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PALYNOSTRATIGRAPHY OF THE DEVONIAN-CARBONIFEROUS BOUNDARY IN SOUTHWEST PORTUGAL

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(3 figures, 1 table & 2 plates)

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ABSTRACT. Miospore assemblages have been recovered from 32 samples from the uppermost Devonian and basal Carboniferous Tercenas and Bordalete Formations in the Pedra Ruiva (North and South) and Monte do Penedo sections, SW Portugal.
The assemblages can be assigned to the *Retispora lepidophyta* - *Verrucosisporites nitidus* (LN) and *Vallatisporites verrucosus* - *Retusotriletes incohatus* (VI) Miospores Biozones of Western Europe. The boundary between the LN and VI Biozones which coincides approximately with the Devonian / Carboniferous boundary is located within the Tercenas Formation, below a quartzitic package at the top of the formation. Acritarch assemblages have been recovered from many of the samples, especially from the LN Biozone. The lithostratigraphic succession spanning the Devonian / Carboniferous boundary in SW Portugal compares closely with that in Southern Ireland.

KEYWORDS: Devonian, Carboniferous, boundary, miospores, acritarchs, Portugal, correlation.

RESUME. Palynostratigraphie de la limite Dévonien/Carbonifère dans le SW Portugal. Des assemblages de miospores ont été reconstitués à partir de 32 échantillons du Dévonien supérieur et du Carbonifère inférieur (Formations de Tercenas et de Bordalete) provenant des coupes de la Pedra Ruiva (nord et sud) et de Monte do Penedo dans le SW du Portugal. Les assemblages peuvent être attribués aux biozones à microspores d'Europe occidentale: *Retispora lepidophyta* - *Verrucosisporites nitidus* (LN) et *Vallatisporites verrucosus* - *Retusotriletes incohatus* (VI). La limite entre les biozones LN et VI qui coincident approximativement avec la limite Dévonien/Carbonifère est située à l'interieur de la Formation de Tercenas, sous un paquet quartzitique du sommet de la formation. Des assemblages d'acritarges ont été reconstitués à partir d'échantillons provenant plus particulièrement de la biozone LN. La succession lithostratigraphique couvrant la limite Dévonien/ Carbonifère dans le SW du Portugal est très semblable à celle d'Ireland meridionale.

MOTS-CLES: Dévonien, Carbonifère, limite, miospores, critarges, Portugal, corrélation.

1. INTRODUCTION

1.1. REGIONAL GEOLOGY

In Southwest Portugal the geology of the Palaeozoic is dominated by the Aljezur and Bordeira Antiforms (Fig. 1). The lithostratigraphic succession of these antiformal structures is represented by three main lithological associations (Oliveira *et al.*, 1985; Ribeiro *et al.*, 1987; Oliveira, 1990) which in ascending order are:

A basal detrital unit, the Tercenas Formation, composed of alternations of tide dominanted quartzitic sandstones and shales, that contain rare Clymenids, brachiopodes and corals of Upper Famennian age. Thickness is in excess of 100 m.

A pelite/carbonate sequence, the Carrapateira Group, comprising dark marine shales and siltstones at the base (Bordalete Formation), marls, shales and dolomitic limestones (Murração Formation), and detrital limestones and black shales (Quebradas

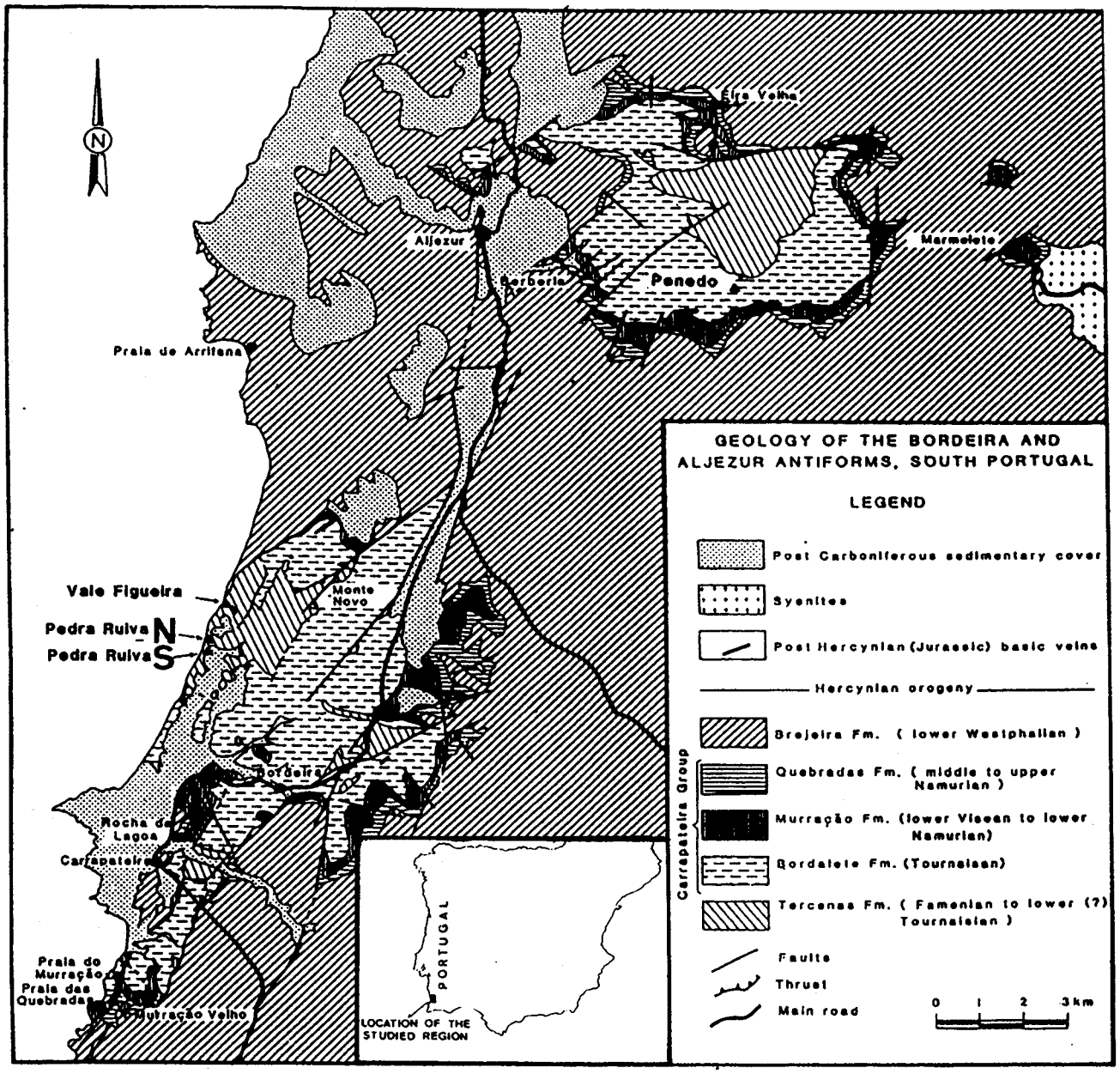


Figure 1. The Geology of Bordeira and Aljezur antiforms, South Portugal (adapt. Oliveira *et al.*, 1985)

Formation). The units are dated as Middle to Upper Tournaisian, Visean and Namurian respectively by means of goniatites, trilobites and corals. Overall the thickness is about 300 m. This succession has been interpreted as a portion of a shale/carbonate platform at the southern edge of the so called South Portuguese Zone.

A turbiditic unit, the Brejeira Formation, with a thickness in excess of 1000 m, dated as Lower Westphalian. The unit represents the younger sediments of a southwestward prograding synorogenic clastic wedge.

All the units were affected by a main NW trending episode of variscan folding, with associated cleavage and thrusting. Metamorphism is low grade, corresponding to a high level of regional coalification.

Portions of the lithostratigraphic succession could not be precisely dated due to lack or bad preservation of macrofaunas, or tectonic disturbance. This is the case of Tercenas and Bordalete Formations. Palynological research is being undertaken in order to establish the age of poorly dated parts of the succession.

This paper deals mainly with the palynological results that were obtain in selected sections of the Tercenas and Bordalete Formations, particularly around the transition between the units which span the Devonian-Carboniferous boundary.

1.2. LOCALITIES

The studied sections are localised at the Pedra Ruiva Cliff, in the Bordeira Antiform and along the

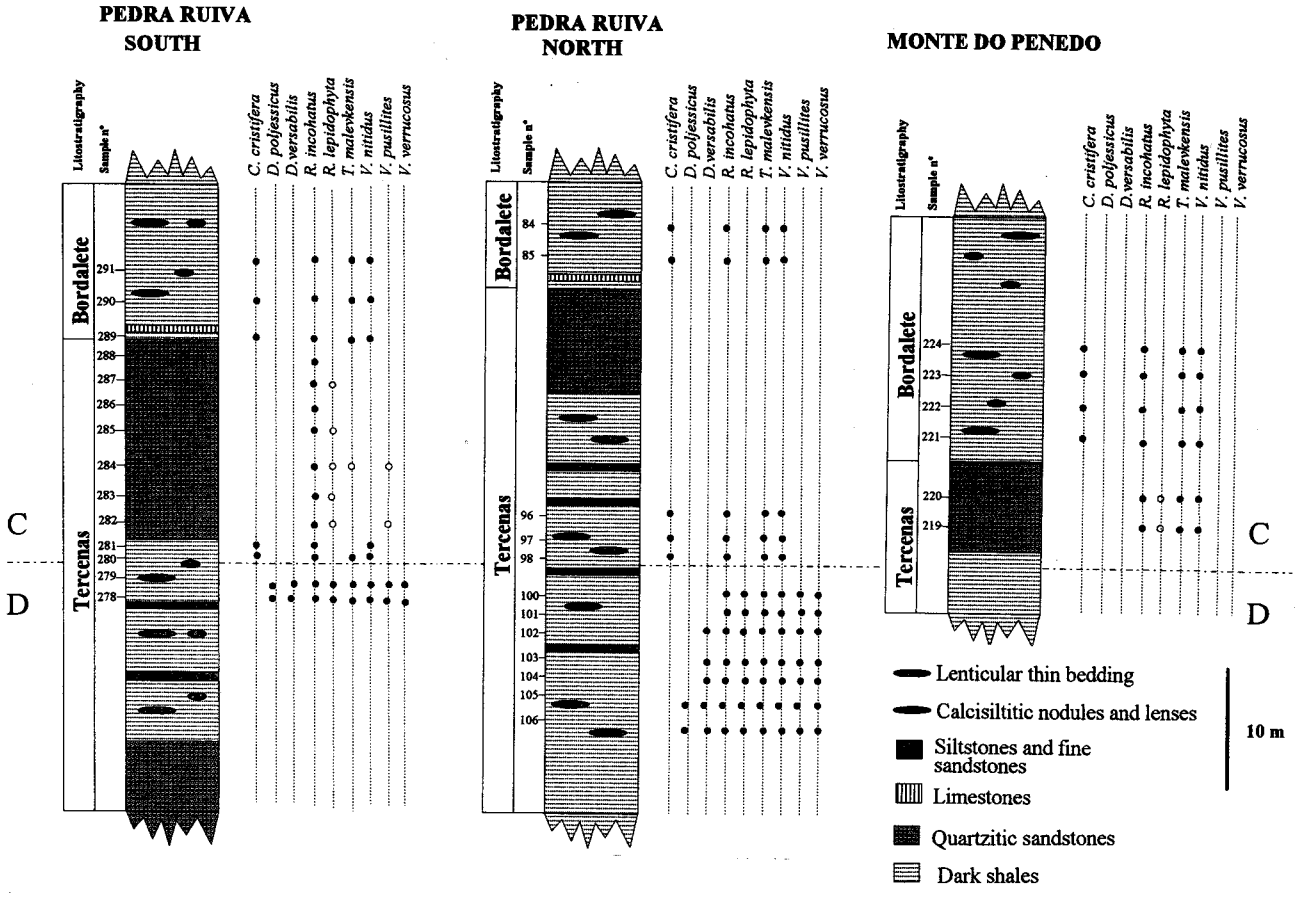


Figure 2. Stratigraphic range of selected miospore taxa in the sections.

track near the Penedo Farm, Aljezur Antiform (Fig. 1).

At Pedra Ruiva the two examined sections expose part of the Tercenas Formation and the lower part of Bordalete Formation (Fig. 2).

The Tercenas Formation is made up of alternations of thin bedded layers of shales, siltstones and quartzitic sandstones, which are frequently lenticular and rippled, and are in places intensely bioturbated. These alternations of layers grade upward to a 20 m thick package of thick bedded medium to course grained sandstones, rich in iron and manganese oxides at the top. These sandstone beds show a large variety of sedimentary structures (large scale, trough and herringbone, convolute bedding, hummocks, synsedimentary folds and slumps) that indicate deposition in a tide dominate environment.

The Bordalete Formation, in the same sections, is composed of thin bedded layers of shales and silstones, and rare calcisiltic lenses and nodules. Centimetric thick layers of fine limestones is well exposed at the base of the unit (Fig. 2).

No macrofaunas were recognised at the studied sections. However, elsewhere in the region, the lower shaly layers of the Tercenas Formation provided Clymenids of Upper Famennian age and the top of the sandstones yielded reworked brachiopods and chonetacea of Upper Devonian to Lower Carboniferous age. Rare goniatites that indicate a Middle to Upper Tournaisian age, are preserved in nodules in the Bordalete Formation.

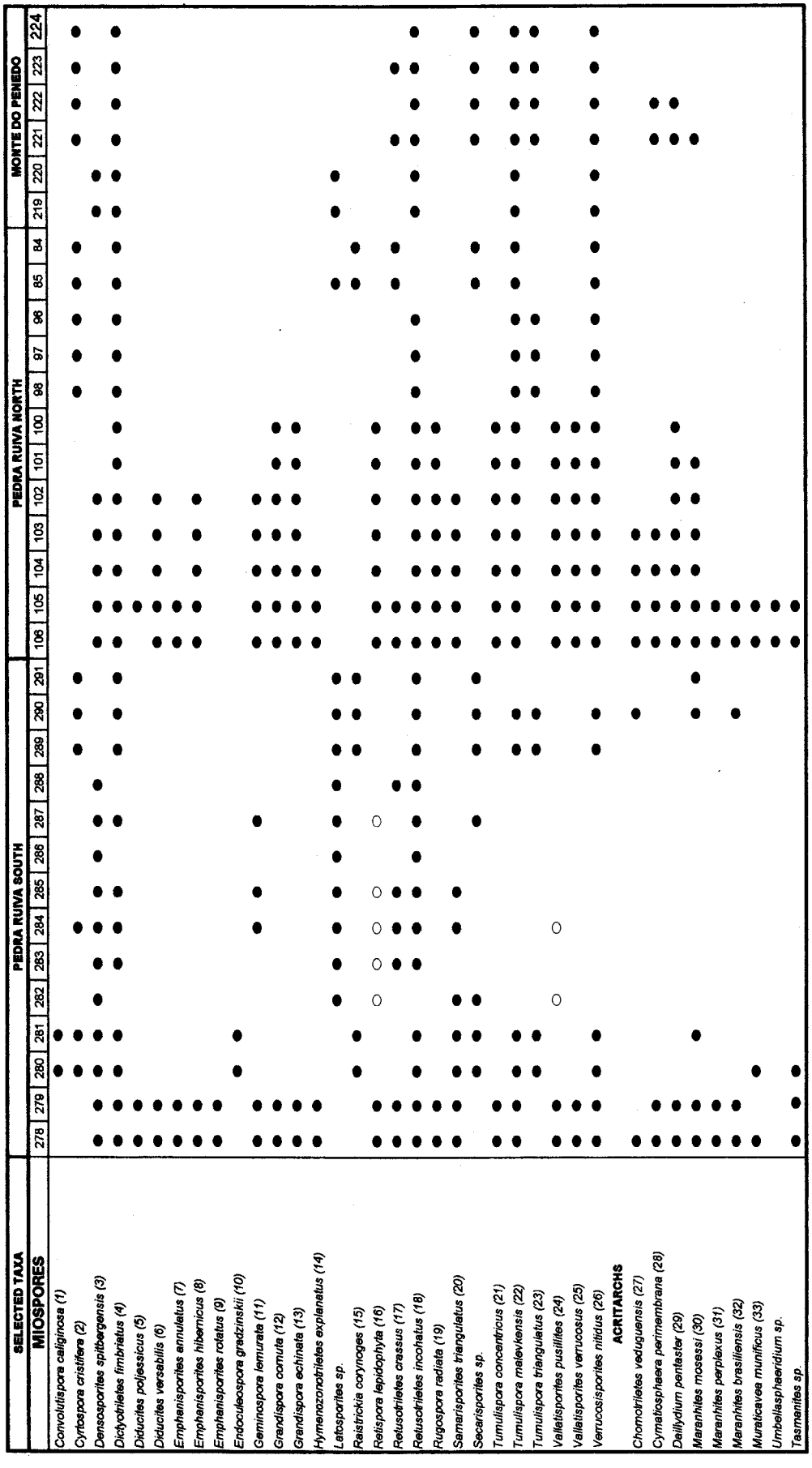
At Monte do Penedo section the Tercenas Formation is represented by poorly exposed shales and the upper sandstone packet, here with thickness around 10 m. The overlying Bordalete Formation exposed along the track consists of shales, siltstones, and rare calcisiltic nodules. No macrofossils were recognised in this section, but trilobites and goniatites from the region indicate also a Middle to Upper Tournaisian age.

2. PALYNOLOGY

2.1. METHODS

All samples were prepared for palynology, using standard preparations techniques, involving treat-

Table 1. Chart showing the selected miospores and acritarch taxa occuring in Pedra Ruiva South, Pedra Ruiva North and Monte do Penedo sections.



ment with hydrochloric, hydrofluoric and nitric acids. Oxidation of the residues was carried out using Schultze Solution; oxidation times varied from 30 minutes to 4 hours. Organic residues were then concentrated through a 18 µm sieve. Palynomorphs reverted to a black, totally opaque state within days of oxidation, so material was studied and photographed immediately after preparation. All samples, residues and slides are stored in the collections of 'Mineralogia e Geologia, Faculdade de Ciências da Universidade do Porto'.

2.2. PALYNOSTRATIGRAPHY

The qualitative composition of the palynomorph assemblages recorded is shown in Table 1, ranges of selected taxa are shown in Figure 2. Stratigraphically important and typical taxa are illustrated in Plate 1. The palynomorph assemblages recovered can be assigned to the *Retispora lepidophyta - Verrucosisporites nitidus* (LN) and the succeeding *Vallatisporites verrucosus - Retusotriletes incohatus* (VI) Miospore Biozones of Western Europe (Higgs *et al.*, 1988).

The base of LN Biozone is defined by the first appearance of V. nitidus. *Vallatisporites verrucosus* also appears for the first time at this level together with *Tumulispora malevkensis.*

The base of VI Biozone is defined by the top of the range of the index taxon *Retispora lepidophyta* and is more-or-less coincident with the Devonian - Carboniferous boundary (Higgs *et al.*, 1993).

2.2.1. Pedra Ruiva South

Assemblages from samples 278 and 279 in the Tercenas Formation contain *R.lepidophyta* and *V. nitidus* and are assigned to the LN Biozone. In addition to the index species *Retispora lepidophyta* and *Verrucosisporites nitidus*, characteristic taxa occuring within this zone include *Densosporites spitsbergensis, Dictyotriletes fimbriatus, Diducites poljessicus, D. versabilis, Emphanisporites* spp., *Grandispora echinata, G. cornuta, Hymenozonotriletes explanatus, Retusotriletes crassus, Rugospora radiata, Tumulispora concentricus, T. malevkensis, Vallatisporites pusillites* and *V. verrucosus.*

Assemblages from samples 280 and 281 lack *R. lepidophyta* and are assigned to the VI Biozone as are assemblage 289 from 20 cm above the base of the Bordalete Formation and assemblages 290 and 291 from slightly higher in this formation. *Cyrtospora cristifera* first appears in assemblage 280 and is common throughout, as are *Secarisporites* sp. and *T. malevkensis.* Other characteristic taxa in these assemblages are *Dictyotriletes fimbriatus, Raistrickia corynoges, Retusotriletes incohatus, Tumulispora triangulatus* and *Verrucosisporites nitidus* .

Assemblages from samples 282 to 288 (inclusive) in the quartzitic sandstones at the top of the Tercenas Formation are dominated by smooth acamerate spores of the genera *Latosporites, Punctatisporites* and *Retusotriletes.* Small numbers of *Retispora lepidophyta, Tumulispora. malevkensis* and *Vallatisporites* spp. are also present but are typically broken; these are interpreted as reworked.

An alternative but less likely interpretation of the miospore data is that the specimens of *R. lepidophyta* from samples 282 to 288 are *in situ,* not reworked, and that these assemblages should therefore be assigned to the LN Biozone. In this case, assemblages 280 and 281 would represent highly anomalous LN Biozone assemblages, lacking not just *R. lepidophyta* but also associated late Devonian taxa such as *Diducites* spp. and *Vallatisporites pusillites.* The presence of *Cyrtospora cristifera* in assemblages 280 and 281 lends further support to the assignment of these assemblages to the VI Biozone.

Geminospora lemurata and *Samarisporites triangulatus* occur frequently in almost all the assemblages assigned to the LN Biozone. These taxa are restricted stratigraphically to the Givetian-Famennian and Givetian-Frasnian respectively, and are therefore clearly reworked.

Tasmanites, Maranhites and other acritarchs are absent from the quartzite unit. Representatives of the former two groups are common in all other samples from the Tercenas Formation and from the Bordalete Formation. Acritarchs are common in the lower part of the Tercenas Formation, rarer in the upper part of this formation and in the overlying Bordalete Formation. Diversity also decreases upwards through the section. Acritarch taxa recorded include *Chomotriletes vedugensis, Cymatiosphaera perimembrana, Daillydium pentaster, Maranhites* spp., *Muraticavea munificus* and *Umbellasphaeridium* sp.

2.2.2. Pedra Ruiva North

Assemblages from samples 100 - 106 (inclusive) in the Tercenas Formation are assigned to the LN Biozone. Assemblages from samples 96, 97 and 98 lack *R. lepidophyta* but contain *Cyrtospora cristifera* and are assigned to the VI Biozone. No miospores have been recovered from the quartzite sandstones at the top of the Tercenas Formation. Assemblages

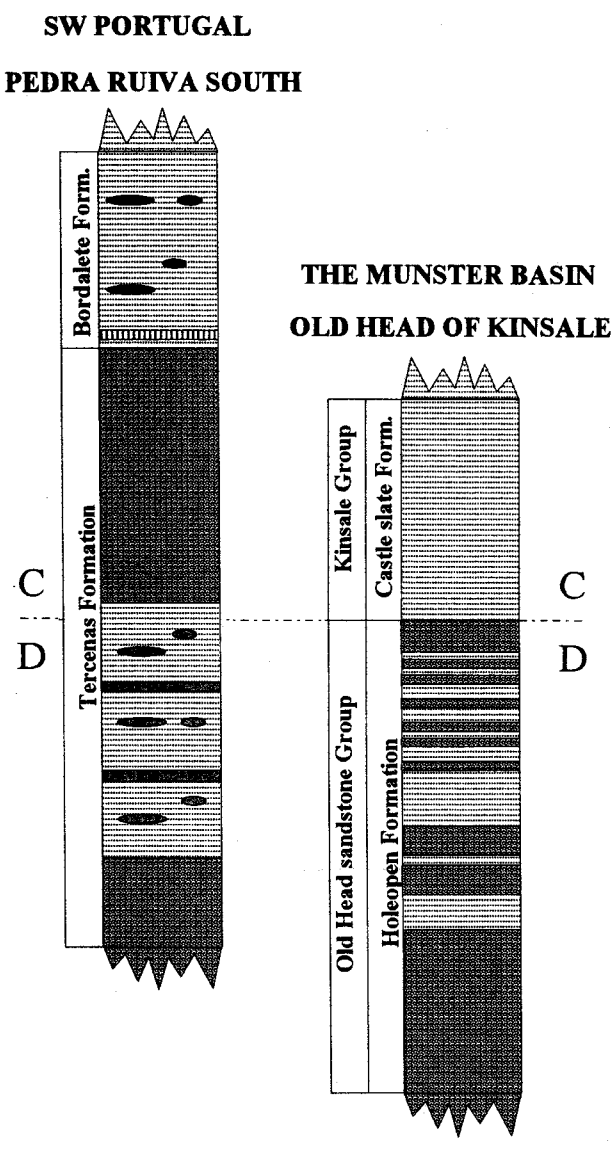


Figure 3. Correlation of the Devonian-Carboniferous Boundary between Sw Portugal and the Munster Basin.

from samples 84 and 85 in the basal part of the Bordalete Formation are also assigned to the VI Biozone. The distribution of acritarchs is similar to that in the Pedra Ruiva South section but acritarchs are more common. Reworked specimens of *G. lemurata* and *S. triangulatus* occur in the LN assemblages as at Pedra Ruiva South.

2.2.3. Monte do Penedo

No miospores have been recovered from the Tercenas Formation below the quartzite unit. Assemblages from the thin shaly layers within the upper quartzitic sandstones of the Tercenas Formation (samples 219 and 220) are very similar in composition to assemblages 282 - 288 from Pedra Ruiva South and include *Densosporites spitsbergensis, Dictyotriletes fimbriatus, Emphanisporites* spp., *Grandispora echinata, G. cornuta, Hymenozonotriletes explanatus, Retispora lepidophyta, Retusotriletes crassus, Rugospora radiata, Tumulispora malevkensis, Vallatisporites pusillites, V. verrucosus* and *Verrucosisporites nitidus.*

Samples 221 - 224 (inclusive) from the lower part of the Bordalete Formation are similar in composition to assemblages from the lower part of this formation in the Pedra Ruiva North and Pedra Ruiva South sections (see Table 1) and include *Cyrtospora cristifera, Dictyotriletes fimbriatus, Retusotriletes incohatus, Secarisporites* sp, *Tumulispora malevkensis, T. triangulatus, Vallatisporites verrucosus* and *Verrucosisporites nitidus.* These assemblages are assigned to the VI Biozone. *Maranhites* spp. are common.

2.3. CORRELATION WITH OTHER AREAS

The Miospore assemblages recorded are very similar in composition to those recorded from the same stratigraphic interval in other areas of Western Europe, for example, the Munster Basin (Ireland) (Higgs *et al.*, 1988), the Ardenne (Belgium) (Streel *et al.*, 1987) and the Rheinisches Schiefergebirge, Germany (Higgs *et al.*, 1993). The acritarch assemblages most closely resemble those recorded from the Illizi Basin, Algeria (Moreau-Benoit *et al.*, 1993) though there are too few detailed accounts of acritarch assemblages around the Devonian / Carboniferous boundary in Western Europe to permit a detailed comparison.

Correlation of the LN/VI boundary between the Munster Basin and SW Portugal (Fig. 3) shows some similarity in lithofacies. In the former area, there is typically an abrupt change from the sand-dominant, tidally-influenced marine Old Head Sandstone Formation to the open marine black mudrocks of the Kinsale Formation at the Devonian / Carboniferous (LN/VI) boundary (Higgs *et al.*, 1988). In the sections described from SW Portugal, the tidally-influenced marine quartzites of the top of the Tercenas Formation are overlain by open marine mudrocks of the Bordalete Formation. Although this lithostratigraphic boundary appears to be slightly younger in Portugal than in Ireland, the presence of extremely organic rich black shales at the base of the Kinsale Formation in the latter area possibly suggests a very condensed sequence.

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PLATE 1

Each specimen is referenced by: collection number and sample number.

1. *Punctatisporites planus* Hacquebard AC28 - 285;
2. *Retusotriletes crassus* Clayton,Johnston, Sevastopulo & Smith AC14 - 280;
3. *Retusotriletes incohatus* Sullivan AC30 - 280;
4. *Apiculatisporis* sp. AC31 - 280;
5. *Verrucosisporites nitidus* (Naumova) Playford AC32 - 285;
6. *Convolutispora caliginosa* Clayton & Keegan AC13 - 285;
7,8. *Endoculeospora gradzinskii* Turnau AC27 - 285 ;AC28 - 285;
9. *Cyrtospora cristifera* (Luber) Van der Zwan AC18 - 288;
10. *Densosporites spitsbergensis* Playford AC1 - 105;
11. *Tumulispora concentricus* Byvscheva AC23 - 106;
12,13. *Tumulispora malevkensis* (Kedo) Turnau AC2 - 279; AC3 - 279;
14. *Hymenozonotriletes explanatus* (Luber) Kedo AC4 - 106;
15. *Diducites poljessicus* (Kedo) Van Veen AC11 - 285;
16. *Rugospora radiata* (Kedo) Byvscheva AC12 - 285

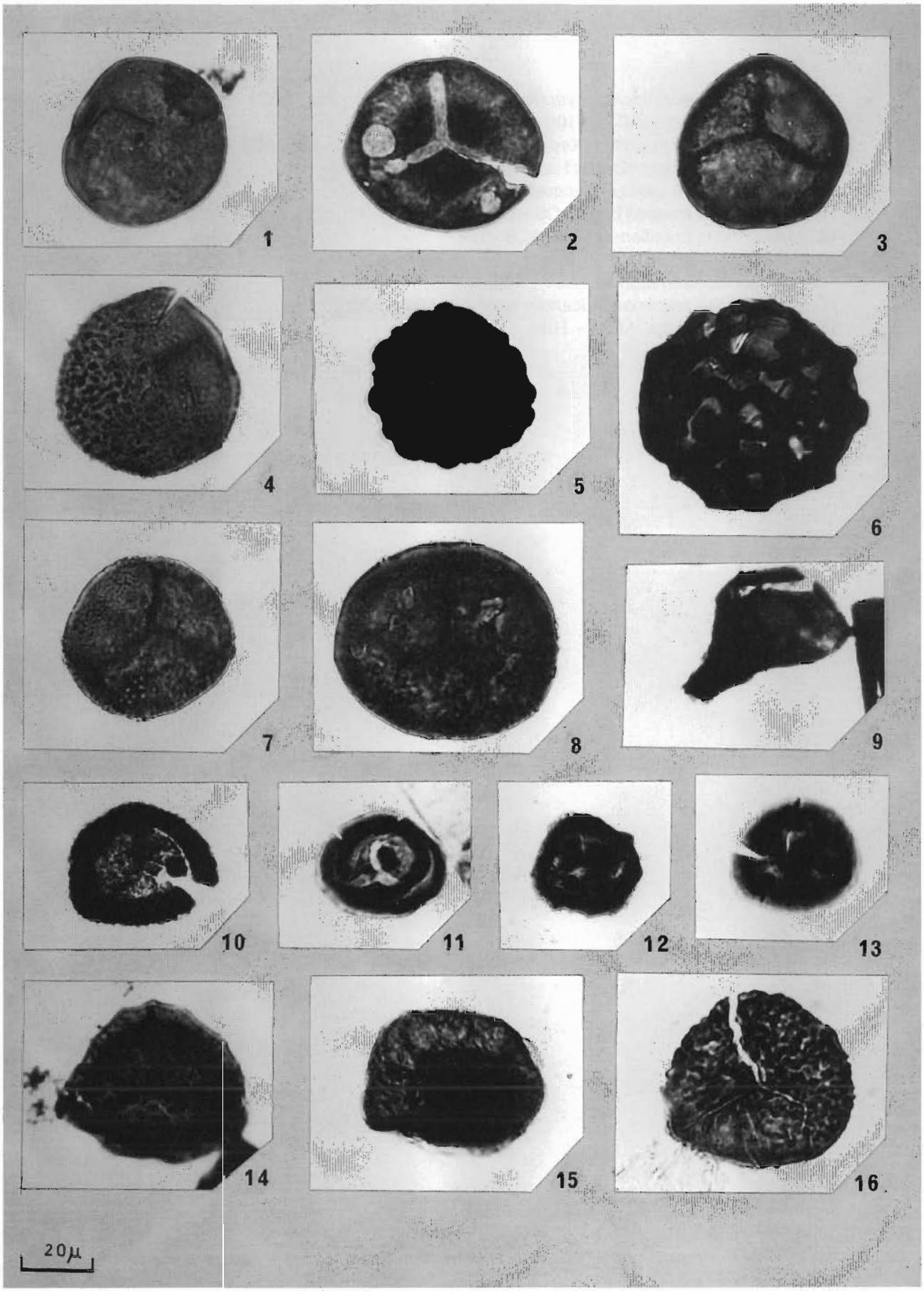
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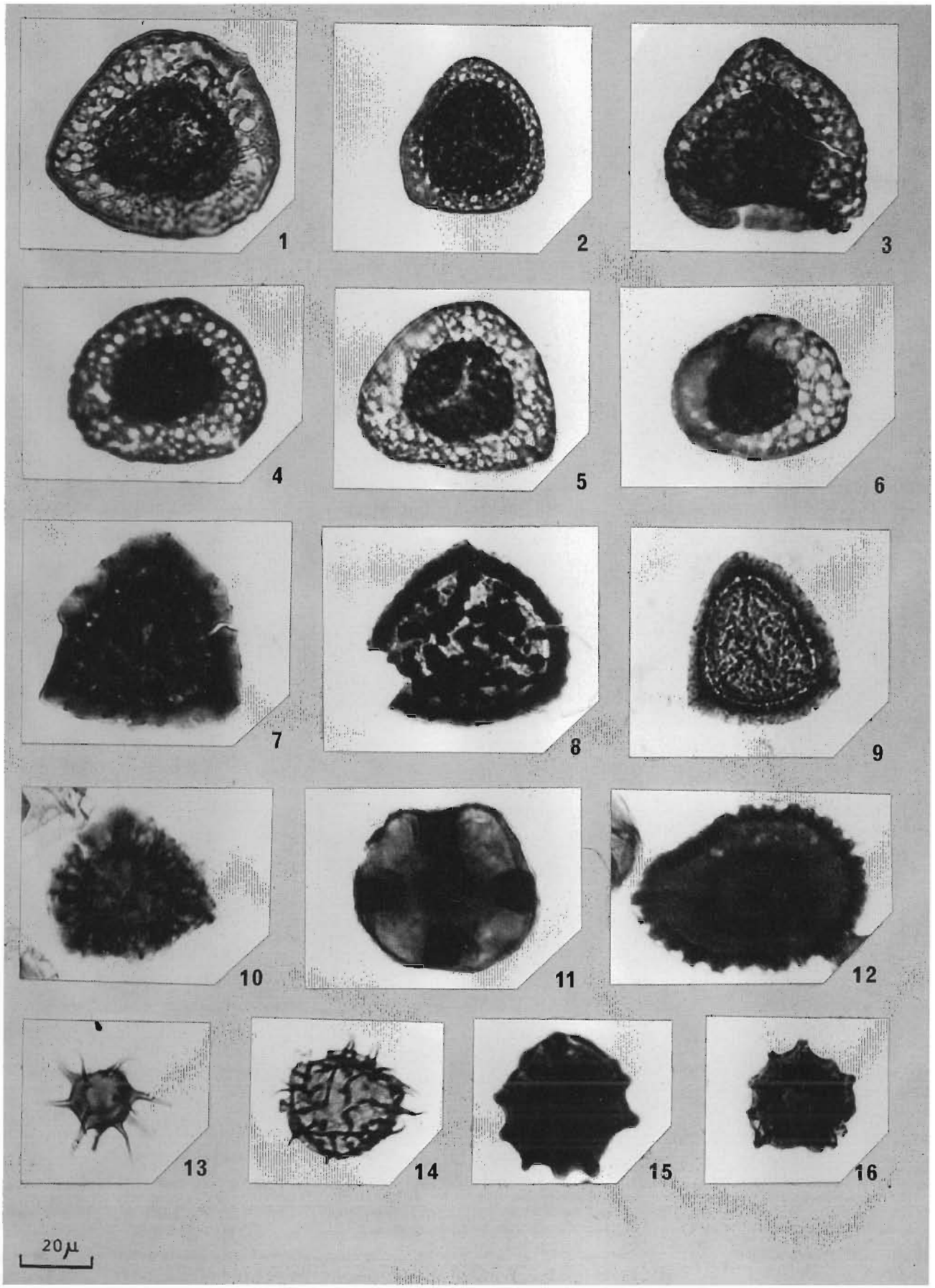
PLATE 2

1,2,3,4,5,6. *Retispora lepidophyta* (Kedo) Playford, AC16 - 285; AC21 - 106; AC25 - 285; AC19 - 283; AC22 - 106; AC20 - 106;
7,10. *Vallatisporites pusillites* (Kedo) Dolby & Neves AC 26 - 285; AC5 - 106;
8 *Vallatisporites verrucosus* Hacquebard AC17 - 285;
9. *Vallatisporites vallatus* Hacquebard AC15 - 285;
11. *Maranhites mosesii* Brito AC6 - 106;
12. *Maranhites brasiliensis* Brito AC9 - 106;
13. *Unellidium* sp. AC10 - 106;
14. *Gorgonisphaeridium* sp. AC7 - 106;
15. *Maranhites preplexus* Wicander & Wood AC8 - 106;
16. *Polyedryxium* sp. AC24 - 105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