-173, EF H18,3 (x400).

12. *Emphanisporites annulatus* McGregor 1961; IGM 98101; Terena Fm.,Sample 64,2, slide 3, MC 1325-125, EF O33,2 (x400).

13. *Brochotriletes foveolatus* Naumova 1953; IGM 98103; Terena Fm.,Sample 70,1, slide 3, MC 1085-05, EF W10,2 (x400).

14. *Apiculiretusispora brandtii* Streel 1964; IGM 98104; Terena Fm.,Sample 172,1, slide 6, MC 1425-178, EF H43,0 (x400).

15. *Apiculatasporites microconus* (Richardson) McGregor and Camfield 1982, IGM 98105; Terena Fm.,Sample 172,1, slide 6, MC 1215-235, EF B22,0 (x400).

SECOND DAY, 28th September 2007

Palynostratigraphic research in the South Portuguese Zone: the Santa Iria, Mina de São Domingos mine and Azenhas (Guadiana River) Sections

Leaders: J. Tomás Oliveira, Zélia Pereira, João Matos - INETI
Paulo Fernandes - ALGARVE UNIVERSITY

ROAD LOG

Departure from the hotel in Barrancos at 8h00, following the road to Ficalho, Santa Iria (Serpa), Mina de São Domingos, Mértola and Lisboa.

Mina de São Domingos mine was an old mine exploited already in Roman times The mine was active during almost a century (1858 to 1966) and produced about 25 M tones of massive sulphides with 1.254b Cu and 2 to 3% Zn· The ore is now exhausted. The village keeps still a mining flavour, particularly the architecture of single door small houses aligned in rows, which were specially built for mine workers.

Mértola is a quite interesting historical small town that was an important trade centre during the Roman and mainly the Arab occupation, taking advantage from its geographic position in the west side of the navigable Guadiana river. The town was incorporated in the Portuguese Kingdom during the 13th century. The castle, originally Romanic, has been rebuild several times and the now catholic church was originally a mosque from which many traces are still preserved. Mértola is now an important centre of archaeological research and has several museums.

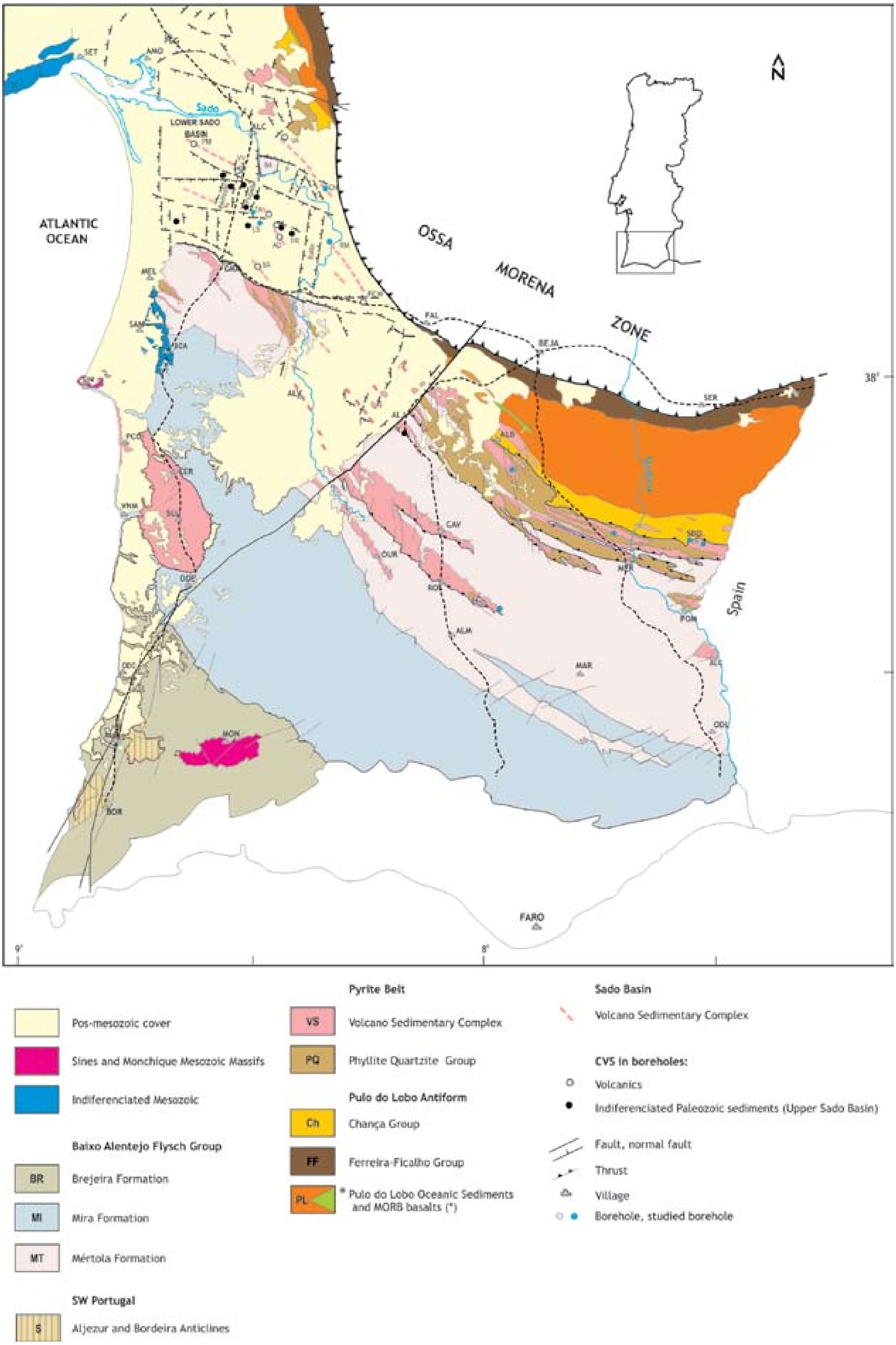


Fig. 9 Geological Map of South Portuguese Zone (Adapt. Oliveira et al., 1990).

BRIEF INTRODUCTION TO THE SOUTH PORTUGUESE ZONE GEOLOGY

The South Portuguese Zone (SPZ) is traditionally divided, from north to south in several domains, also called sectors or zones, designated as Pulo do Lobo Antiform, Pyrite Belt, Baixo Alentejo Flysch Group and Southwest Portugal (Oliveira, 1983; 1990, Fig. 9). At the boundary between the SPZ and the OMZ outcrops a belt of basic and ultrabasic rocks which have been considered an ophiolite suite, the so-called Beja-Acebuches Ophiolite (Munhá et al., 1986; Fonseca and Ribeiro, 1993; Quesada et al., 1994).

The Pulo do Lobo Antiform comprises highly sheared phyllites and quartzites at the base (Pulo do Lobo Fm.) which are unconformably overlain by metarenites, shales and metagreywackes forming the flysch-like succession of the Ferreira-Ficalho Group (Carvalho et al., 1976; Oliveira et al., 1986; Giese et al., 1988). Mafic rocks with N-MORB geochemical signature appears interbedded in the Pulo do Lobo Fm. (Munhá, 1983). Palynomorphs recently recovered from the Ferreira-Ficalho Group indicates a Frasnian to late Famennian age (Oliveira et al., 1986; Eden, 1991; Pereira et al., 2006b, 2006c).

At the southern limb of this Antiform, a flysch-like succession composed of greywackes, siltstones and shales (Chança Group) also occurs (Oliveira, 1990) and again with a Frasnian to late Famennian age, given by miospores (Cunha and Oliveira, 1989; Pereira et al., 2006b, 2006c).

All the Pulo do Lobo units were strongly deformed and metamorphosed during the Variscan orogeny. The units of the Pulo do Lobo Antiform have been interpreted as an accretionary prism, in close relation with a northward directed (present coordinates) subduction zone of which the Beja-Acebuches Ophiolite is presently a geological remnant (Silva et al., 1990; Quesada et al. 1994; Fonseca and Ribeiro, 1993).

The Pyrite Belt succession is composed of a shallow water detritic substrate comprising shales, sandstones and minor limestone lenses, the Phyllite Quartzite Fm., of late Devonian age, which is conformably overlain by a Volcanic Sedimentary Complex (VSC) of late Famennian to early late Visean age (Boogaard, 1967; Schermerhorn, 1971; Oliveira, 1983; Oliveira, 1990; Oliveira et al., 1997; 2004, 2005; Pereira et al., 2003; 2006d). The main characteristics of this complex are: the bimodal signature of the volcanism, with a clear predominance of felsic volcanics (lavas, pyroclasts, ignimbrites) and spilites (former basalts); the large predominance of black shales in which the volcanics are inerbedded; the occurrence of huge massive sulfide deposits which make the Pyrite Belt one of the world most important mining districts.

The Baixo Alentejo Flych Group, comprising three lithostratigraphic units (Mértola, Mira and Brejeira Formations), represents a turbiditic sequence that consists of shales and greywackes and interbedded conglomerates, the latter more frequent near the Pyrite Belt. The age given by goniatites and miospores ranges from the Late Visean, in the northern areas, to Late Moscovian in the South, showing so a clear southward sedimentary progradation. Evidence gathered from the clasts composition of the interbedded conglomerates and the petrologícal composition of the greywackes indicates that the source area of these sediments was the proper Pyrite Belt and, to a lesser extend, the OMZ (Boogaard, 1967; Schermerhorn, 1971; Oliveira, 1983).

The Southwest Portugal domain shows a clearly distinct stratigraphic sequence. From bottom to top the following units can be identified (Oliveira et al. 1985; Oliveira, 1990, Korn, 1997; Pereira, 1999):

· a shallow water detrital sequence (Tercenas Formation) of late Famennian to early Tournaisian age, given by miospores. This unit shows lithological and sedimentological similarities to the Pyrite Belt detrital basement (PQ Group);

· a mixed terrigenous and carbonate sequence (Carrapateira Group) whose deposition took place in a distal carbonate platform. Detailed miospore (Pereira et al, 1994; 1995; Pereira, 1997; 1999) and amonoid (Korn, 1997) studies have shown that the age of this group ranges from the early Tournaisian to the Baskirian;

· the Brejeira Formation turbidites (the younger unit of the Baixo Alentejo Flysch Group) of early to late Moscovian age given by miospores, which mark the local deepening of the basin floor, probably as a response to the southward moving orogenic wave.

All the South Portuguese Zone Domains were affected by the Variscan orogeny. Sedimentation, volcanism (?) and tectonic deformation prograded southwestard, from the upper Devonian to the late Moscovian, giving way to a thrust and sheet tectonic belt.

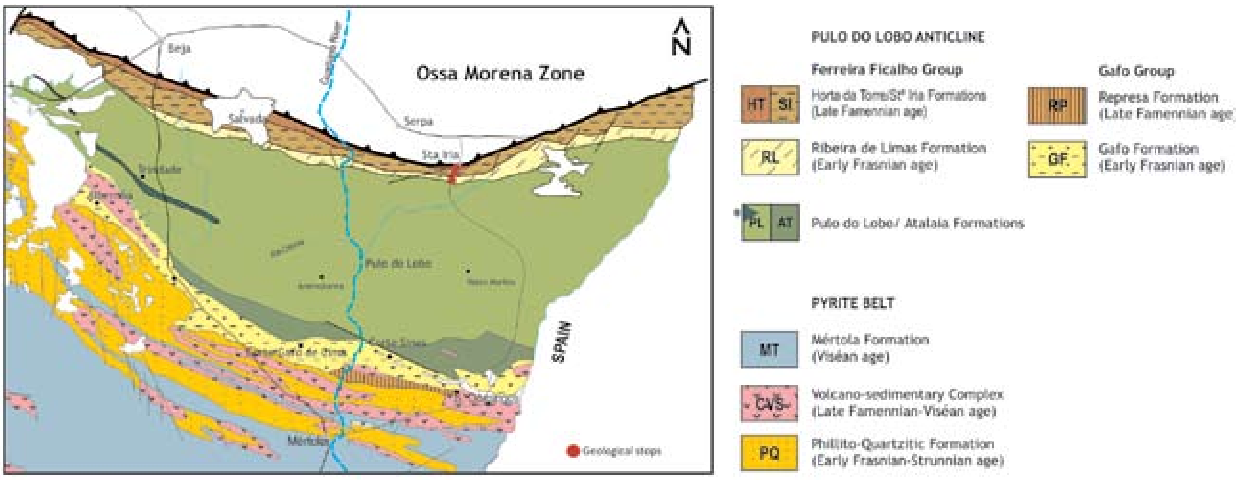


Fig. 10 Geological sketch map of the Pulo do Lobo Antiform (Adapt. from Geological Map of Portugal 1/500 000).

GEOLOGICAL STOP 1

Palynostratigraphy of the north limb of the Pulo do Lobo Antiform: the Santa Iria Section

Location (Fig. 10)**:** along the road from Serpa to Mina de São Domigos, near the Santa Iria village.

Brief description of the geology and palynostratigraphy

The aim of this stop is to show the units that compose the Ferreira-Ficalho Group and discuss their palynological content within the context of the Pulo do Lobo Antiform geodynamic evolution.

Ranges of selected miospore taxa recovered and the zonal scheme used are presented in Fig. 11. Stratigraphically important and typical miospore taxa are illustrated in PLATE II.

The Ferreira-Ficalho Group is build up of three lithostratigraphic units (Fig. 10), which are from top to base:

· **Horta da Torre Fm.**, comprising dark shales, thin bedded siltstones and sandstones, which yielded an assemblage of VH biozone miospores contain *Grandispora echinata* toghether with *Ancyrospora* sp., *Apiculiretusispora verrucosa*, *Auroraspora macra*, *Cristicavatispora dispersa*, *Diducites* spp., *Emphanisporites annulatus*, *Grandispora cornuta*, *G. famenensis*, *G. gracilis*, *Rugospora explicata, R. radiata* and *Teichertospora iberica.* All samples showed very rich assemblages of acritarchs and prasinophytes.

· **Santa Iria Fm.**, a shale and greywack flysh succession from which the following late Famennian miospores were recovered: *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.* This assemblage indicates the VH biozone of late Famennan age. All samples contain very rich assemblages of acritarchs and prasinophytes.

· **Ribeira de Limas Fm.**, a highly deformed sequence of shales, quartzwackes and impure quarzites, that provided an assemblage of miospores including *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*. This assemblage is assigned to the BM biozone of early Frasnian age. All samples contain rare acritarchs and prasinophytes.

The ages of the Ribeira de Limas and Santa Iria/ Horta da Torre, based on miospores, 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.

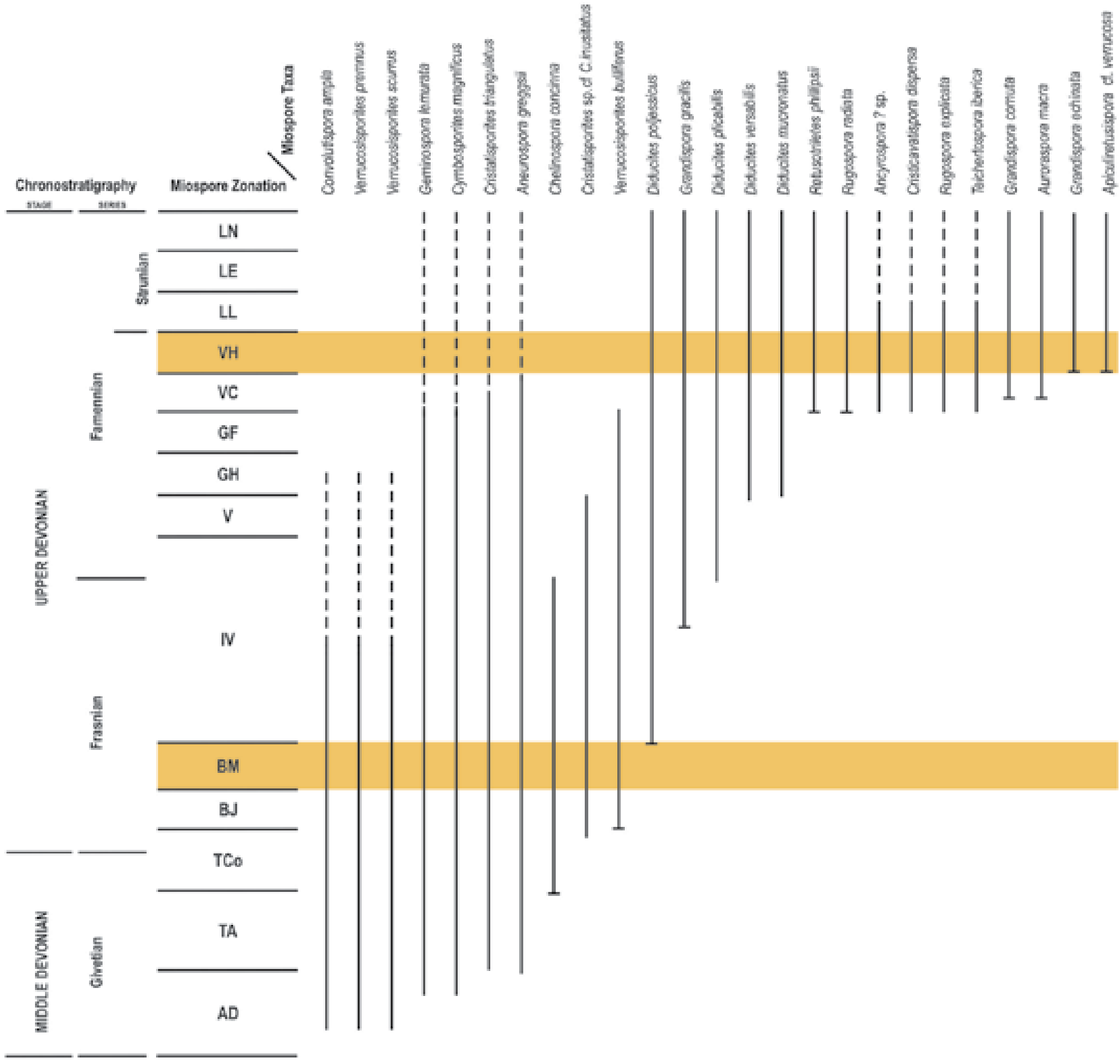


Fig. 11. Ranges of selected miospore species in comparison to the miospore biozonal scheme used.

It is worth noting that the age of the Chança Group composing units (from top to base, the Represa, Gafo and Atalaia Fms.), that crop out at the southern edge of the Pulo do Lobo Domain yileded assemblages of miospores that are very similar to those of the Ferreira-Ficalho Group, reinforcing the suggestion (Pereira et al., 2006) that the Pulo do Lobo Domain forms an antiformal structure.

STOP 1A. Just in the Santa Iria village (Fig. 10). The Horta da Torre Fm. shales, siltstones and sandstones are exposed in the road cuts. Vertical folds and cleavage affect the succession.

STOP 1B. The shales and greywackes of the Santa Iria Fm. can be seen in road cuts (Fig. 10). The greywckes show Bouma´s sedimentary structures and are also folded and cleaved.

STOP 1C. Here the lithologies of the Ribeira de Limas Fm. can be observed. Note that the quartzvaques, quartzites and shales are highly deformed, showing three episodes of folding and associated cleavags, in contrast with the Horta da Torre and Santa Iria Fms., which show one main episode of tectonic deformation.

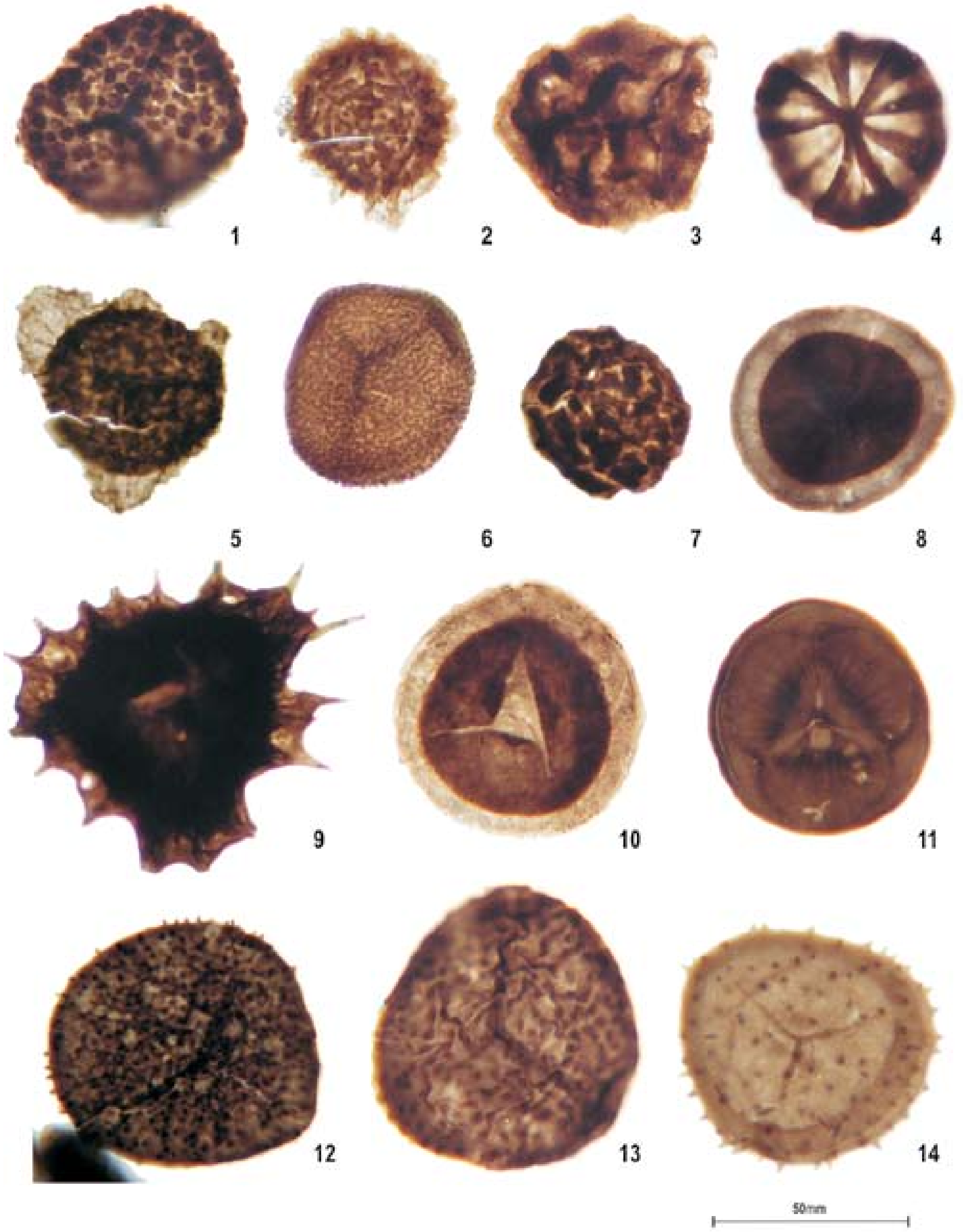


PLATE II. Miospores from the Pulo do Lobo Domain (Pereira et al., 2006).

Plate captions list the taxonomic name of the Fig.d specimen, followed by the formation, sample number, slide number, microscopic coordinates and INETI/SG collection number of the specimen.

1. *Verrucosisporites bulliferus* Richardson and McGregor, 1986, Ribeira de Limas Fm. Sample 3-1, 1190-218, INETI 0701.

2. *Cristatisporites* sp. cf. *C. inusitatus* (Allen) McGregor and Camfield, 1982, Ribeira de Limas Fm. Sample 3-3, 1260-228, INETI 0703.

3. *Chelinospora concinna* Allen, 1965, Ribeira de Limas Fm. Sample 1-1, 1320-205, INETI 0705.

4. *Emphanisporites rotatus* McGregor emend. McGregor, 1973, Ribeira de Limas Fm. Sample 2-3-1285-230, INETI 0706.

5. *Cristatisporites triangulatus* (Allen) McGregor and Camfield, 1982, Gafo Fm. Sample 13-2, 1315-165, INETI 0702.

6. *Aneurospora greggsii* (McGregor) Streel in Becker, Bless, Streel and Thorez, 1974, Gafo Fm. Sample 13-3, 1290-100, INETI 0704.

7. *Verrucosisporites scurrus* (Naumova) McGregor and Camfield, 1982, Gafo Fm. Sample 13-4, 1275-90, INETI 0707.

8. *Auroraspora macra* Sullivan, 1968, Horta da Torre Fm. Sample 8-1, 1445-245, INETI 0708.

9. *Ancyrospora* sp., HT8-1, 1440-120, INETI 0709.

10. *Teichertospora iberica* Gonzalez, Playford andMoreno, 2005, Horta da Torre Fm. Sample 7-2b-1450-185, INETI 0710.

11. *Retusotriletes phillipsii* Clendening, Eames and Wood, 1980, Horta da Torre Fm. Sample 7-2a, 1395-50, INETI 0711.

12. *Rugospora explicata* Gonzalez, Playford andMoreno, 2005, Horta da Torre Fm. Sample 7-3, 1505-200, INETI 0712.

13. *Rugospora flexuosa* (Jushko) Streel, 1974, Horta da Torre Fm. Sample 7-1a, 1390-105, INETI 0713.

14. *Grandispora echinata* Hacquebard emend. Utting,1987, Horta da Torre Fm. Sample 8-2, 1015-246, INETI 0714.

GEOLOGICAL STOP 2

A recent palynostratigraphic contribution to the understanding of the Mina de São Domingos mine geology, Pyrite Belt: the Mina de São Domingos Section

Location (Fig. 12)**:** Mina de São Domingos village neighborhoods.

A brief introduction to the São Domingos mine geology and palynostratigraphy

The Mina de São Domingos old mine is situated in the north branch of the Pyrite Belt. The regional geology is shown in Fig. 12 and the stratigraphic sequence depicted in Fig. 13 is derived from outcrops and drill cores (Fig. 14).

Stratigraphically important and typical miospore taxa are illustrated in PLATE III and acritarchs and prasinophytes in PLATE IV.

The following lithostratigraphic units have been defined:

· the **Represa Fm.**, the upper unit of the Chança Group, comprising quartzvaques, silstones, shales and minor volcanogenic sediments. Miospore assemblages contain Auroraspora sp., Cymbosporitessp. C. triangulatus, Diducites sp., Emphanisporites sp., Geminospora lemurata, Grandispora cornuta. G. echinata, G. famenensis e Rugospora radiata, which indicate the late Famennian age. Abundant and well preserved acritarchs and prasinophytes are present in the assemblages (PLATE III and IV).

· the **Phyllite Quartzite Fm.** (PQ), composed of phyllites, quartzites quartzwackes and shales. Macrofossils of Clymenia sp. (Oliveira et al., 1986) recovered from the quatzites and palynomorphs from the shales (Cunha and Oliveira, 1989; Oliveira et al., 2005; Matos et al., 2006) point to Late Strunian age. The miospore assemblages contain Verrucosisporites nitidus, the index species and the taxa Crassispora sp., Densosporites spitsbergensis, Geminospora lemurata, G. spongiata, Punctatisporites sp., Retispora lepidophyta, Rugospora radiata and Vallatisporites sp.. Rare acritarchs and prasinophytes are present (PLATE III).

· the **Volcanic Sedimentary Complex** (VSC), made up of rhyolites, basalts, diabases and intercalations of shales, a purple shale horizon, and volcanogenic sediments with phosphate nodules at the upper part. The shales interbeded in the volcanic suite yielded miospores of the Pu biozone, early Visean, as shown by the presence of Lycospora pusilla in association with Densosporites brevispinosum, Dictyotriletes sp., Knoxisporites cf. triradiatus and Vallatisporites sp. (See PLATE III). The VSC appears to be tectonically overlain by phyllites and quartzites of the PQ Group and is also thrusted by the quartzwackes, siltstones and shales of the Represa Formation, the upper unit of the Pulo do Lobo Antiform.

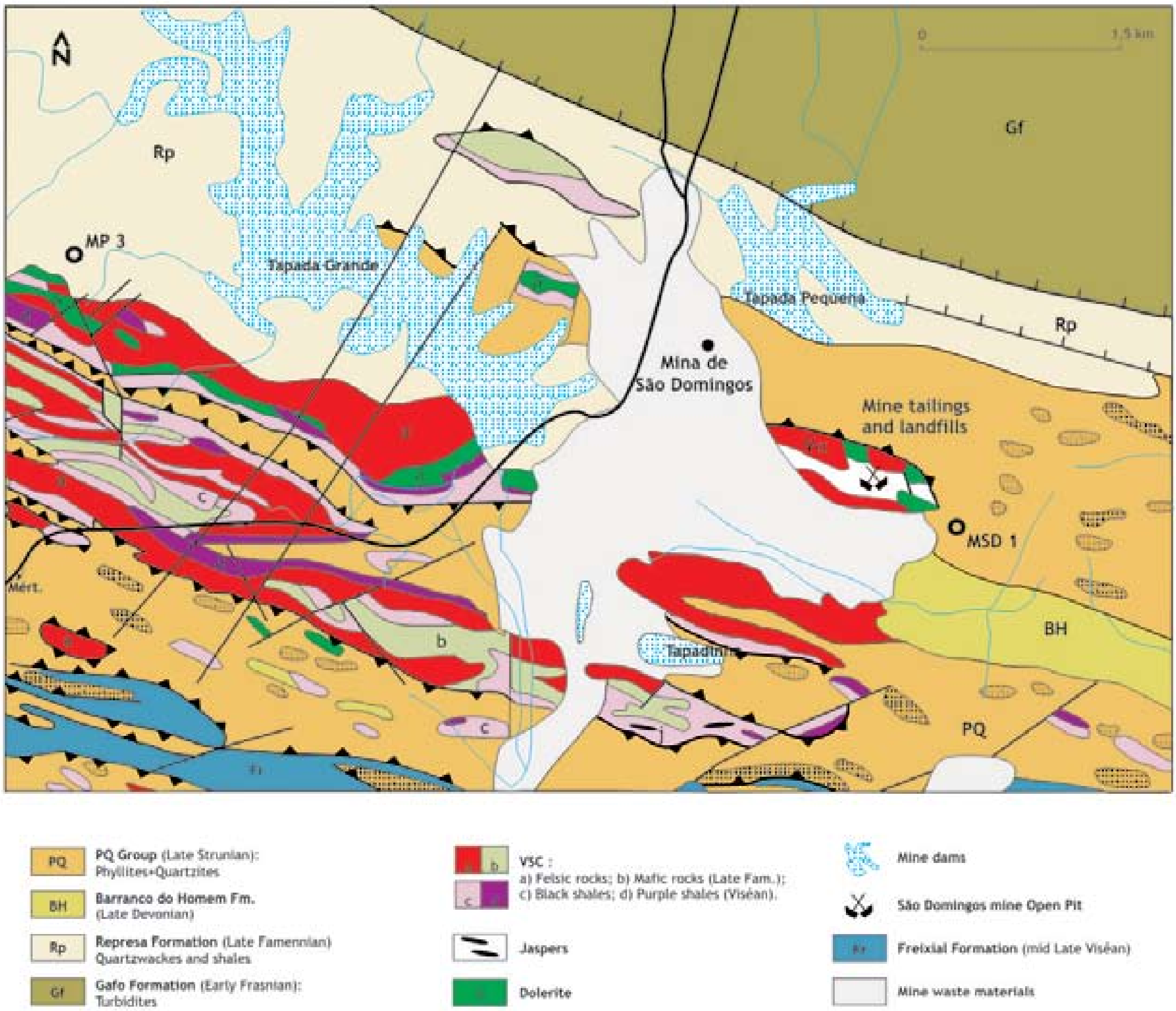


Fig. 12 Geological sketch map of the Mina de São Domingos region (Adapt. from Geological Map of Portugal 1/500 000).

· the **Freixial Fm.**, a thin bedded turbiditic succession composed of siltstones, greywackes and shales. This unit, which is very well exposed along the north branch of the Pyrite Belt, in the mine area has only been identified in drill cores. These provided the miospores Crassispora trychera, Densosporites spp., Lycospora pusilla, Microreticulatisporites sp., and Waltzispora planiangulata, in association to the nominal specie Raistrickia nigra. This assemblage has been assigned to the mid Late Viséan NM Biozone (See PLATE III).

All these units were folded and thrusted during the Variscan orogeny, forming now a southwest verging imbricate tectonic pile.

Mine Open Pit STOP

São Domingos mine, one of the most emblematic Portuguese massive sulphide deposits, was exploited between 1857 and 1966. The Mason and Barry Company, the mine owner, exploited the deposit by open pit until 120m depth and by underground works until 420m depth. Between 1867 and 1880 3Mm3 of rock were extracted from the open pit (Fig. 15, 16). Fig. 17 is a photo perspective of the present open pit.

The São Domingos pyrite orebody was located at the top of a VSC sequence represented by black shales, felsic, basic and intermediate volcanics (Matos et al., 2006, 2004; Oliveira and Matos, 2004; Oliveira et al. 1998; Silva et al. 1997). These rocks are affected by hydrothermal alteration related with the ore genesis. The occurrence of a pyrite proximal stockwork and the metal zonation of the orebody (Webb, 1958) support an inferred sequence polarity that indicates hangingwall southward. The orebody, a 25 Mt massive sulfide, was bounded to the south by an intrusive diabase which is presently very well exposed in the eastern side of the open pit. The mineral assemblage contained mostly pyrite, sphaerelite, chalcopyrite, arsenpyrite and sulfossalts. The metalic content was 1,25% Cu, 2-3% Zn and 45-48% S. The CVS and the orebody appear preserved in a sigmodal tectonic sheet bounded by top to

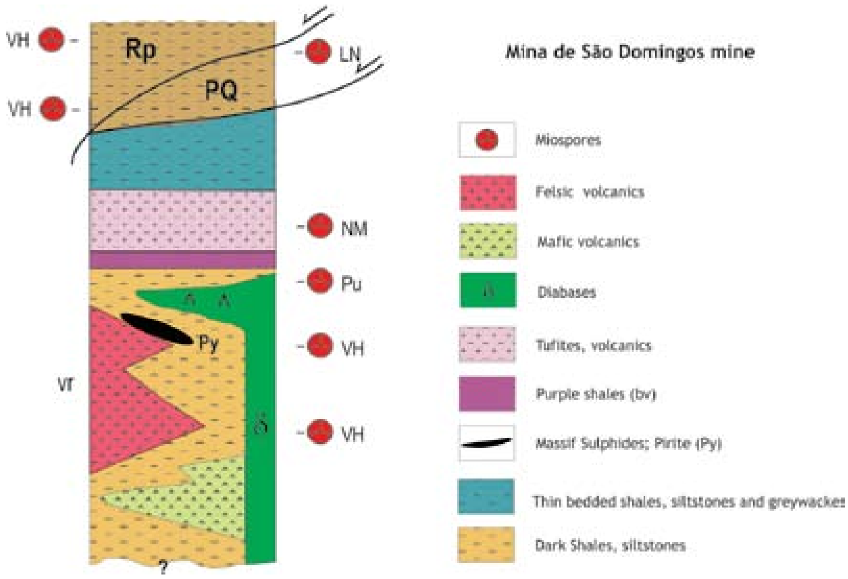


Fig. 13 Mina de São Domingos mine open pit stratigraphical log (**Rp** - Represa Fm.; **PQ** - Phyllite Quartzite Fm.).

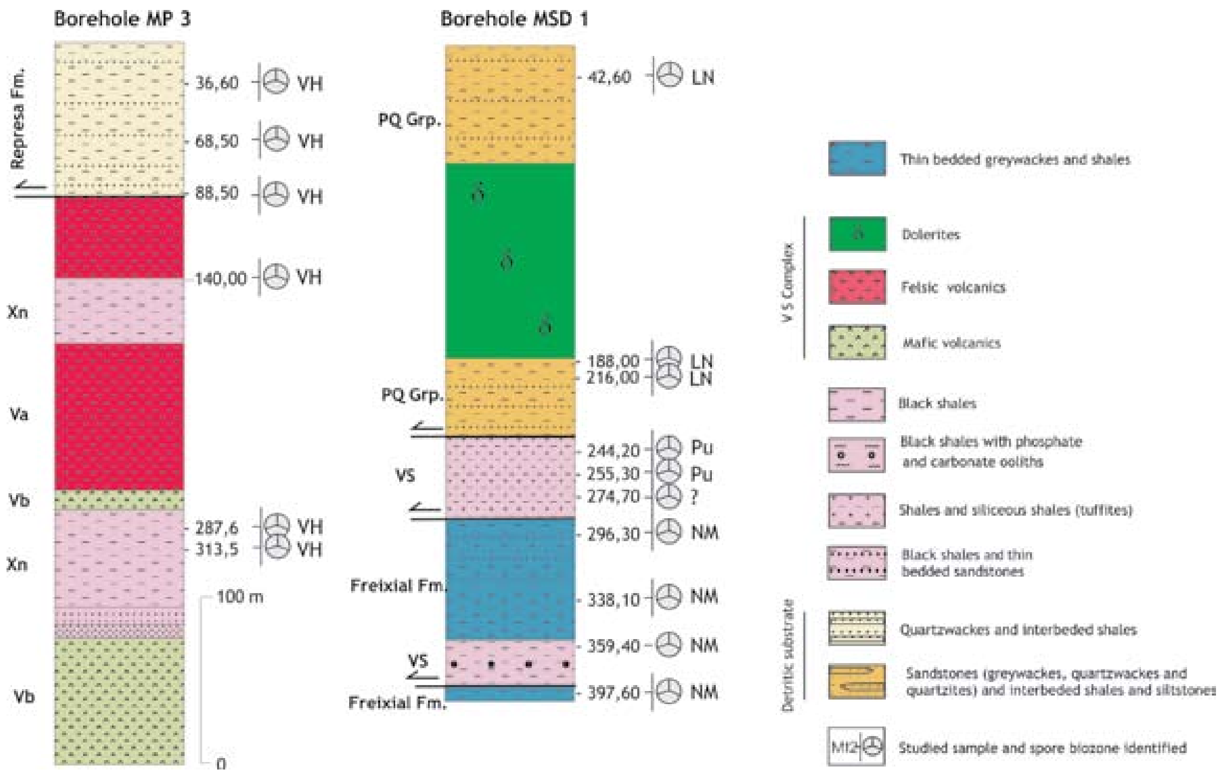


Fig. 14 Mina de São Domingos mine region studied boreholes (MSD1 and MP3).

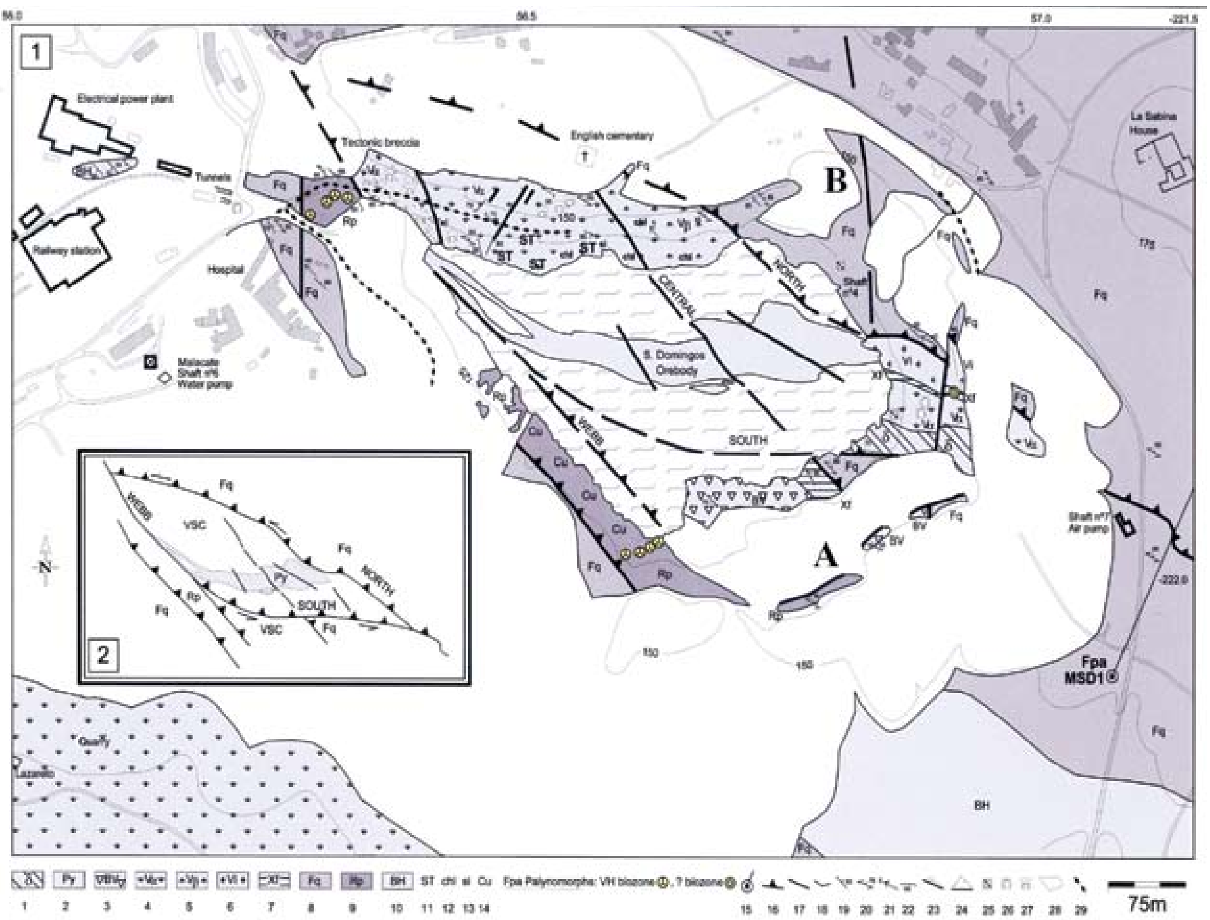


Fig. 15 Mina de S. Domingos open pit geology (Adapt. Matos et al., 2006):

Fig. 15.1 Geology: Volcano Sedimentary Complex (Late Famennian – Late Visean): **1** - Diabase; **2** - São Domingos orebody; **3** - coarse polymict felsic volcaniclastic breccia; **4** - porphyritic coherent felsic volcanics (rhyollite/rhyodacite); **5** - basic volcanics; **6** - intermediate volcanics; **7** - footwall black shales; Phyllite Quartzite Formation (Late Strunian): **8** - shales and quartzites; Represa Fm. (Late Famennian): **9** - black shales with disseminated pyrite, banded siltitic shales; Barranco do Homem Fm. (Famennian?) – phyllites, greywackes, quartzwackes. Other: **11** - stockwork; hydrothermal alteration: **12** - chlorite, **13** - silica; **14** - Cu minerals in cleavage and fractures; Fpa Palynomorphs; **15** - MSD1 Billiton borehole, **16** - thrust; **17** - fault; **18** - limit; **19** - S0; **20** - S1; **21** - L1; **22** - D1; **23** - Movement; **24** - landfill and tailings, **25** - shaft, **26** - modern addict, **27** - roman ad., **28** - flooded open pit, acid water level 107m, **29** - pedestrian track.

Fig. 15.2 Tectonic model. VSC - Volcano Sedimentary Complex A-B Cross section (see Fig. 15). Hayford-Gauss coordinates in km.

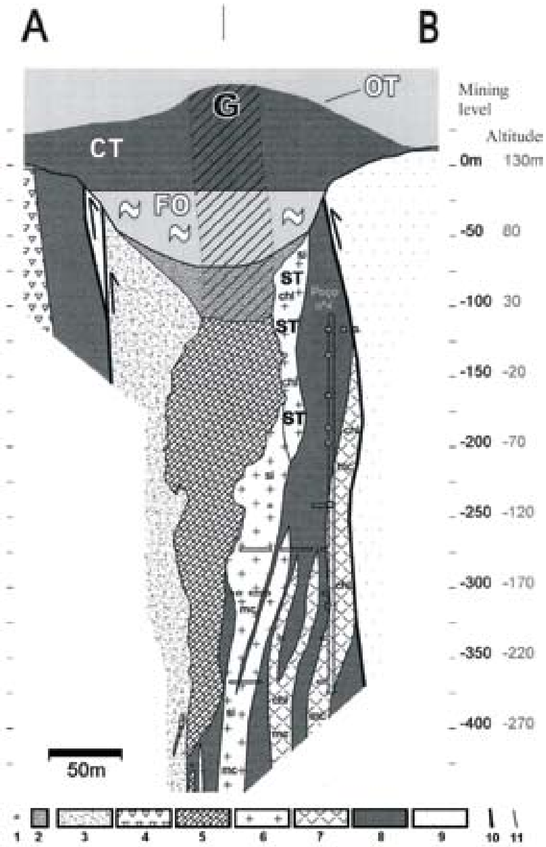


Fig. 16 Mina de São Domingos orebody, south-north geological cross-section (Adapt. Oliveira and Matos, 2004).

Legend: **OT** - Original topography; **CT** - current topography; **G** - mined gossan; **FO** - flooded open pit (acid water); **1** - mine addict; **2** - mining waste.

Geology: Volcano Sedimentary Complex (Late Famennian - Late Visean): **3** - Diabase; **4** - coarse polymict felsic volcaniclastic breccia; **5** - São Domingos orebody; **6** - porphyritic coherent felsic volcanics rhyollite/rhyodacite with hydrothermal alteration (**mc** - sericite, **si** - silica, **chl** - chlorite); **7** - basic/ intermediate volcanics; **8** - footwall black shales; Phyllite Quartzite Formation (Late Strunnian): **9** - shales and quartzites. **10** -Thrust; **11** - Geological limit.

Fig. 17 Photo perpective of the São Domingos Mine open pit (Adapt. Matos et al., 2004). Volcano Sedimentary Complex: **D** - diabase, **Va** - Felsic volcanics, **Vb** - Basic volcanics, **Vi** - Intermediate volcanics, **Xn** - Black shales with chert levels, **BT** - tectonic breccia, **BV** - epiclastic breccia. Phyllite-Quartzite Formation: **Pq** - Shales and quartzites. **Py** - Probale location of São Domingos ore; **ST** – Stockwork; **Cu** - Coper minerals (secundary); **K** - Superge K; ⬠ - Columnar disjunction in ryolites; **G** - Galery; **E** - Mining waste modern; **R** - Mining waste roman; **Epy** - Mining waste pyrite.

╲ Main Fault

PLATE III. Miospores of the Mina de São Domingos mine region.

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

1. *Grandispora echinata* Hacquebard, 1957; MP3 Borehole, Represa Fm., Sample 36,60-1, 1244-45, INETI 0501.

2. *Grandispora cornuta* Higgs 1975; MP3 Borehole, Represa Fm., Sample 36,60-1, 1305-225, INETI 0502.

3. *Cristatisporites triangulatus* Allen 1965; MP3 Borehole, Represa Fm., Sample 36,60-1, 1090-180, INETI 0503.

4. *Ancyrospora*? *implicata* González, Playford and Moreno, 2005; Open pit Mina de S. Domingos mine, Represa Fm., Sample EM1-1, 1257-28.

5. *Cristicavatispora dispersa* González, Playford and Moreno, 2005; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-1, 1225-185.

6. *Diducites poljessicus* (Kedo) emend Van Veen 1981; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-2, 1085-120.

7. *Emphanisporites annulatus* McGregor, 1961; MP3 Borehole, Represa Fm., Sample 36,60-2, 1335-160, INETI 0507.

8. *Rugospora radiata* (Jushko) Byvscheva 1985; MP3 Borehole, Represa Fm., Sample 36,60-1, 1340-148, INETI 0508.

9. *Retispora lepidophyta* (Kedo) Playford, 1976; MSD1 Borehole, PQ Fm., Sample 42,60-1, 1245-100, INETI 0509.

10. *Lycospora pusilla* (Ibrahim) Schopf, Wilson and Bentall 1944; MSD1 Borehole, VSC, Sample 255,30-1, 1155-75, INETI 0510.

11. *Densosporites* sp.; MSD 1 Borehole, VSC, Sample 255,30-1, 1095-135, INETI 0511.

12. *Raistrickia nigra* Love, 1960; MSD1 Borehole, VSC, Sample 359,40-1, 1380-180, INETI 0512.

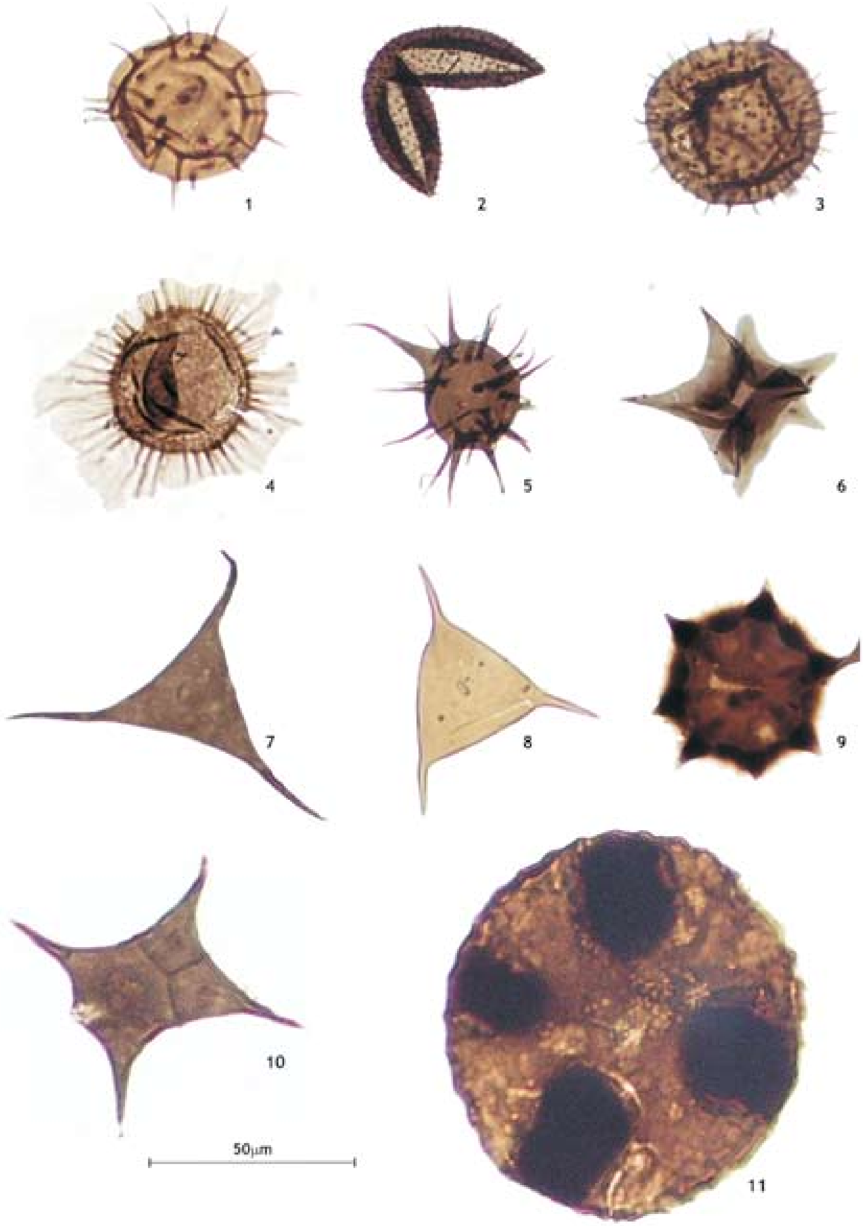


PLATE IV. Acritarchs and prasinophytes of the Mina de São Domingos mine region.

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

1. *Gorgonisphaeridium ohioense* (Winslow) Wicander, 1974; MP3 Borehole, Represa Fm., Sample 36,60-3, 1200-138, INETI 0504.

2. *Gorgonisphaeridium plerispinosum* Wicander 1974; MP3 Borehole, Represa Fm., Sample 36,60-3, 1190-175, INETI 0505.

3. *Gorgonisphaeridium plerispinosum* Wicander 1974; Open pit Mina de São Domingos mine, Represa Fm., Sample EM 4-1d, 1085-157.

4. *Pterospmella* sp.; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-2,1465-125.

5. *Unellidium lunatum* Eisenack, Cramer and Diez, 1979; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-6, 1264-198.

6*.* *Stellinium micropolygonale* Playford, 1977; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-2, 1232-056.

7. *Veryhachium trispinosum* Stockmans and Williere, 1962; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-2a, 1421-175.

8. *Veryhachium downiei* Stockmans and Willière, 1962; MSD 1 Bore-hole, PQ Fm., Sample 42,60-1, 1120-110, INETI 0506.

9. *Dupliciradiatum crassum* González, Playford and Moreno, 2005; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-5, 1035-155.

10. *Winwaloeusia repagulata* González, Playford and Moreno, 2005; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-2, 1145-175.

11. *Maranhites mosesii* (Sommer) Brito 1967; Open pit Mina de São Domingos mine, Represa Fm., Sample EM4-1a, 1356-098.

southwest thrust faults (Fig. 12). Late basic sills and NW-SE faults disrupted the tectonic sheet (Matos et al., 2006).

The weathering of the Mina de São Domingos deposit originated an important gossan that was intensely mined during Roman time and totally exploited in the XIX century. The supergene alteration of the sulphides is reflected by a large presence of Fe oxides in veins and fractures.

The mine closure in the 60's led to a social and economic depression. Presently a large negative environmental impact is observed in the mining area along the São Domingos stream valley. Acid rock drainage in the Achada do Gamo sulphur factories is marked by significant Pb, As, Sb, Cu, Zn and Fe anomalies in stream sediments, soils and waters. Since 2004 INETI, Mértola municipality and CCDR Alentejo promote a new approach to the São Domingos mining site having in mind the development of geo-eco-mining tourism. Based in the excellent site conditions geological and mining heritage are largely promoted (Matos and Martins, 2006; Oliveira and Silva, 1990; Oliveira and Matos, 2004).

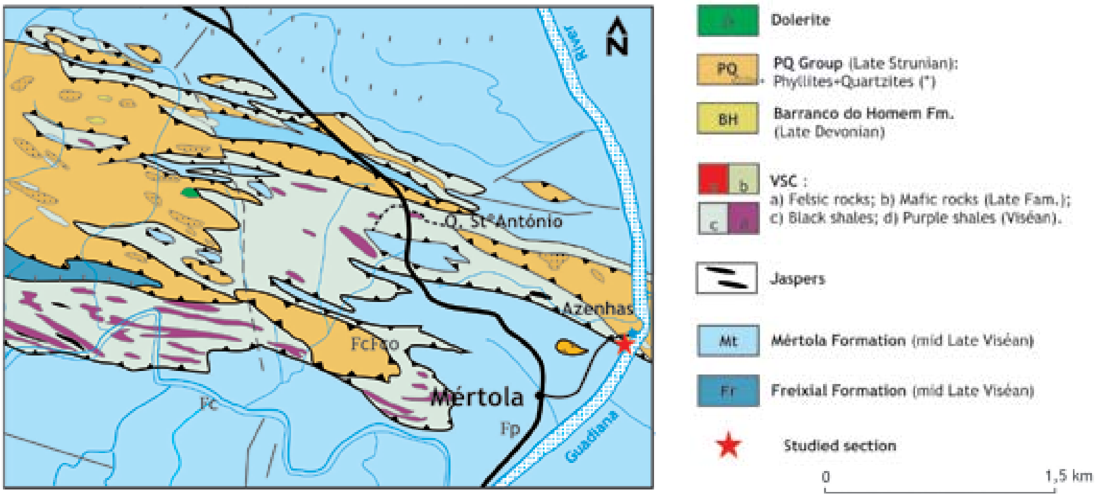


Fig. 18 Geology of the Mértola region (Adapt. Geological map, 50 000 Mértola).

GEOLOGICAL STOP 3

The Pyrite Belt overthrusts at the light of the palinostratigraphy: the Azenhas Section, Guadiana River

Location (Fig. 18)**:** the Azenhas section is situated about 500m NE of Mértola, in the west margin of the Guadiana River

Short introduction to the local geology

Almost continuous outcrops along the Guadiana River valley constitute one of the best exposures of the entire Pyrite Belt. The Azenhas section is a classic one, where overthrusting was firstly demonstrated (Fantinet, 1971; Silva et al., 1990; Fig. 18). The aim of this stop is to show the role of the palynostratigraphy for the best understanding of the overthrusts.

Three main litostratigraphic units can be observed in the Mértola region:

- **Phyllite Quartzite Fm** (PQ), with its classical composition, i.e. shales with intercalations of disrupted beds of quarzites, quartzwackes and siltstones, and lenses of limestones.The latter, west of Mértola town, provided conodonts of late Devonian age (Fantinet et al., 1976).
- **Volcano Sedimentary Complex** (VSC) whose main lithologies are, in this region, volcanogenic sediments (tuffites), green and purple shales, dark gray argilaceous and siliceous shales with lenses and nodules of manganes oxides and silicates. The gray shales and the volcanogenic sediments contain miospores of early Visean age.
- **Mértola Formation**, the basal unit of the Baixo Alentejo Flysch Group. The unit is made up dominantly of classical turbidites with conglomerate intercalations and thick bands of shales and thin

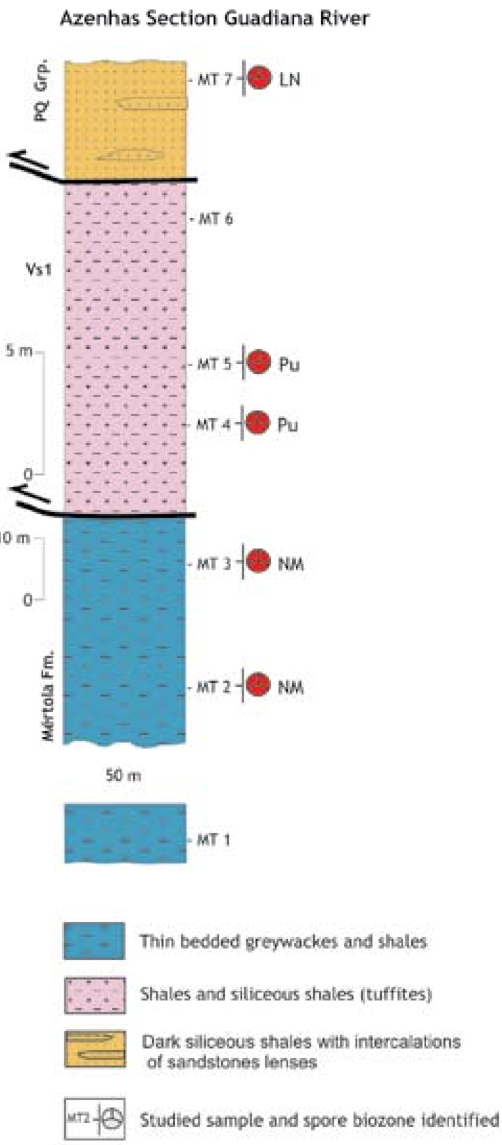


Fig. 19 Tectonostratigraphic log of the Azenhas Section, Guadiana River.

bedded turbidites. This unit has been studied and mapped in detail using the thick bands of shales as marker beds (Oliveira, 1988, Mértola Geological Map, 1:50 000). These marker beds provided Posidonia becheri and a good collection of late Visean amonoids (Korn, 1997). Late Visean miospore assemblages were also recovered from this unit.

These units are affected by NW trending and SW verging folds and thrusts with associated cleavage, and are arranged in two main overthrusts, the Mértola and Galé-Cela overthrusts, that were generated during the Variscan Orogeny. Late NW-SE faults are also frequent. The rocks are affected by a metamorphism of the prehnit-pumpellyte facies (Munhá, 1976).

The Azenhas Section, Guadiana River STOP

Walking along the west bank of the Guadiana River, from south to north, the following lithological succession can be observed (Fig. 18, 19):

· Centimetric to decimetric thick beds os grewackes with intercalations of thin bedded shales and siltstones that belong to the Mértola Fm. The rock succession dips about 70º to the North and the greywackes show way up criteria (graded bedding, load casts, small scale cross bedding, etc) that clearly indicate top to the North. The shales yielded poorly to moderately preserved miospores assigned to the NM Biozone of early mid Viséan age. The assemblage contain common *Raistrickia nigra* and is composed of the presence of *Crassispora trychera, Densosporites* sp.*, Granulatisporites sp., Knoxisporites hederatus, Leiotriletes* sp.*, Lycospora pusilla, Microreticulatisporites* sp.*, Vallatisporites* sp. and *Waltzispora* sp.

· VSC gray and dark siliceous shales with a total thickness of 25 meters. These shales provided moderately preserved miospores ascribed to the *Lycospora pusilla* Biozone of early Visean age. The assemblage includes the zonal specie *Lycospora pusilla* in association with *Auroraspora macra, Convolutispora* sp., *Crassispora trychera, Densosporites* sp., *D. brevispinosum*, *Dictyotriletes castaneaeformis*, *Discernisporites micromanifestus, Knoxisporites* cf. *triradiatus*, *Retusotriletes incohatus* and *Vallatisporites* sp. and rare prasinophytes of the genus *Maranhites* spp..

These VSC shales are tectonically above the underlying Mértola Fm. turbidites and their boundary is the local expression of the Mértola overthrust. The boundary was reworked during the late Variscan episodes as shown by the presence of quartz veinlets.

· PQ shales with thin intercalations of tectonically disrupted siltstones and quartzitic layers. Compared with the VSC and the Mértola Fm. shales, these are slightly more tectonically deformed and metamorphosed. Poorly to moderately preserved miospores assigned to the LN Biozone of late Strunnian age (Late Famennian) were recovered from these unit. The assemblage contains and *Verrucosisporites nitidus* the nominal species and the taxa *Auroraspora* sp., *Densosporites spitsbergensis, Diducites* spp.*, Geminospora lemurata, Leiotriletes strunniensis, Punctatisporites irrasus* and *Retispora lepidophyta.* Rare acritarchs and prasinophytes are present.

The unit is tectonically superposed over the VSC litologies and their boundary underlines the trace of the Galé-Cela overthrust.

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NOTES

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