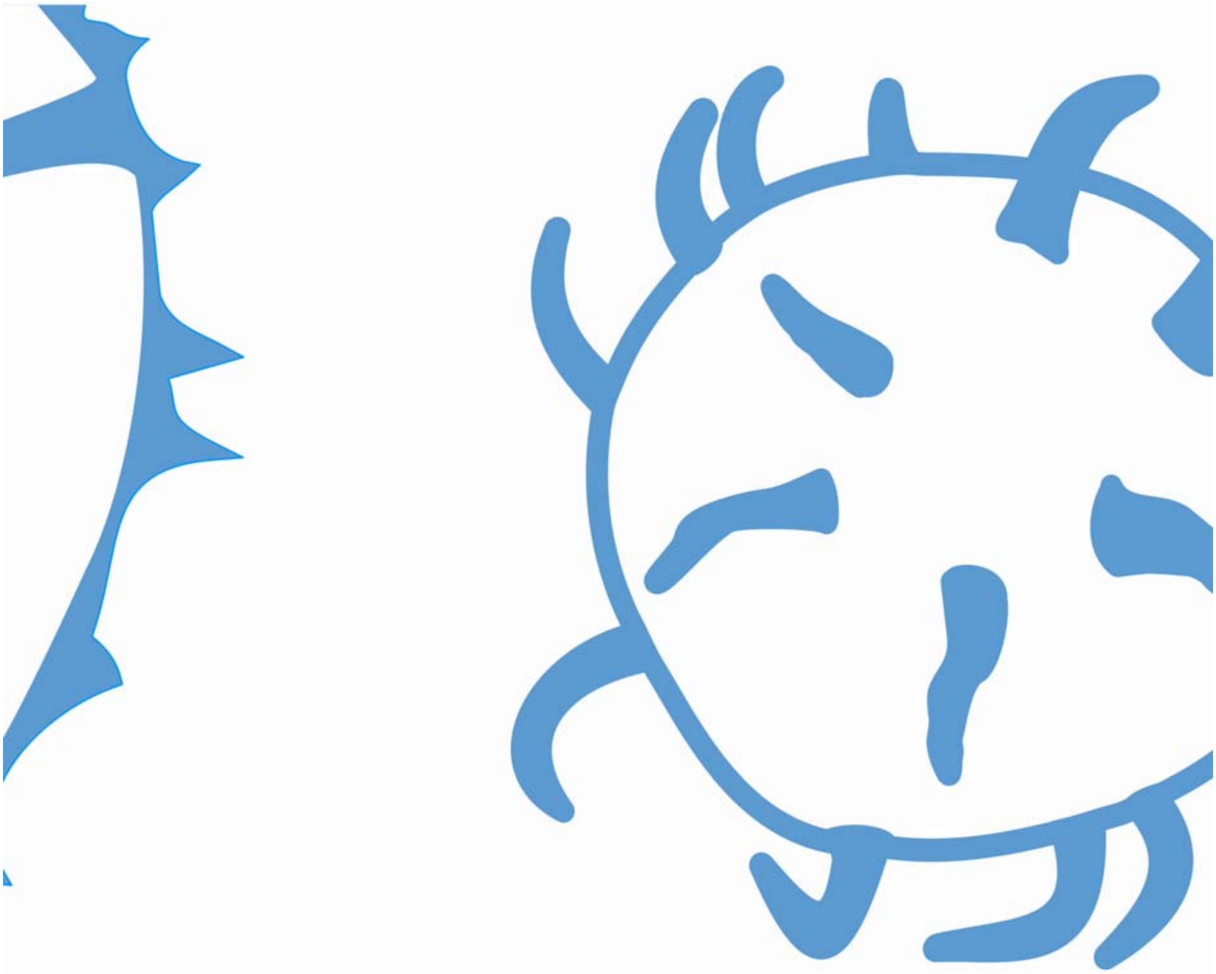

CIMP Faro'09

II Joint Meeting of Spores/Pollen and Acritarch Subcommissions

Abstracts

Edited by P. Fernandes, Z. Pereira, J. Tomás Oliveira, G. Clayton and R. Wicander

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WELCOME to CIMP Faro'09

This meeting builds on the last CIMP meeting held in 2007 in Lisbon and the suggestion of organizing a Second Joint Meeting of Spore/Pollen and Acritarch Subcommissions in Portugal was warmly accepted by us. For this year reunion theme we chose the Euramerica - Gondwana collision and the utility of palynomorphs in its reconstruction.

The meeting is co-organized by Centro de Investigação Marinha e Ambiental (CIMA) from the UALG (University of Algarve) and LNEG - LGM (Laboratório Nacional de Energia e Geologia - Geological Survey). The venue of the meeting is the University of Algarve, Campus de Gambelas, in Faro, from the 21st to the 24th of September 2009. Although, theme of the reunion is the Euramerica - Gondwana reconstruction, it is open to all researches interested in any aspect of Palaeozoic palynology. The program includes a two-day scientific and technical sessions followed by a two-day field trip to the west part of the Algarve, between Aljezur and Lagos.

In 2009 the University of Algarve commemorates its 30th anniversary; therefore it is an honour to host CIMP Faro'09 and all its delegates in this special occasion. All facilities were kindly provided by the UALG, CIMA and LNEG. Financial support for the publication of this book of abstracts was provided by Portuguese government agency Fundação para a Ciência e a Tecnologia (FCT).

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The editors thanks Geoff Clayton, Reed Wicander and Ken Higgs for encouraging the organisation of this second CIMP meeting in Portugal and to all valuable help that greatly improve CIMP Faro'09. Special thanks to all colleagues who enthusiastically accepted to help in this meeting: Filipe Barreira for the conception of the design of the meeting, Bruno Rodrigues, Nuno Vaz and Gilda Lopes for all the logistic and technical help.

Lastly, a word to all CIMP Faro'09 participants. We express our sincere thanks to all the authors for their invaluable contributions that are published in this Book of Abstracts.

Bem-vindos ao Algarve

The Editors

September 2009

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USE OF PALYNOLOGY IN DETECTING FAULTED SEQUENCES, AL KHLATA FORMATION, PERMO-CARBONIFEROUS, SOUTH OMAN

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SUMMARY

Well-A in the Study Area in southern Oman represents an excellent example of defining faults in structurally complex zones using high resolution palynological correlation. Adapting the Penney et al. (2008) Biozonation scheme, the palynological investigations indicate a Pennsylvanian-Sakmarian age for this section assigned to the Al Khlata and the Lower Gharif formations of the Haushi Group. An unusual palynological succession was revealed in the well where the 2159B Biozone (Bashkirian) deposits of the Al Khlata Formation overlie younger deposits of the 2141A/ 2165B biozones (Asselian), which in turn overlie even younger deposits of the 2141B Biozone (Asselian-Sakmarian). This reversed palynological succession suggests the existence of two normal faults. The existence of these faults is confirmed by the seismological interpretations of the well section. Similarly, the obtained wireline logs data from the studied section exhibited repeated trends associated with these palynological zones supporting the existence of the two faults.

Keywords: Palynology; Gharif Formation; Al Khlata Formation; Carboniferous; Permian; normal faults.

INTRODUCTION

The Al Khlata Formation is the lower part of the Haushi Group and a well-known glacially influenced formation of Permo-Carboniferous age that underlies much of interior Oman, and outcrops in the Huqf area in eastern Oman (e.g. Levell et al. 1988; Heward, 1990; Love, 1994; Al Belushi et al. 1996; Osterloff et al. 2004) (Figure 1). The Al Khlata Formation unconformably overlies various Lower Palaeozoic formations and conformably underlies the Permian continental Gharif Formation.

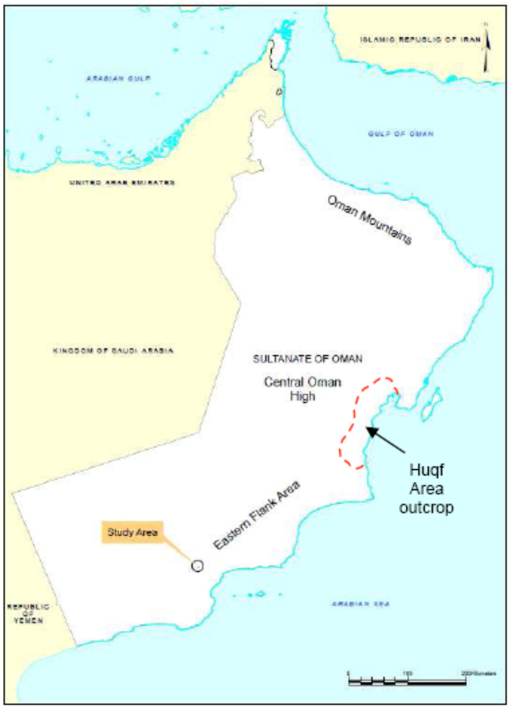

Figure 1. Oman location map.

Correlating the Al Khlata Formation has always been problematic (e.g. Love, 1994; Stephenson et al. 2003; Penney et al. 2008). This is mainly due to the rapid lateral and vertical change in lithology (e.g. Levell et al. 1988; Al Belushi et al. 1996). In addition the Al Khlata Formation lacks marine fauna which precludes precise dating. The only fossil contents that are present in the Al Khlata Formation are palynomorphs, and therefore palynology is the only dating tool. Petroleum Development Oman (PDO) have developed a high resolution biozonation for the Al Khlata Formation over decades and this has recently been summarised in

Penney et al. (2008) (Figure 2).

The biozonation is sufficiently precise to allow the resolution of stratigraphical structural problems. This abstract discusses one such problem.

Well-A was drilled in 2008 for hydrocarbon recovery. The seismic data from the study area shows the occurrence of complex fault structure (flower structure) intersected by the well (Figure 3). Seismic resolution is insufficient to reliably identify the top and the different production units of the Al Khlata Formation in the faulted zone. Post drilling an enigmatic wireline profile hampered correlation or resolution units. Palynological investigation resolved the structural complexity.

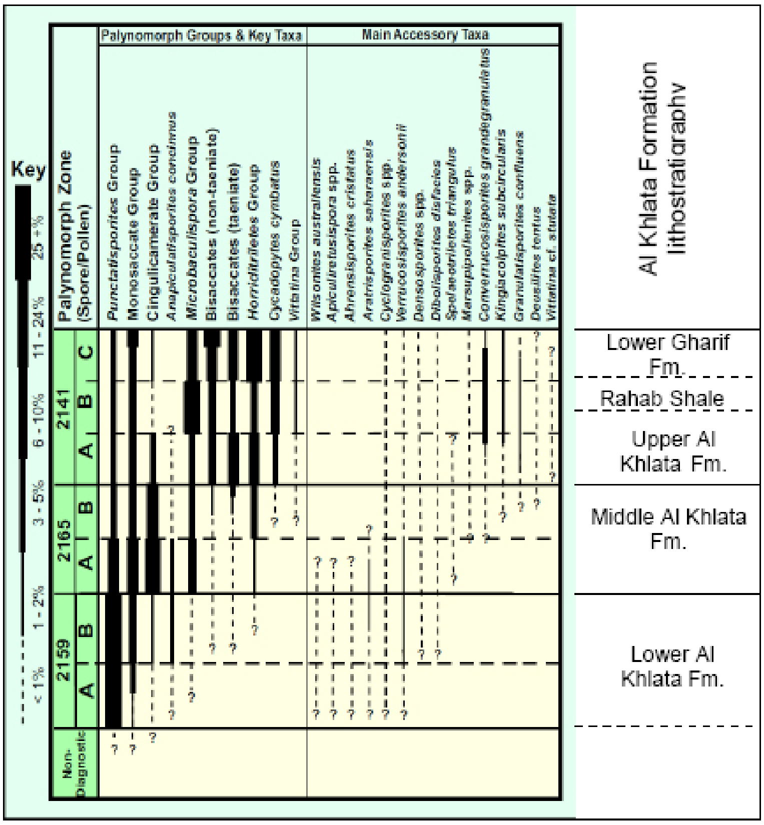

Figure 2. Modified from Penney et al. (2008) Al Khlata Formation Biozonation scheme. (Fm. = Formation; Mmb. = Member).

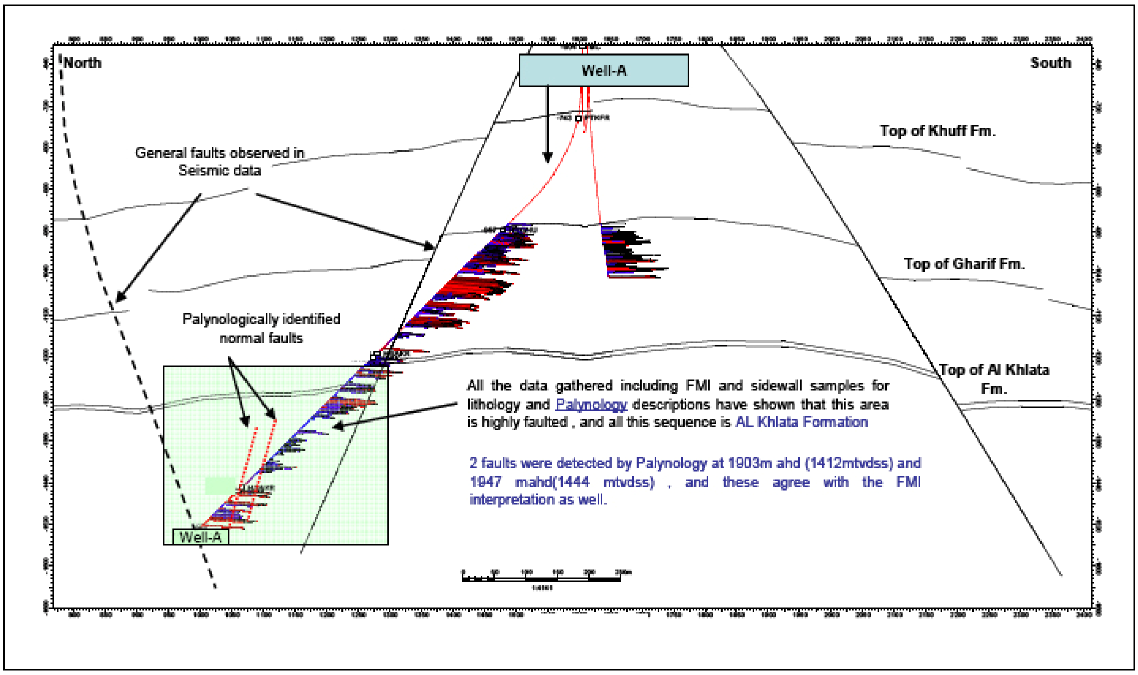

Figure 3. A simple cartoon illustrates where is the unknown lithologies encountered along the well path. This resulted in gathering sidewall samples in this section (with shaded square) for palynology study.

At depth 1821m Biozone 2159 was determined; however, at 1907m the younger 2141A Biozone was encountered (Figures 4a & b). At 1953m the even younger 2141B biozone was encountered.

The sequence was thus interpreted as being faulted based on the palynological interpretation. This case study illustrates the power of palynology in solving correlation in complex zones (Figure 5).

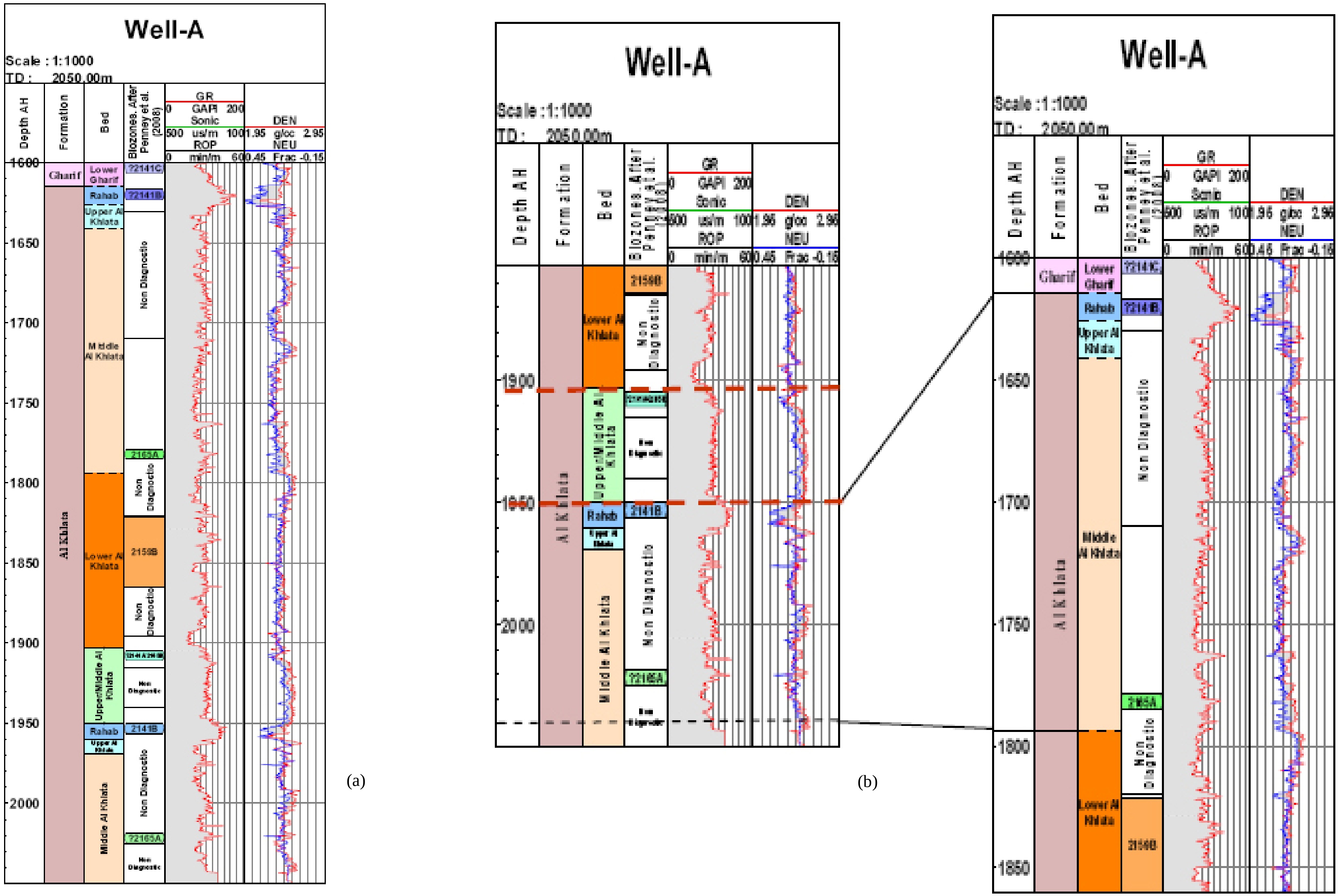

Figure 4. (a) Palynostratigraphic and wireline log characters of Well-A. (b) Palynostratigraphic repeated sections of Well-A implying the occurrence of two normal faults. Note the similarities in wireline log characters of the faulted sections. Dashed red line indicates the location of faults

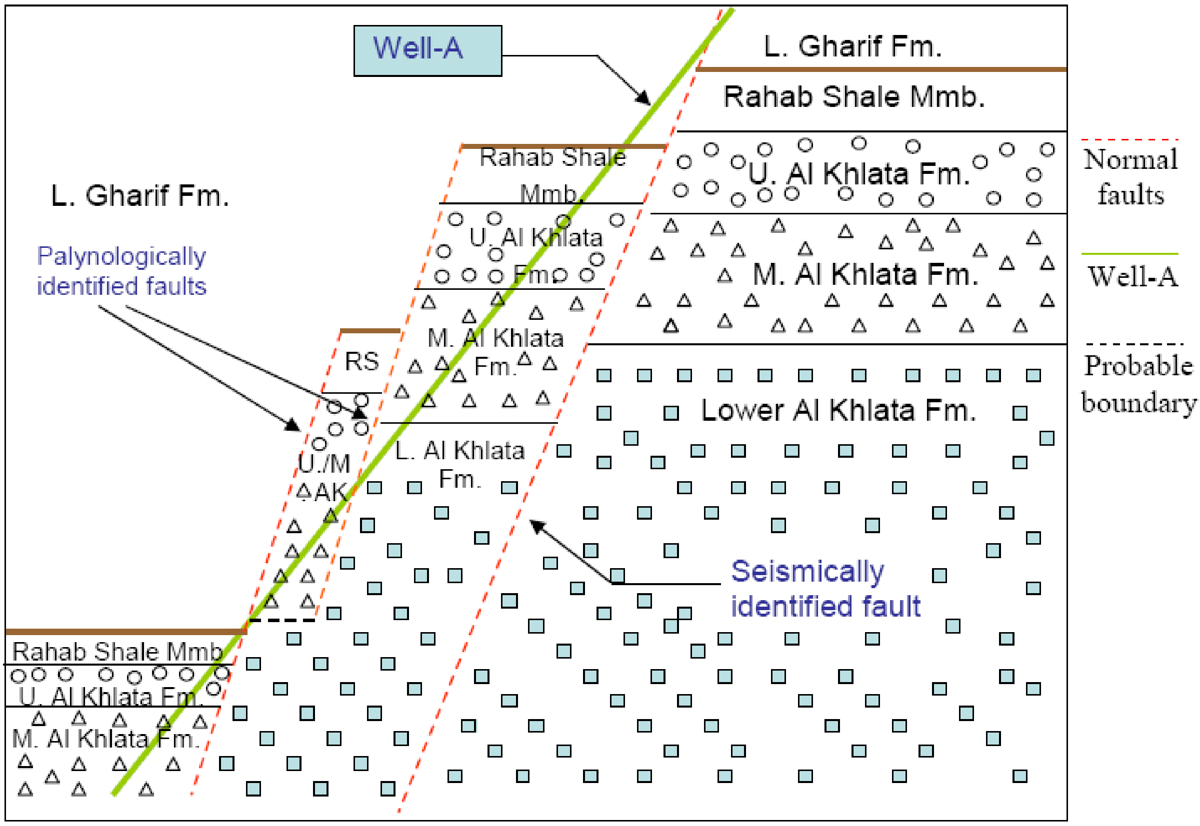

Figure 5. A schematic diagram of structural details of the shaded square in Fig 3. Note the difference of the of the Al Khlata Fm. Picked by poor seismic in Fig 3. and by palynology on this figure. Figures not to scale. (U=Upper; M=Middle; L-lower; AK=Al Khlata Formation; RS=Rahab Shale; Mmb=Member; Fm=Formation).

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LATE MISSISSIPPIAN - EARLY PENNSYLVANIAN (SERPUKHOVIAN-BASHKIRIAN) MIOSPORE ASSEMBLAGES FROM THE BOHEMIAN PART OF THE UPPER SILESIAN BASIN, CZECH REPUBLIC

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SUMMARY

Palynological samples from thirty-four boreholes drilled in the Bohemian part of the Upper Silesian Basin in the Czech Republic during the last fifty years were examined. Coal samples from the Ostrava (Jaklovec and Poruba members) and Karviná (Saddle, Lower and Upper Suchá members) formations of Serpukhovian to Bashkirian age (Arnsbergian-Langsettian) were palynologically studied. Fifty-six genera with two hundred and forty-seven species were recognised by four palynologists. A brief review of the history of geological, palaeobotanical and palynological research is given. The changes in the dominance of the two principal miospore groups, lycospores and densospores, are the most significant criteria for the determination and characterization of dispersed miospore assemblages. A reconstruction of coal-forming vegetation is suggested. Comparisons with some other European, and American coal basins and Western Europe palynozonation are made.

Keywords: Carboniferous, miospores, biostratigraphy, Upper Silesian Basin, palynozonation

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INTRODUCTION

The Upper Silesian Basin is one of the most important coal basins of the Carboniferous age in Europe and geological research in this area started at the beginning of the 19th century. The stratigraphical range of coal-bearing strata in the Czech part of the Upper Silesian Basin is Serpukhovian to Bashkirian (former late Namurian A-Langsettian). Palynological samples were obtained from the Ostrava (Jaklovec and Poruba members) and Karviná (Saddle, Lower and Upper Suchá members) formations (Tab. 1) from coals in mines and boreholes. The preservation of miospore assemblages in the Czech part of the Upper Silesian Basin is very poor in comparison with well-preserved and diversified assemblages of the same age in Poland. Czech miospores are often damaged and very dark brown in colour, suggesting extensive coalification. All palynological data from the Czech part of the basin are from coal seams.

All data from the Polish part (with the exception of clastics of the Jejkowice beds which are not developed in the Czech part) are also of coal seam origin (Oliwkiewicz–Miklasińska, pers. comm.).

Age			Formation	Member			
				Czech part		Polish part	
						Western part	Eastern part
LANGSETTIAN	WESTPHALIAN	LANGSETTIAN	KARVINÁ	SUCHÁ	UPPER	ZAŁĘSKIE	ZAŁĘSKIE
YEADONIAN	NAMURIAN	C B			LOWER	RUDZKIE	RUDZKIE
MARSDENIAN				SADDLE		SIODŁOWE	ZABRSKIE
CHOKERIAN-KINDERSCOUTIAN		A	Hiathus			Hiathus /JEJKOWICKIE/	Hiathus
ARNSBERGIAN			OSTRAVA	PORUBA		PORĘBSKIE	GRODZIECKIE
				JAKLOVEC		JAKLOWIECKIE	

Table 1. Lithostratigraphical units of the Czech and Polish parts of the Upper Silesian Basin and their stratigraphical levels.

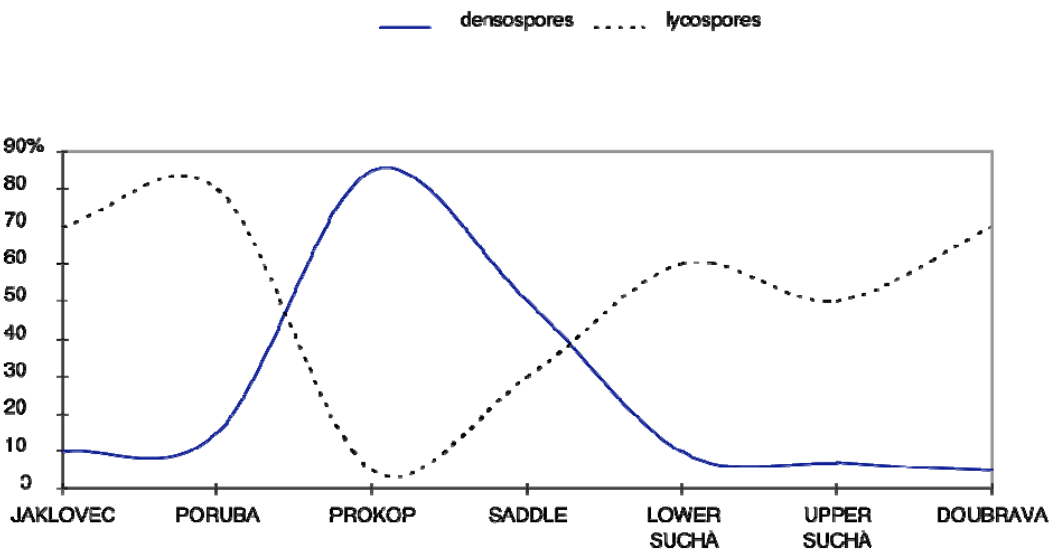

Figure 1. Percentage of two main spore groups in dispersed spore assemblages of the Czech part of the Upper Silesian Basin, Czech Republic (dash line represents lycospores and continuous line densospores with the maximum within the Prokop Seam).

Lycospores and Densospores are two major miospore groups in the Czech part of the Upper Silesian Basin and made up almost 80% of all specimens recorded. The relative proportions of these two main miospore groups are shown in Fig. 1. The parent plants of the lycospores, arborescent lycopsids of the genera *Lepidodendron* and *Lepidophloios* Sternberg were the principal contributors to biomass. The general decline of arborescent lycopsids during the sedimentation of the Saddle Member corresponds with relatively dry intervals favourable for dominance of densospores produced by the higher abundance of their parent plants, sub-arborescent lycopsids of the genus *Omphalophloios*. The general character of the spore assemblages is the same in both parts of the basin but there are some differences in the stratigraphical ranges of selected spore taxa. These differences were probably influenced by lateral development in various parts of the basin, i.e. they probably were ecologically controlled. Some significant spore taxa survived longer in the Czech part of the basin than in Poland (e.g. *Tripartites* and *Rotaspora knoxi*) while others appeared earlier in the Polish part (*Florinites*, *Schulzospora, Bellispores, Tripartites, Dictyotriletes bireticulatus, Crassispora*). Most important are the longer stratigraphical ranges of the index species *Rotaspora knoxi* and the important genus *Tripartites* in the Czech part, and the earlier appearance of *Florinites, Crassispora* and *Schulzospora* in the Polish part (Tab. 2). These results were confirmed by the study of of Carboniferous plants material in collections (The Natural History Museum in Ostrava, Czech Republic; the Geological Institute in Sosnowiec, Poland; the Institute of Geology, Academy of Sciences, Cracow, Poland) from the Czech and Polish parts of the basin by the author.

A number of palynozones have been proposed for the Carboniferous in Western Europe (Alpern et al., 1967; Loboziak, 1971; Grebe, 1972; Chateauneuf,1973;Wijhe et al.,1974; Peppers, 1979 and others), but only a few of them (Smith and Butterworth, 1967; Clayton et al., 1977; Owens et al., 2004) are regularly used for comparison and correlation by most palynologists. The stratigraphic ranges and occurrences of miospores from the Czech part of the Upper Silesian Basin and Western Europe are broadly comparable. However, even though both regions were at the same palaeolatitude on the same palaeo-continent, it is necessary to intergrate all available independent biostratigraphic data in the definition of palynological zonal units (Owens et al., 2004). In general terms, the broad (continental) changes which appear to be reflected in the composition of the assemblages mirror similar changes in Western Europe. On the other hand, the ages inferred for the biozones are rarely supported by independent biostratigraphic evidence. Some miospore taxa that are important in Western Europe (Clayton et al., 1977; Owens et al., 2004) are not recorded in the Czech and/or Polish parts of the Upper Silesian Basin, whereas others have different stratigraphical ranges. It is difficult to establish whether these are real differences between the two regions or whether these merely reflect different approaches to nomenclature and taxonomy and also different preservation.

Spore taxa		Jaklovec	Poruba	Saddle	Lower Suchá	Upper Suchá
Reinschospora speciosa	Czech part (C) Polish part (P)					
Florinites	C					
	P					
Schulzospora ocellata	C					
	P					
Simozonotriletes intortus	C					
	P					
Tripartites	C					
	P					
Dictyotriletes bireticulatus	C					
	P					
Punctatosporites minutus	C					
	P					
Raistrickia fulva	C					
	P					
Punctatisporites sinuatus	C					
	P					
Crassispora kosankei	C					
	P					

Table. 2. Comparison of occurrence of the most important miospore taxa described from Czech and Polish parts of the Upper Silesian Basin.

Another reason for the observed differences could be that Clayton et al. (1977) sometimes combined palynological data from coal seams and clastics while data from both parts of the Upper Silesian Basin are only from coal seams.

Palynological assemblages from the Czech part of the Upper Silesian Basin are not comparable with any assemblage of the same age in the Czech Republic. Spore assemblages from the Upper Silesian Basin are well comparable with those of the same age described by Loboziak (1972) from France and by Artűz (1957) from Turkey while assemblages published by Dimitrova (1993) from Bulgaria, Grebe (1972) and Döring (1975) from Germany, Hoffmeister et al. (1955b) and Eble (1996) from the USA and those reported by several British palynologists (Neves,1958; Butterworth and Millott, 1960; Neves, 1961; Neves et al., 1972, 1973; Owens et al., 1977; Clayton et al.,1978; Butterworth and Mahdi, 1982; Owens,1982; Turner et al.,1994; Owens et al., 2004) from the UK exhibit more differences. Comparison of the Western Europe zonation (Clayton et al., 1977) and spore assemblages from the Upper Silesian Basin suggests major differences in terms of the stratigraphic ranges of several important taxa. Correlation is also made difficult by floral provincialism, resulting in major compositional differences between the various regions in the Northern Hemisphere during late Mississippian – earliest Pennsylvanian time.

Although the Western Europemiospore zonation (Clayton et al., 1977) is applicable in several countries in Western Europe, it cannot generally be applied in parts of Central Europe including Poland, the Czech Republic and probably also the former East Germany. This suggests the need for an independent palynozonation for Central Europe.

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PALAEOPHYTOGEOGRAPHY OF DEVONIAN MIOSPORE ASSEMBLAGES

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SUMMARY

The review of the Emsian-Givetian miospore assemblages from the literature allows evaluation of the provincialism of assemblages on a worldwide scale during this interval. Coefficient of similarity is calculated between palynofloras from northern Euramerica, southern Euramerica, northwestern Gondwana, southwestern Gondwana and eastern Gondwana. The resulting low values correspond to low to moderate similarity of miospore assemblages during the interval investigated. The provincialism may be explained by a latitudinal climatic gradient as no palaeogeographic barrier is known during this time interval. However, it seems that a progressive homogenization of the vegetation took place in the Middle Devonian. This transition from provincialism to cosmopolitanism during the Devonian is not only shown by palynofloras but also by the palaeogeographic distribution of many other fossil groups. It is probably due to a decrease of the latitudinal climatic gradient.

Keywords: Palaeogeography, Devonian, Miospores, Gondwana.

INTRODUCTION

McGregor (1979) agreed that Devonian miospores had a cosmopolitan distribution, but he indicated that detailed palynological records show evidence of provincialism during the Devonian. McGregor and Playford (1992) also suggested certain cosmopolitanism in the Devonian land vegetation during Middle through Late Devonian time, allowing considerable floristic interchange, although some provincialism does exist. Streel et al. (1990) noted that analyses of Euramerican miospore assemblages suggest vegetation differences between the northern and southern parts of Euramerica. According to Steemans et al. (2007), at least two main phytogeographical provinces existed in earliest Devonian (Lochkovian): western Gondwana and Euramerica. Steemans and Lakova (2004) defined the Early Devonian *sinuosus-zavallatus* Phytogeographic Province which is a subprovince of Euramerica covering the eastern part of the Caledonian Mountains. Marshall (1996) applied multivariate methods to analyze the global miospore distribution notably for Emsian and Givetian intervals. In the Emsian, the different regions where miospores have been encountered are linked at low levels and are quite distinct. The Emsian miospore assemblages are therefore characterized by a marked provincialism. The Givetian results demonstrate higher level linkage between regions, thus demonstrating an apparently progressive decrease in provincialism during the Devonian. Di Pasquo et al. (2007, 2009) defined the Afro-South American Subrealm restricted to palaeolatitudes between 55° and 75° S in South America and Africa from the Givetian to Frasnian on the basis of endemic miospores and plant fossils. Although many cosmopolitan species are present, some degree of provincialism is evident at this time.

COEFFICIENT OF SIMILARITY

A way to estimate most objectively the similarity between the miospore assemblages from different regions is the coefficient of similarity (CS) *sensu* Clark and Harteberg (1983) for the evaluation of bioprovincialism. This simple and straight-forward approach is expressed by the equation:

$$CS = 2v/a+b$$

Where *v* is the number of species in common between the two compared assemblages, and *a* and *b* are the total numbers of species in each assemblage, respectively. CS has been calculated between northern and southern Euramerica, western, northwestern and eastern Gondwana for the Emsian-Givetian interval, based on the most substantial papers available. Northern Euramerican miospore assemblages are described in four major papers from Arctic Canada, Spitsbergen and Eastern Europe (e.g. McGregor and Camfield, 1982; Avkhimovitch et al., 1993). Southern Euramerican miospores assemblages have been listed from 12 papers from Scotland, the Ardenne-Rhenish regions, Poland and Canada (e.g. Richardson, 1965; McGregor, 1973; Riëgel, 1973; Turnau, 1986). Species occurring in southwestern Gondwana from Emsian to Givetian are discussed in 15 papers from South America (e.g. Menéndez and Pöthe de Baldis, 1967; Daemon et al., 1967; Dino, 1999; Melo and Loboziak, 2003). For the northwestern Gondwanan assemblages, the species from eight significant works, from Morocco to Saudi Arabia eastwards (e.g. Massa and Moreau-Benoit, 1976; Moreau-Benoit, 1989; Breuer, 2008), have been listed. In eastern Gondwana, Emsian-Givetian palynological records are described in four main papers from Antarctica and Australia (e.g. McGregor and Playford, 1992; Hashemi and Playford, 2005).

RESULTS

The total number of species in each region and the number of species in common between two compared regions are summarized in Table 1.

Number of species in common between 2 regions	northern Euramerica	southern Euramerica	southwestern Gondwana	northwestern Gondwana	eastern Gondwana
northern Euramerica	271	95	48	79	51
southern Euramerica	95	299	62	103	41
southwestern Gondwana	48	62	123	76	32
northwestern Gondwana	79	103	76	299	55
eastern Gondwana	51	41	32	55	198

Table. 1 Matrix of numbers of species in common between two compared regions. The total numbers of species for each region are distributed diagonally.

The resulting CS is plotted between the different regions for the considered interval (Fig. 1). The most striking result is the low general values which correspond to a low to moderate similarity of miospore assemblages between the different regions considered according to the criteria of Clark and Harteberg (1983). As suggested by Streel et al. (1990), the vegetational differences between northern and southern Euramerica are confirmed by a CS equal to 0.34. Northwestern Gondwana constituted an intermediate region that shared mainly taxa with Euramerica in the North and southwestern Gondwanan localities at higher latitudes. Enough similarities exist between Euramerican and Australian assemblages in Middle and Late Devonian to sustain long distance biostratigraphic correlation, but the low CS between eastern Gondwana and other regions may correspond to a single phytogeographic province as suggested by Streel and Loboziak (1996). The low to moderate CS in the whole of Gondwana seems to point to the existence of different climates through Gondwana as no physical barriers are known during the Emsian-Givetian interval.

CONCLUSIONS

An analysis of the palynological literature has allowed the calculation of CS in the Emsian-Givetian interval between coeval miospore assemblages from five regions (northern Euramerica, southern Euramerica, northwestern Gondwana, southwestern Gondwana, and eastern Gondwana). CS has proved to be a good indicator for the evaluation of provincialism. The resulting generally low values correspond to a low to moderate similarity of miospore assemblages between the different regions considered. The provincialism could be mainly due to latitudinal climatic gradient since the proximity of the Euramerican and Gondwanan land masses as early as the Lochkovian would have enabled plant migration. Despite this moderate degree of provincialism, floristic interchanges existed. The global calculation of CS should be treated with caution as it could not be calculated precisely for each stage. However, it appears that homogenization of the vegetation took place from the Emsian to the Givetian. The transition from provincialism to cosmopolitanism during the Devonian is not only shown by palynofloras but also by the palaeogeographic distribution of other fossil groups. It is probably due to a decrease of the latitudinal climatic gradient.

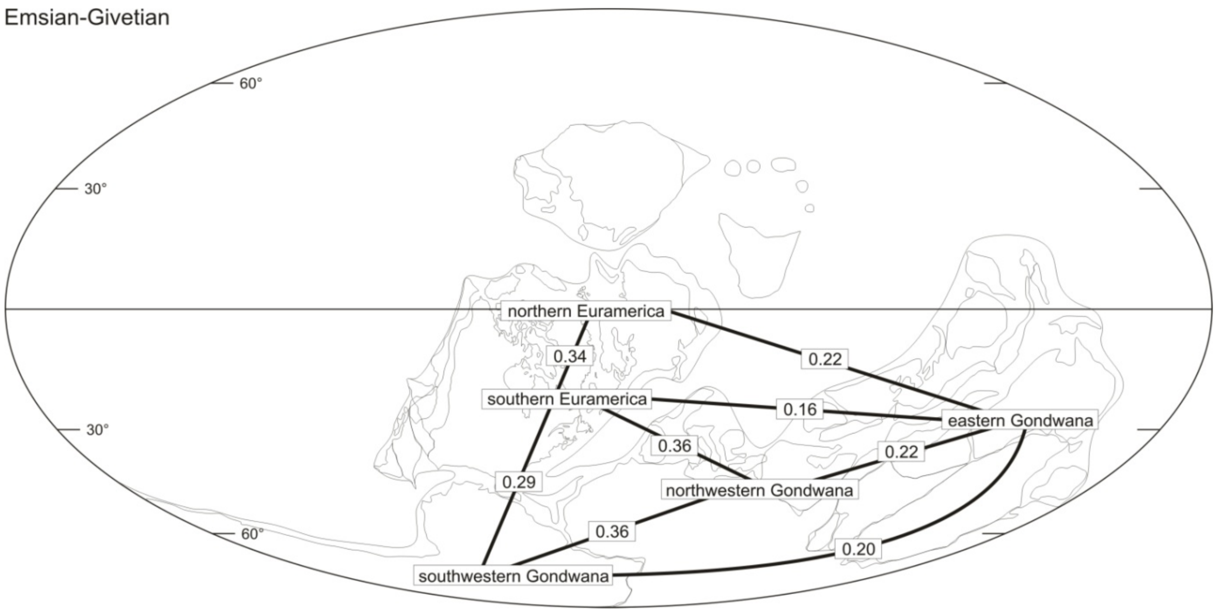

Figure 1. Coefficients of similarity between the different regions calculated on the basis of Emsian-Givetian miospore assemblages. Palaeogeographic reconstruction modified after Scotese (2000).

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RECENT ADVANCES IN THE LATE DEVONIAN / MISSISSIPPIAN PALYNOSTRATIGRAPHY OF THE USA

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SUMMARY

Numerous (>250) late Devonian and early Mississippian palynomorph assemblages have been investigated from the Appalachian and Illinois basins of the Eastern – Midwest USA. All of the miospore zones described from the same stratigraphic interval in Western Europe have been recognised, with the exception the *Cristatisporites hibernicus – Umbonatisporites distinctus* (HD) Biozone. Based on independent biostratigraphic evidence, the ages of the bases of the biozones are very similar in both regions except for the *Lycospora pusilla* (Pu) Biozone whose base is considerably younger in the Illinois Basin than in Western Europe. Miospores and conodonts suggest different ages for part of the late Famennian Ohio Shale in the Appalachian Basin, suggesting that more detailed investigation is needed.

Keywords: Late Devonian, Mississippian, palynostratigraphy, miospores, USA.

INTRODUCTION

More than 250 productive samples have been obtained from the late Devonian (Famennian) and early Mississippian (Tournaisian) in the Appalachian and Illinois basins of the USA. Sections investigated range geographically from West Virginia in the east, through Kentucky and Ohio to the Mississippi Valley (Illinois and Missouri) in the West. All of the sampled strata have been interpreted to be of marine to near-marine origin. The Appalachian Basin samples generally contain abundant land-derived organic matter including miospores, especially those from the Mississippian. However, independent biostratigraphic control in these sections is limited. In contrast, the 'type' Mississippian of the Mississippi Valley (Illinois Basin; also known as the Eastern Interior Basin) is extremely well known in terms of its fauna which includes conodonts and foraminifera. Unfortunately, carbonates dominate the succession in this region and palynomorph recovery is limited to shales intercalated between the limestones and dolomites. Moreover, the palynomorph assemblages tend to be of low diversity with relatively few stratigraphically-significant miospore taxa recorded (Heal and Clayton, 2008).

PALYNOSTRATIGRAPHY

Late Devonian palynomorph assemblages investigated from Kentucky and Ohio contain abundant acritarchs, prasinophytes and miospores. On the basis of the miospore taxa identified, the upper part of the Ohio Shale (above the base of the Three Lick Bed) can be confidently assigned to the *R. lepidophyta - V. nitidus* (LN) Miospore Biozone of Western Europe, suggesting correlation with the Mid- or Upper *praesulcata* Conodont Zone (Streel and Loboziak, 1996; Streel, 2009). However, conodonts described from the same sections in Kentucky are considered to be no younger than the

Lower *expansa* Conodont Zone (Over *et al.*, 2009), raising major questions concerning the correlation of miospore and conodont zonal schemes at this level and suggesting that further investigation is needed to resolve this biostratigraphic conflict.

The Devonian / Carboniferous boundary in the western part of the Appalachian Basin can be easily recognised palynologically on the disappearance of *Retispora lepidophyta* and associated taxa. In the eastern part of the basin, the presence of abundant reworked Devonian miospores (including *R. lepidophyta*) in the early Mississippian causes major problems with regard to the recognition of this boundary. In the Mississippi Valley sections of the Illinois Basin, the latest Devonian rocks present are typically limestone or dolomite units such as the Louisiana Limestone, which contain no palynomorphs.

All of the Western European Tournaisian miospore biozones can be recognised in the Appalachian Basin except for the *Cristatisporites hibernicus* – *Umbonatisporites distinctus* (HD) Biozone. *C. hibernicus*, the index species for this zone, has not yet been recorded in the USA and *U. distinctus* occurs only sporadically. Independently dated miospore assemblages in the Mississippi Valley and Kentucky suggest that the zonal boundaries established in the USA are closely comparable in age with Western Europe with the exception of the base of the *Lycospora pusilla* Biozone. In Europe, *Lycospora pusilla* first appears just below the base of the Viséan Series but in the Mississippi Valley, it first appears much later, within the late Chesterian (late Viséan) Cypress Formation.

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ENVIRONMENTAL DIFFERENCES AMONG THE UPPER SILESIAN BLOCK, THE MAŁOPOLSKA BLOCK AND THE ŁYSOGÓRY BLOCK (SOUTHERN POLAND) DURING THE EARLY DEVONIAN

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SUMMARY

The organic content of samples derived from three geological units of early Devonian in age in southern Poland has been investigated for palynofacies. The age of the samples investigated was established as the *polygonalis-emsiensis* to *velatus-langii* Miospore Zones (Pragian-Eifelian). Small differences have been observed in palynofacies composition between the Upper Silesian Block and Małoposka Block. In both regions, the organic matter is dominated by miospores accompanied by higher plant tracheids, *Cosmochlaina* and *Nematothallus* sheets, and arthropod remains. Leiospheres are uncommon and acritarchs are single here. The results may point to marginal-marine depositional conditions very close to the shoreline with high rate of sedimentation and/or alluvial deposition. Different palynofacies have been recognized in the Łysogóry unit in the douglastownense-eurypterota Miospore Zone. The palynomorph assemblage contains common miospores and diverse acritarchs together with chitinozoans and scolecodonts. The presence of finely ornamented acritarchs (e.g. *Multiplicisphaeridium* spp.) may indicate offshore deposition in a low-energy, deep-water marine environment. However, the high abundance of miospores may indicate that sedimentation took place not far from the shoreline.

Keywords: palynofacies, Lower Devonian, Upper Silesian Block, Małoposka Block, Łysogóry Block, southern Poland

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INTRODUCTION

The data presented here are part of a palynological investigation of the Lower and Middle Devonian sequences in southern Poland. Samples for the present study were collected from two boreholes and one quarry belonging to three geological units: 1. Upper Silesian Block (USB) - Klucze 1 borehole, 2. Małopolska Block (MB) - Dyminy IG2 borehole and 3. Łysogóry Block (ŁB) - the Bukowa Góra Quarry (Fig. 1). These regions border each other tectonically and are located in southern Poland.

Palynological recognition of the Lower and Middle Devonian in southern Poland is tenuous. Konior and Turnau (1973) and Turnau (1974) described sporomorphs from the Bielsko-Wadowice area (Fig. 1) and suggested a Late Emsian age. Turnau (1985, 1986), Turnau and Jakubowska (1989) and Turnau et al., (2005) recognized Lower Devonian to Givetian miospore assemblages from the Radom-Lublin area (central Poland; Fig 2) but until now palynological data from the Lower Devonian of the Holy Cross Mountains (HCM) have been very scarce and poorly documented. Palynostratigraphical data are very useful, especially in clastic rocks from the Lower Devonian in which the fauna is sparse and of little stratigraphic value. The present palynological investigation supplements earlier research conducted in the region situated between the Radom–Lublin and the Bielsko-Wadowice areas (see Fig.1).

The Lower Devonian in the areas investigated is represented by sequences of sandstones with intercalated mudstones and siltstones (Konior and Turnau, 1973; Buła 2000; Malec, 2005). The thicknesses of the sequences vary, sometimes exceeding one hundred meters but sometimes they may be completely reduced (e.g. Buła, 2000; Malec, 2005). The clastic deposits are overlain by carbonate rocks dated as Eifelian.

PALYNOLOGY

All of the samples from the clastic rocks yielded very well-preserved organic residues consisting of miospores, mainly accompanied by upper plant tracheids and cuticles. The worst preserved organic residues were derived from the carbonate rocks. Phytoplankton, mainly leiospheres, together with acritarchs and some scolecodonts and chitinozoans were also present in varying numbers.

Based on the presence of important and characteristic miospores (Richardson and McGregor, 1986; Streel et al., 1987), the samples from the Klucze 1 borehole were assigned to the annulatus-sextantii (1580-1535 m) and douglastownense-eurypterota (1530-1485 m) zones; the samples from the Dyminy IG2 borehole were assigned to the polygonalis-emsiensis (169-157 m), annulatus-sextantii (151-147 m), douglastownense-eurypterota (143-126 m) and velatus-langii (110-96 m) zones; the samples from the Bukowa Góra Quarry were assigned to the douglastownense-eurypterota (Bukowa Góra Member) Miospore Zone.

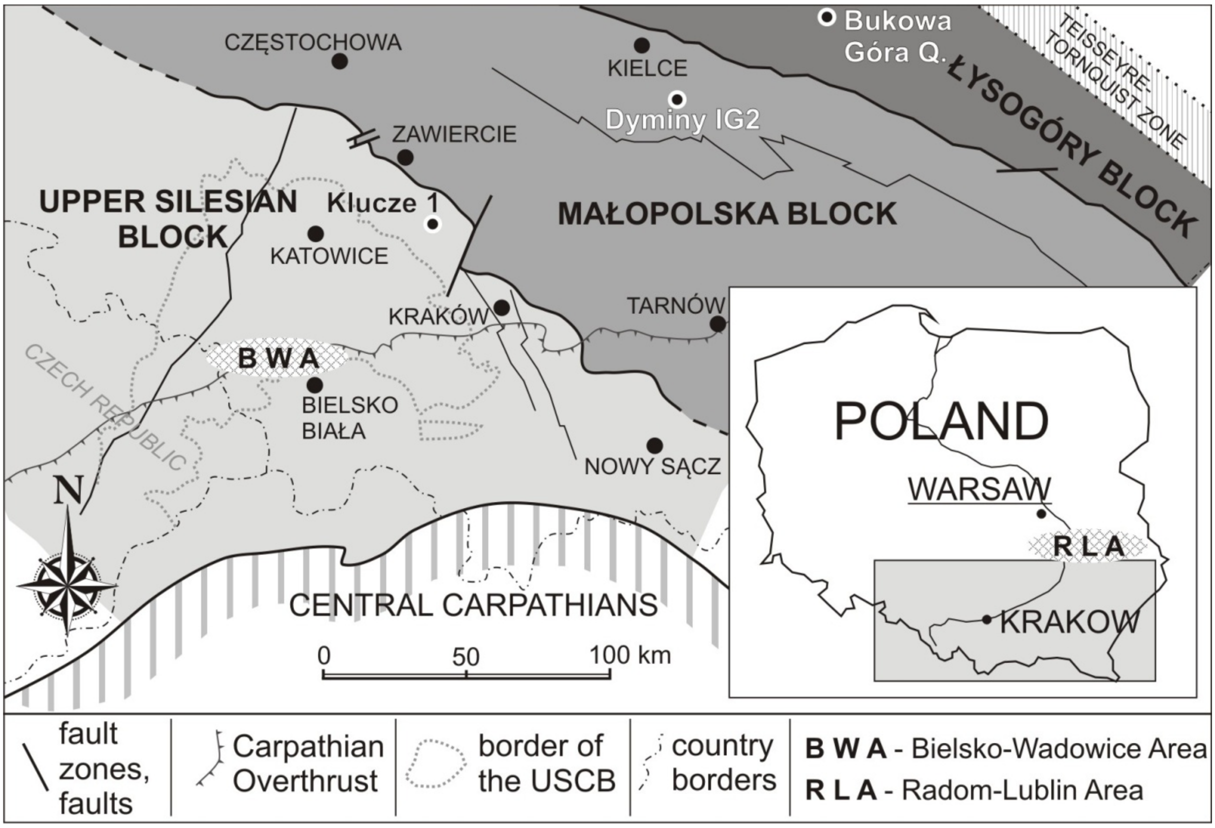

Figure 1. Localization of the investigated boreholes and previously investigated areas.

The Lower Devonian palynofacies from the USB and MB are similar. Generally, in the samples dated as polygonalis-emsiensis and annulatus-sextantii, the miospores (~90 %) with other land-derived particles are dominant. Here, the phytoplankton was represented by leiospheres (~10 %) and just a few acritarch species. Scolecodonts were also rare. In contrast, large, delicate cuticles with stomata, big sheets of cuticles of enigmatic *Nematothallus* and *Cosmochlaina* taxa, and *Musivum gradzinskii* (freshwater Chlorococcales) were quite common components together with some arthropod remains. This may indicate that the lower clastic part of the sections were deposited very close to the shoreline in marginal-marine and/or alluvial conditions (Fig. 2). In such environmental conditions, the land-derived organic particles are frequently deposited (e.g. Tyson, 1993; Batten, 1996). Depositional conditions may have become slightly more marine during douglastownense-eurypterota Miospore Zone time in this area. Acritarchs and scolecodonts taxa were noted here but still as single specimens. Slightly increased amounts of phytoplankton coincide with fewer land-derived particles (tracheids and cuticles), and miospores. Leiospheres and especially taxonomically more differentiated acritarchs together with scolecodonts appear more frequently in the upper part of the section in the velatus-langii Miospore Zone (Eifelian). Also, the presence of amorphous organic matter (AOM) in some samples from the upper part (130-110 m) of the Dyminy IG2 borehole may indicate anoxic sea-floor conditions (e.g. Batten, 1996).

In palynofacies from the Bukowa Góra Quarry (ŁB), from the douglastownense-eurypterota Zone, the miospores are still the most frequent component consisting of ~80-90 %. Contrary to the USB and MB, more abundant and taxonomically differentiated is phytoplankton taxa here. Acritarchs (~5-10 %) are represented by *Multiplicisphaeridium ramusculosum*, M. cf. *M. raspa*, *Polyedryxium pharaonis* and *Stellinium micropolygonale*. Less frequently *Exochoderma arca*, and *Gorgonisphaeridium discissum* have been noticed in the samples, as well. Additionally, some prasinophyta taxa belonging to *Cymatiosphaera* and *Pterospermella* were present in restricted amount. The presence of finely ornamented acritarchs may indicates the offshore deposition with low-energy, deeper-water marine environment (Fig. 2). Frequent presence of differentiated acritarcha and prasinophyta (~5 %) taxa, together with chitinozoans and scolecodonts confirms this hypothesis (e.g. Tyson, 1993; Batten, 1996). AOM presence in the upper part of this section indicates the deposition in anoxic conditions. However, still strong concentration of large-sized miospores can indicate that the sedimentation took place not so far from the shoreline.

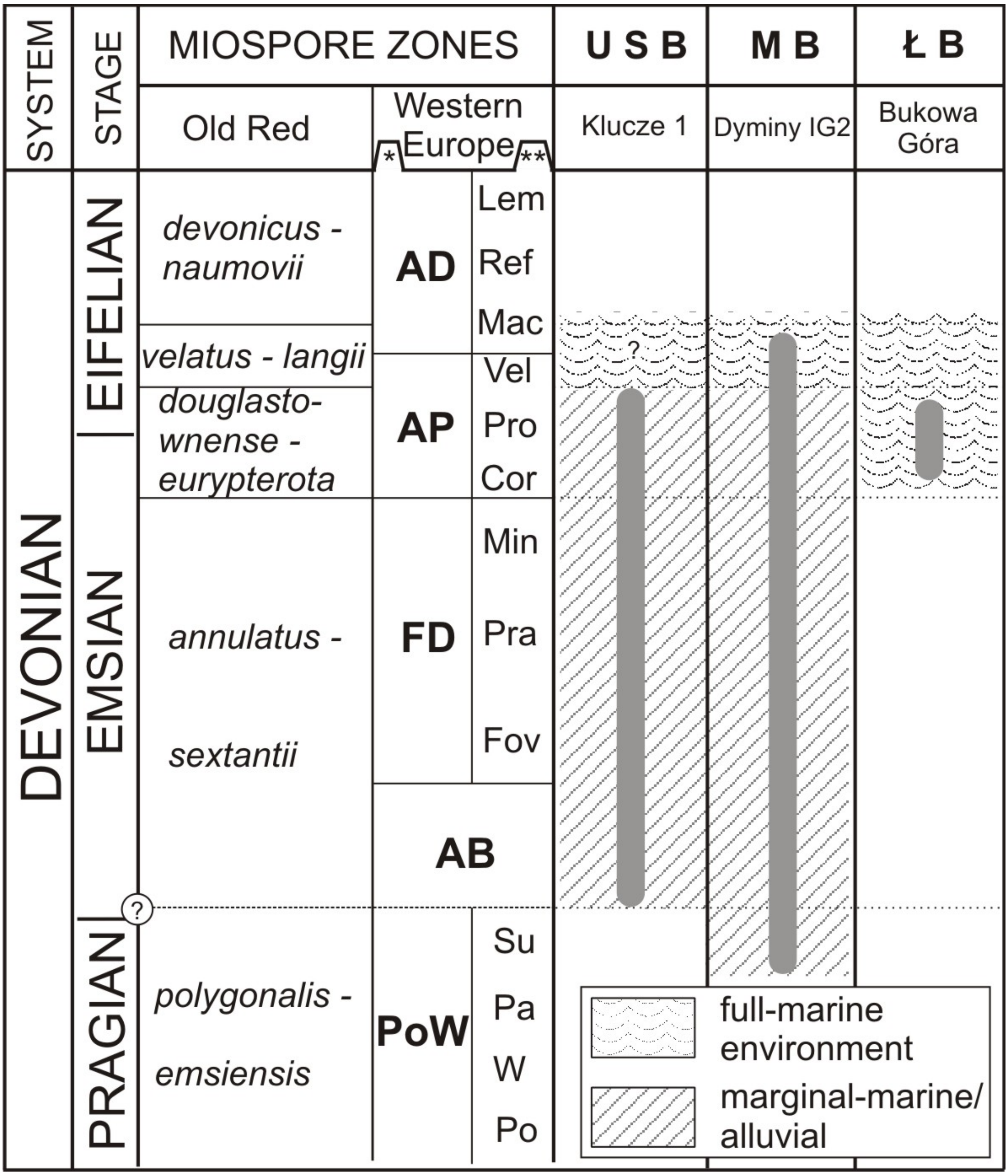

Figure 2. Palynostratigraphy and palynofacies of the investigated boreholes. *Oppel Zones; **Interval Zones (*sensu* Streel et al., 1987).

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PALYNOSTRATIGRAPHY AND PALAEOGEOGRAPHY OF ORDOVICIAN STRATA (ABASTU AND ABARSAJ FORMATIONS) FROM THE SOUTHEASTERN CASPIAN SEA, NORTHERN IRAN

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SUMMARY

A well-preserved, abundant, and diverse assemblage of acritarchs, chitinozoans, scolecodonts, and graptolite remains was recovered from the Early Ordovician (Tremadocian) Abastu and Late Ordovician (Katian-Hirnantian) Abarsaj formations in the Alborz Mountains in Northern Iran. In the study area, 10 samples from the 108 m thick Abastu Formation yielded acritarchs indicative of an Early Ordovician (Tremadocian) age. No chitinozoans were recovered from this formation. Forty samples from the 194 m thick Abarsaj Formation yielded acritarchs and chitinozoans characteristic of a Late Ordovician (Katian-Hirnantian) age. Acritarchs from the Abastu Formation show a PeriGondwana relationship, whereas those from the Anarsaj Formation indicate a more cosmopolitan distribution. Chitinozoans from the Abarsaj Formation allow assignment to the Northern Gondwana Domain, thus demonstrating that the Alborz Mountains were clearly part of the Northern Gondwana Domain during the Ordovician. Based on the recovered palynomorph assemblage, the Abastu and Abarsaj formations were deposited in a shallow marine environment.

Keywords: Acritarchs, chitinozoans, Early and Late Ordovician, biostratigraphy, palaeogeography, Northern Iran

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Lower Palaeozoic strata are well-exposed near Kholin-Darreh village, located 19 km south of the town of Fazelabad, and approximately 46 km southeast of the city of Gorgan. The road from Gorgan to Fazelabad-Aliabad is the principle link to the study area (Figure 1). The Palaeozoic strata are well-exposed along the Alestan River, where a secondary dirt road connects Fazelabad to Kholin-Darreh.

In this area, the Palaeozoic sequence has been divided, in ascending stratigraphic order, into the Lalun (Lower Cambrian), Abastu, Abarsaj, Negarman (Silurian), Khoshyeilagh (Upper Devonian), Mobarak (Lower Carboniferous), Qezelqaleh, Dorud (Lower Permian), Ruteh (Middle Permian) and Nessen formations (Upper Permian). Due to lack of both a diagnostic macro- and microfauna, the ages of the Lower Palaeozoic Lalun, Abastu, and Abarsaj formations have not been previously determined. However, based on palynologic evidence, two major hiatuses are indicated within the study area. The first is between the Lalun Formation (Lower Cambrian) and the Abastu Formation (Tremadocian). The second is between the Abastu Formation (Tremadocian) and the Abarsaj Formation (Katian-Hirnantian). This unconformity corresponds to the uplift related to the initial stage of rifting of the paleo Tethys Ocean.

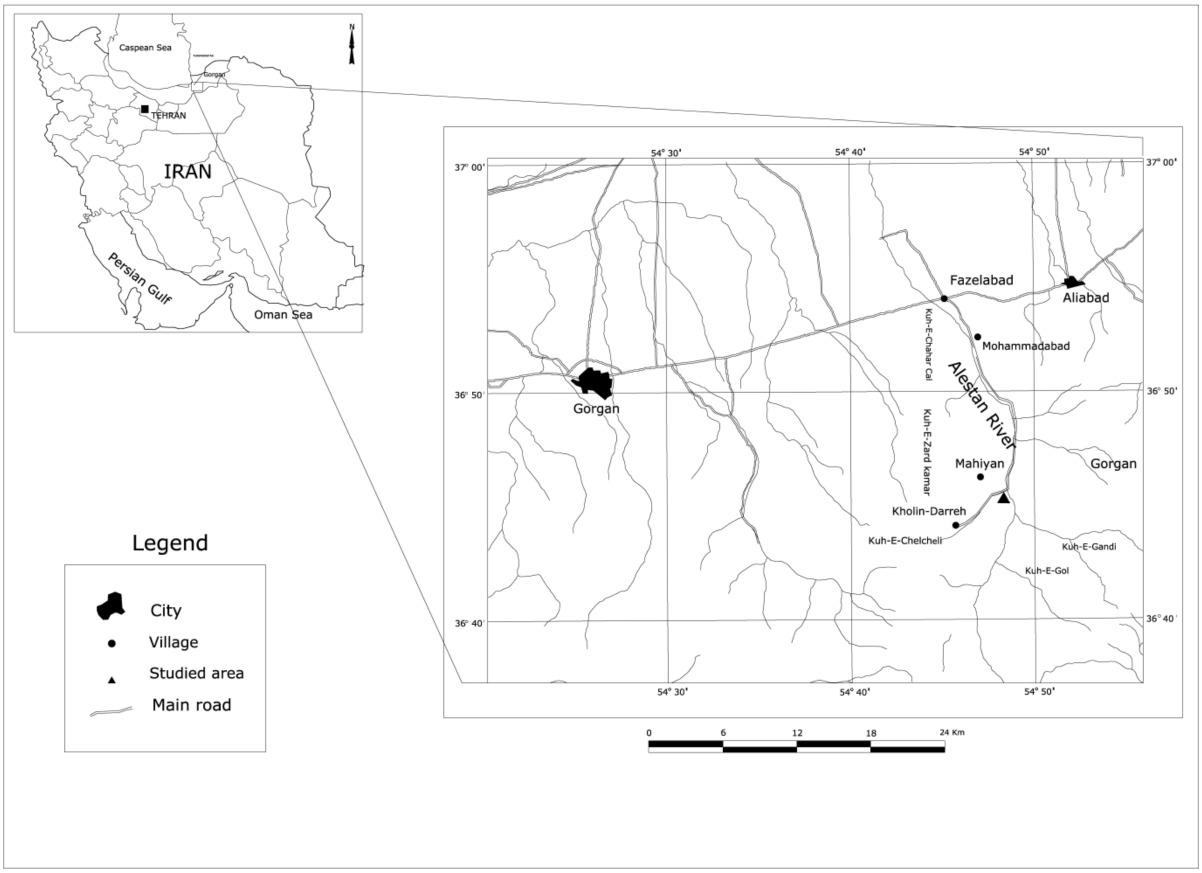

Figure 1. Location of the studied area.

A stratigraphic section encompassing the Lalun, Abastu and Abarsaj formations was measured and sampled for palynomorphs to determine the age of the formations, the palaeogeographic position of the Alborz Mountains in the study area, and the affiliation of the palynologic assemblage to the Gondwana and/or the Laurentian palaeoprovince.

Sixty-four samples were collected from the Lalun, Abastu, and Abarsai formations. Samples from the Lalun Formation proved to be palynologically barren, but samples from the Abastu and Abarsai formations contained a well-preserved assemblage of acritarchs, chitinozoans, scolecodonts, and graptolite remains (Figure 2).

Based on the presence of the acritarch species *Acanthodiacrodiun ubuii, Athabascaela penika*, *Cymatiogalea boulouardii, C. cylindrata, Dactylofusa squama, Michrystridium shintonensis, Saharidia fragilis, Vulcanisphaera africana* and *V. britannica* (acritarch assemblage Zone I), an age of Early Ordovician (Tremadocian) is suggested for the Abastu Formation (Figure 2). No chitinozoans were recovered from the Abastu Formation. Characteristic Late Ordovician acritarch and chitinozoan (*Ancyrochitina merga*, *Armoricochitina nigerica*, *Spinachitina oulebsiri,* and *Tanuchitina elongate*) species indicate a Katian-Hirnantian age for the Abarsaj Formation (Figure 2).

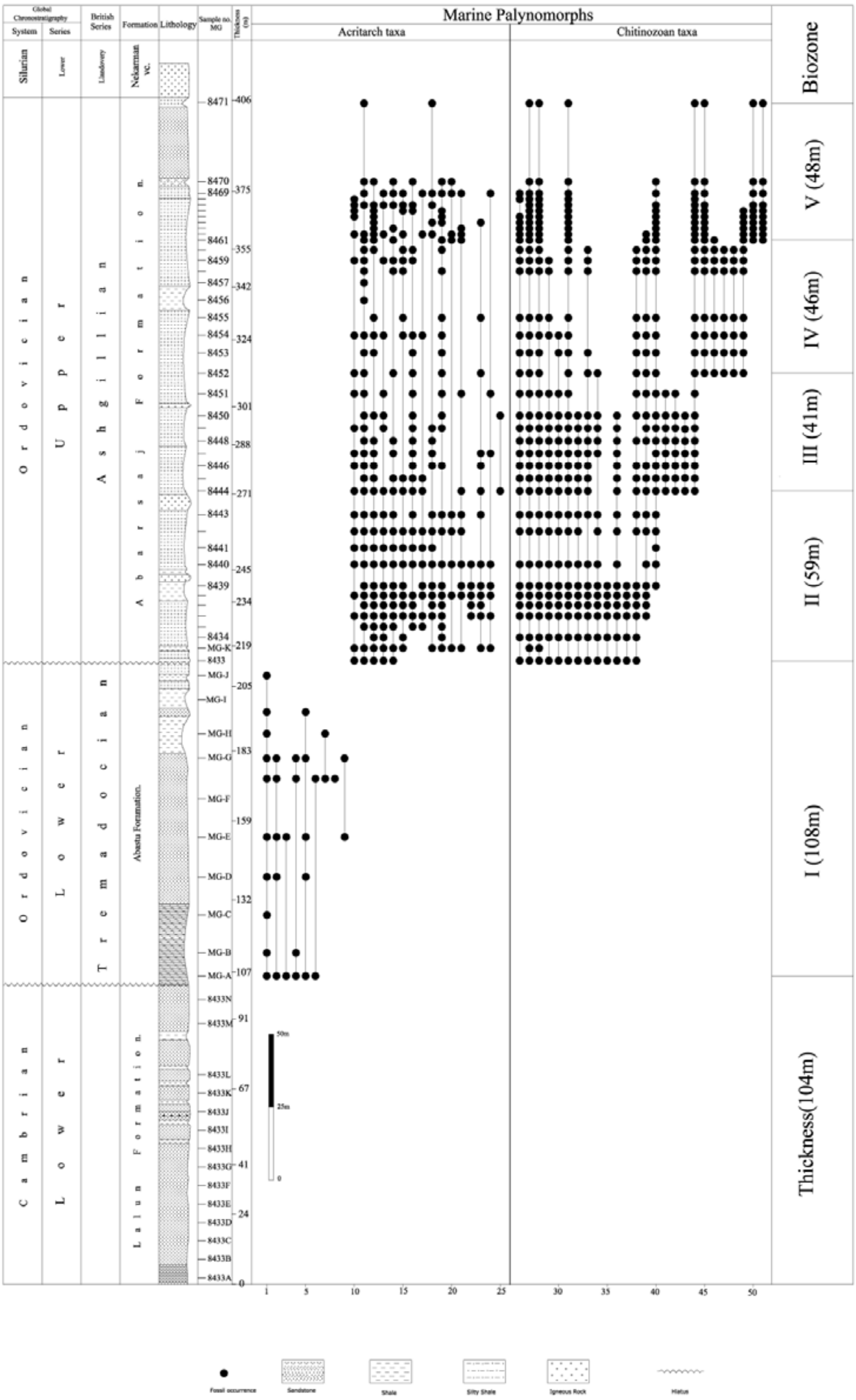

Figure 2. Stratigraphic distribution of selected acritarch and chitinozoan taxa from Ordovician strata near Kholin-Darreh village in the Fazelabad area, southeast of the Caspian Sea, northern Iran. Numbers refer to the corresponding columns in the figure. 1= *Saharidia fragilis ;2=Michrystridium shinetonensis; 3=Vulcanisphaera britannica; 4=Leiofusa squama; 5=Acanthodiacrodiun ubuii; 6=Cymatiogalea boulouardi; 7=Cymatiogalea cylindrata; 8=Athabascaella penika; 9=Vulcanisphaera africana; 10=Veryhachium lairdii; 11= Multiplicisphaeridium irregulare; 12= Veryhachium subglobosum; 13= Multiplicisphaeridium bifurcatum*; 14= *Villosacapsula setosapellicula*; 15= *Orthosphaeridium insculptum*; 16= *Veryhachium reductum; 17= Actinotodissus crassus;* 18= O*rdovicidium elegantulum; 19=* Ordovicidium *elegantulum; 20= Baltisphaeridium perclarum;* 21= *Navifusa ancepsipuncta; 22= Dactylofusa striata; 23=Baltisphaeridium oligopsakium;* 24= *Orthosphaeridium ternatum; 25=Striathoteca principalis;26= Armoricochitina nigerica; 27=Lagenochitina*

baltica; 28= *Desmochitina minor*; 29=*Armoricochitina iranica*; 30=*Armoricochitina alborzensis*; 31= *Calpichitina lenticularis; 32= Desmochitina juglandiformis*; 33= *Desmochitina nodosa; 34= Desmochitina erinacea; 35= Conochitina chydea*; 36= *Spinachitina bulmani*; 37= *Desmochitina cocca; 38=Rhabdochitina gracilis*; 39= *Cyathochitina campanulaeformis; 40= Lagenochitina prussica; 41= Ancyrochitina merga*; 42= *Plectochitina concinna*; 43=*Plectochitina sylvanica;44= Euconochitina lepta*; 45= *Tanuchitina elongata*; 46= *Tanuchitina* sp. ; 47= *Tanuchitina ontariensis; 48= Hercochitina crickmayi; 49=Hyalochitina* sp.*; 50= Spinachitina oulebsiri*; 51= *Spinachitina* aff. *oulebsiri*.

The acritarch taxa from the Abastu Formation show a PeriGondwana relationship, whereas those recovered from the Anarsaj Formation have broad similarities to those from Libya, Morocco, Algeria, Saudi Arabia, Portugal, England, the United State, and Canada, indicating a cosmopolitan nature for the acritarchs during the Late Ordovician. Chitinozoans recovered from the Abarsaj Formation allow assignment to the *Armoricochitina nigerica*, *Ancyrochitina merga*, *Tanuchitina elongata* and *Spinachitina oulebsiri* Biozones, which have been established for the Northern Gondwana Domain. These chitinozoan biozones clearly indicate that the Alborz Mountains were part of the Northern Gondwana Domain during the Ordovician. The presence of various chitinozoan and acritarch taxa from Baltica and Laurentia in Gondwanan chitinozoan biozones of the Fazelabad area suggest the existence of counter clockwise marine currents which resulted in bringing planktonic organisms (acritarchs and chitinozoans) from the lower latitudes (Baltica) to the higher latitudes (Northern Gondwana). A shallow marine environment is indicated during deposition of the Abastu and Anarsaj formations based on the recovered acritarchs, chitinozoans, scolecodonts and graptolite remains.

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EVIDENCES OF ONTOGENY IN THE ORGANIC-WALLED MICROPHYTOPLANKTON GENUS *MARANHITES*

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SUMMARY

The exceptional state of preservation of the Upper Devonian palynoflora recovered in the Iberian Pyrite Belt, southwest Spain, has permitted new observations on the morphology of the organic-walled microphytoplankton genus *Maranhites* and on the potential functionality of some of its structural elements. These observations have permitted the reassessment of the systematic status of the species previously ascribed to the genus. Some of these species probably correspond to different ontogenetic stages of a single species, *M. mosesii*. The growth trend evidenced in *M. mosesii*, also detected in other species of the genus, is principally manifested by the appearance, development, and final release of thin, translucent bladders, following equatorial rupture of the outer wall layer (perieilyma). The release of bladders can be interpreted as an excystment mechanism for this taxon.

Keywords: *Maranhites*; organic-walled microphytoplankton; ontogeny; Upper Devonian; Iberian Pyrite Belt

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The genus *Maranhites* was described by Brito (1965) from the Middle Devonian of the Parnaíba Basin, northern Brazil, to include discoidal, thick-walled acritarchs bearing equatorial shields associated with a conspicuous, distinctive marginal structure. Morphologically, *Maranhites* Brito 1965 clearly differs from other genera of organic-walled microphytoplankton, but at subgeneric level, the boundary between some of its most widely reported species remains controversial. This debate centers on differing taxonomic viewpoints as to the morphological variability applicable to individual species. Some authors have suggested that such variations must be interpreted as infra-specific within a broadly defined species (Daemon et al. 1967), or as inter-specific within a "complex" (Wood 1984), other, by contrast, clearly support taxonomic oversplitting of the genus supposedly to enhance its biostratigraphic potentialities (Burjack and Oliveira 1989).

The remarkably well preserved palynoflora recovered in Tharsis, Iberian Pyrite Belt, has provided further observations on the morphological variability of the genus *Maranhites* (González 2009). Many of the form-species hitherto attributed to this genus are thought to represent different ontogenetic stages of a single species, i.e., *M. mosesii*. The detected growth trend can be tentatively subdivided into six stages (Plate 1), which correspond to a succession of several species previously assigned to *Maranhites*. Initial stages are characterized by a continuous arched or gently undulated equatorial thickening (Plate 1-1) that becomes segmented to form incipient embracing cells connected by small lateral thickenings (Plate 1-2). In subsequent intermediate stages the well-developed embracing cells, (Plate. 1-3), are opened equatorially to develop the translucent bladders (Plate 1-4). Enlargement of embracing cells and bladders generally produces the progressive scalloping of the vesicle periphery and the equatorial unthickened endeilyma (Plate. 1-5). In mature stages, the bladders, or bladder content, are released from the vesicle after equatorial rupture of perieilyma (Plate 1-6). Considering that this is the final step of an ontogenetic process, and that it is apparently the only mechanism of interchange with the external environment, it is possible to interpret the release of bladders as a potential excystment method for *Maranhites*.

ACKNOWLEDGMENTS

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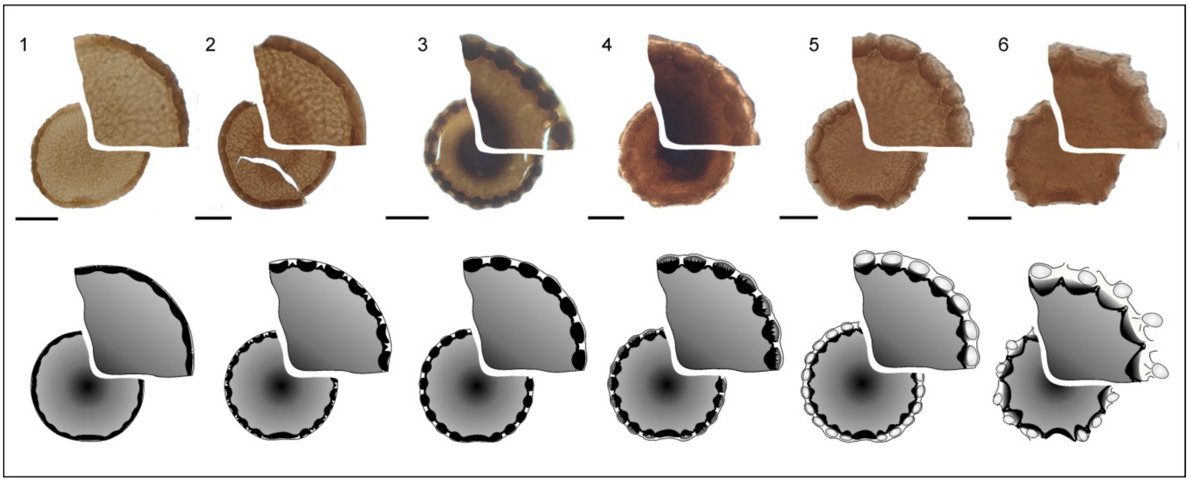

Plate 1. Photomicrographs and schematic diagrams of the six inferred growth stages of *Maranhites mosesii* (Sommer) Brito, 1967 emend. González 2009. Scale bar = 20 µm.
1. Photomicrograph and schematic diagram of the earliest stage showing a gently undulating, incipiently segmented equatorial thickening.
2. Photomicrograph and schematic diagram of an early stage showing incipient embracing cells connected by lateral thickenings.
3. Photomicrograph and schematic diagram of a middle stage showing well-developed embracing cells.
4. Photomicrograph and schematic diagram of a middle stage showing incipient development of translucent bladders from the embracing cells.
5. Photomicrograph and schematic diagram of a late stage showing embracing cells (clearly dehiscent equatorially) and well-developed translucent bladders.
6. Photomicrograph and schematic diagram of the latest stage showing equatorial rupture of perieilyma as a consequence of the opening or release of translucent bladders.

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PALYNOMORPH DARKNESS INDEX - A NEW QUANTITATIVE METHOD FOR ASSESSING THERMAL MATURITY

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SUMMARY

A new method of quantitatively assessing the darkening of palynomorphs resulting from thermal maturation is presented. Using readily-available digital cameras and transmitted light microscopes, the technique integrates measured red, green and blue (RGB) colour intensities to produce a single greyscale value from which the newly defined 'Palynomorph Darkness Index' (PDI) is calculated. The calibration of different microscope / camera combinations using photographic filters is discussed and an example of the application of the technique is presented.

The PDI method is a rapid and inexpensive, cross-platform technique that overcomes the subjectivity of human colour perception. It can be used on a range of palynomorph groups and has considerable potential for the investigation of rocks that lie within the 'oil window' or within the main zone of gas generation in terms of thermal maturity. The PDI method will enable researchers to establish the thermal maturity of rocks that contain insufficient woody debris for the determination of vitrinite reflectance, for example, pre-Devonian and distal marine strata.

Keywords: Thermal maturation, colour, palynomorph, transmitted light, RGB

INVESTIGATION OF POSSIBLE UPPER BOLSOVIAN, ASTURIAN AND LOWER CANTABRIAN (PENNSYLVANIAN) AGE MARINE INTERCALATIONS IN OFFSHORE WESTERN IRISH SEDIMENTARY BASINS

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Previous biostratigraphic studies of Carboniferous hydrocarbon well sections from the Porcupine Basin, offshore Western Ireland, identify potential marine intercalations in Upper Bolsovian, Asturian and Lower Cantabrian age strata, based on the occurrence of marine ostracods. Lithology data suggests the possible marine horizons alternate with non-marine strata characterised by freshwater ostracods, thin coals, carbonaceous sediments, siderite mineralization, red/green mottled caliches and red siltstones. The proposed marine intercalations in Asturian and Lower Cantabrian age strata are unlike anything known from onshore Ireland and Great Britain; the nearest comparable Late Carboniferous marine rocks are located in the Norwegian Oslo Graben and the Spanish Cantabrian Mountains.

To confirm the presence of the offshore Western Irish marine intercalations, thirty new palynological samples from three marine ostracod bearing Porcupine Basin well sections and one Donegal Basin well section were analysed. All samples were derived from well-bore cuttings samples, often collected over a significant depth interval.

The palynological analysis of samples from the Porcupine Basin wells identifies possible evidence for Upper Bolsovian to Lower Cantabrian marine influences, including the pyritisation of spores, rare acritarchs and possible scolecodonts. Rare occurrences of pyritised spores and acritarchs are also encountered in Asturian age strata from the Donegal Basin. However, none of the palynological samples are exclusively marine in character, with the freshwater-brackish algae *Botryococcus* occurring in all samples. The mixed marine and non-marine characteristics may reflect the incorporation of thinly interbedded marine and non-marine strata into the cuttings samples, caving within the well-bore, or the occurrence of transitional marine to non-marine depositional environments.

Palynofacies analysis of palynological samples and the plotting of relative proportions of phytoclasts, amorphous organic matter (AOM) and palynomorphs on ternary diagrams suggest that if marine, the depositional environments varied from proximal oxic shelf to distal dysoxic-anoxic shelf. However, it is also possible that the samples represent transitional marine to non-marine depositional environments, such as lagoonal. Isotopic analyses ($\delta^{13}C$ and $\delta^{18}O$) of infrequent, thin limestones encountered in the Porcupine Basin wells also indicate a non-marine origin.

PALYNOLOGY OF LATE DEVONIAN TIDAL AND ESTUARINE DEPOSITS IN THE CORK HARBOUR AREA OF THE SOUTH MUNSTER BASIN, IRELAND

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SUMMARY

An integrated study of palynology, ichnology and sedimentology has been carried out on the Late Devonian non-marine to marine transition in the Cork Harbour area. New palynological and ichnological data are described from the upper part of the Gyleen Formation at the Graball Bay and White Bay sections and from lower part of the Old Head Sandstone Formation at the Ringabella Bay sections. The upper part of Gyleen formation has previously been interpreted as a non –marine fluvial sequence (Old Red Sandstone facies) whilst the lower part of the Old Head Sandstone is considered to be a shallow marine tidally influenced sequence. Well preserved miospore assemblages assignable to the *Retispora lepidophyta* – *Knoxisporites literatus* LL Miospore Biozone have been obtained from both these stratigraphical intervals indicating they are coeval in age.

New discoveries of U-shaped burrows of the tidal - shallow marine *Diplocraterion* and the record of scolecodonts in the associated palynological assemblages indicate a previously unsuspected marine influence within the upper part of the Gyleen Formation (Upper Old Red Sandstone). Palynological results from the tidal deposits in the lower part of the Old Head Sandstone Formation at Ringabella Bay contain both scolecodonts, sparse acritarchs and marine trace fossils. Integration of the new palaeontological and sedimentological data allows a revised palaleoenvironmental model to be presented that shows a major estuary with tidal flats in the vicinity of the present Cork Harbour area in Late Devonian times.

NEW DATA ON THE LATE EDIACARAN AND TERRENEUVIAN ORGANIC MICROFOSSILS FROM THE KRAKÓW AREA OF SOUTHERN POLAND

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SUMMARY

Detailed palynologic analysis from two boreholes (Cianowice 2 and Trojanowice 2) located on opposite sites of the Cracow-Lubliniec fault zone (southern Poland) allows for the dating of clastic sediments that are part of the Upper Silesian and Małopolska tectonic blocks. Two characteristic microfossils assemblages are documented. The first indicates a Late Ediacaran age for the Małopolska Block basement rocks, and the second, placement in the Terreneuvian stage of the Cambrian for the Upper Silesian Block.

Keywords: acritarchs, Ediacaran, Terreneuvian, Poland

INTRODUCTION

According to Buła et al. (1997), Buła (2000), and Buła & Zaba (2005), the Cracow region lies within the Upper Silesian and Małopolska tectonic blocks. These two large regional tectonic units are separated on the basis of distinct differences in the structure of their Precambrian basement and overlying Palaeozoic rock cover, which show different palaeogeographic facies and palaeotectonic development. These tectonic units are separated by the narrow Cracow-Lubliniec fault zone, which is approximately 500 m wide, and has displaced all of the Precambrian and Palaeozoic rocks in the region (Buła, 2000).

The Upper Silesian Block, together with the Brno Block, are located in the Czech Republic and form a large unit called the Brunovistulicum (Dudek, 1980; Buła et al., 1997; Buła & Żaba, 2005). Its Precambrian basement is heterogeneous, and composed of Precambrian (Archean and Proterozoic) crystalline and anchimetamorphic rocks, with consolidation occurring in the Late Cadomian (Buła & Żaba, 2005). Studies by Buła & Jachowicz, (1996), Buła, (2000), and Jachowicz & Přichystal (1997), show that the Lower Palaeozoic cover is incomplete in this area. Lower Cambrian clastic rocks documented in the southern and eastern marginal parts of the Upper Silesian Block are thus far the best recognized. Middle Cambrian and Ordovician units are only recognized in some boreholes in the northern part of the block (Buła & Jachowicz, 1996; Jachowicz, 2005). The oldest Cambrian clastic rocks (Subholmia Zone) form a three-unit regressive sequence of the Borzęta Formation, and are documented in the easternmost area of the Upper Silesian Block.

The crystalline basement of the Małopolska Block is unknown. The weakly metamorphosed clastic rocks, which are the oldest known in this block, have a thickness, variously estimated, to range from a minimum of 2000 m, up to 20 km. The anchimetamorphic rocks, of flysch character, lie beneath a variety of lithologies, ranging in age from Ordovician to Miocene.

The stratigraphy of the oldest clastic sediments from the Upper Silesian and Małopolska blocks is based primarily on organic microfossils assemblages (Buła & Jachowicz, 1996; Moryc & Jachowicz, 2000; Jachowicz, 2005). The trilobite fauna (Holmia Zone) has only been documented from the upper part of the Lower Cambrian profile in the Upper Silesian Block (Orłowski, 1975). A zircon U-Pb age from the tuff layer provides a date of 549 ± 3Ma, thus indicating an Ediacaran age for the Małopolska Block anchimetamorphic rocks.

Two boreholes, situated on the opposite sides of the Cracow–Lubliniec fault zone, and approximately six kilometers apart, were recently drilled in the Cracow area. The Cianowice 2 borehole, located at the western boundary of the Małopolska Block, penetrates Miocene rocks, Jurassic carbonates and clastics, and at 265.3 m, encounters more than 300 m of clastic sediments of a flysch nature, and strongly tectonized. The clastic sediments of a platform nature are documented in the Trojanowice 2 borehole (557-602 m), at the eastern margin of the Upper Silesian Block.

Neither of the boreholes yielded any macrofossils. In both boreholes, however, palynomorphs have been recovered. The abundant and relatively well preserved organic microfossils present represent can be placed in the following subgroups: Nematomorphitae (Diver & Peat, 1979), Sphaeromorphitae (Downie, Evitt, & Sarjeant, 1963), Netromorphitae (Downie, Evitt, & Sarjeant, 1963), Disphaeromorphitae (Downie, Evitt, & Sarjeant, 1963), Pteromorphitae (Downie, Evitt, & Sarjeant, 1963), Acanthomorphitae (Downie, Evitt, & Sarjeant, 1963) and Synaplomorphitae (Diver & Peat, 1979). In general, palynomorphs from the simple Sphaeromorphitae and Nematomorphitae groups predominate and comprise approximately 80% of the assemblages.

Late Ediacaran assemblages were documented in the Cianowice 2 borehole with small sphaeromorphs (10-30 µm) and simple cyanobacteria dominating. Less common taxa include: *Granomarginata prima*, *Pterospermopsimorpha solida*, *Asteridium*, *Comasphaeridium*, and *Leiovalia*.

In the Trojanowice 2 borehole, dark-grey claystones and laminated siltstones yield early Early Cambrian age microfossils. Genera include: *Ceratophyton*, *Chuaria*, *Granomarginata*, *Leiosphaeridia*, *Leiovalia*, and *Tasmanites*, as well as very abundant cyanobacteria. In the Upper Silesian Block, similar organic microfossil assemblages are known from the lower part of the Borzęta Formation (Buła & Jachowicz, 1996). According to Landing et al. (2007), the oldest Cambrian sediments are of pre-trilobite age and are placed in the Terreneuvian series of the newest Cambrian chronostratigraphic scheme.

Detailed palynologic analysis allows comparison of poorly differentiated microfloral assemblages from Late Ediacaran and Terreneuvian intervals. The material studied provides new data about the organic microfossil distribution near the Precambrian/Cambrian boundary.

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PALYNOLOGY OF THE UPPER SILURIAN TO MIDDLE DEVONIAN IN THE REGGANE BASIN, SOUTHERN ALGERIA

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SUMMARY

A palynological study was carried out in the upper Silurian to Middle Devonian of three wells in the Reggane Basin, southern Algeria. Wells 1 & 2 are located at the margin of the Hoggar block; well 3 was drilled about 70 km to the west, within the basin. Palynomorphs were recorded from all samples, comprising mainly miospores, with less common acritarchs and other palynomorphs. Based on the miospores, a detailed palynostratigraphic correlation was established, showing almost continuous deposition from the Upper Silurian to the Middle Devonian. Minor stratigraphical gaps are observed in the Lower and Middle Devonian of wells 1 & 2. Palynofacies and lithological analysis show a proximal position for wells 1 & 2 and a more distal position for well 3. At the Silurian/Devonian boundary, the palynofacies shows a rapid change from marine to terrestrial in wells 1 and 2, whereas well 3 shows a gradual shift from the uppermost Pridolian to lower Lochkovian. Palynofacies also shows four transgressive intervals in the Lower to Middle Devonian, less clearly observed in the distal well 3. Palynofacies analysis was also used for a sequence stratigraphic interpretation, showing four sequences correlating to 3rd order cycles of previous models.

Keywords: palynostratigraphy, palynofacies analysis, sequence stratigraphy, Silurian, Devonian, Algeria

INTRODUCTION

The study area is located in the eastern part of the Saharan platform, on the northern part of the African Precambrian platform, where sedimentary basins have subsided continuously since the Cambrian. The Reggane basin is a large intra-cratonic Paleozoic basin bounded by the Hoggar Shield in the east and the Ougarta Arch to the north, placed between the Tindouf and the Ahnet basins (Fig.1). The Palaeozoic basin fill was deposited on the northern Gondwana passive margin (Cambrian to Devonian) and in foreland and intra-orogenic basins related to the Gondwana-Laurussia continent collision (Carboniferous to early Permian). The upper Silurian consists of dark organic-rich shales that form part of a major source rock interval in North African Palaeozoic basins. The Silurian/Devonian boundary is marked by a rapid change from shaly marine to sand-rich near-shore deposits. The Lower to Middle Devonian is dominated by sand- to siltstones of tidal to subtidal/foreshore settings with mudstone dominated intervals in the Pragian, Emsian and Givetian and calcareous intervals in the lower Emsian and upper Givetian. Lithological changes provide evidence for several transgressive/regressive events in this interval.

PALYNOSTRATIGRAPHY

Palynomorphs (mainly miospores) are present in all samples. Acritarchs are less common, followed by Prasinophytes. Chitinozoa are very rare to absent. From wells 1 and 2 to well 3 the proportion of miospores falls by half, whereas acritarchs increase by about 30%. Prasinophytes and chitinozoa show no remarkable change. Due to taphonomic processes, preservation of terrestrial palynomorphs is often worse than that of marine forms, especially in well 3. High resolution palynological studies in well 1 and 3 enable the identification of all nine spore biozones of the Lower to Middle Devonian standard spore zonal scheme (Streel et al. 1987). Combined with local and regional schemes from northern Gondwana (Breuer et al. 2007, Kermandji 2007, Loboziak et al. 1992, Loboziak & Streel 1989, 1995, Moreau-Benoit 1988, Pereira et al. 1999 and Rubinstein & Steemans 2002) a detailed palynostratigraphic framework has been established for the Upper Silurian to Middle Devonian in the sections studied (Fig. 1). Low resolution sampling in well 2 leads to much less accurate correlation.

In the Givetian all three spore biozones (TCo, TA, upper AD) are recorded. Miospore assemblages are generally highly diverse and moderately to well preserved, including typical Mid-Devonian taxa. The base is marked by the first appearence of *Geminospora piliformis* and *Hystricosporites mitratus*. Index taxa present are *Chelinospora concinna*, *Samarisporites triangulatus*. The Eifelian (lower AD - upper AP spore zone) is palynological identified in well 3 only, showing highly diverse, moderately preserved spore assemblages. In addition to typical taxa from the Lower Devonian, taxa specific for the Eifelian are present, including *Grandispora velata* (upper AP) and *Densosporites devonicus* (AD).

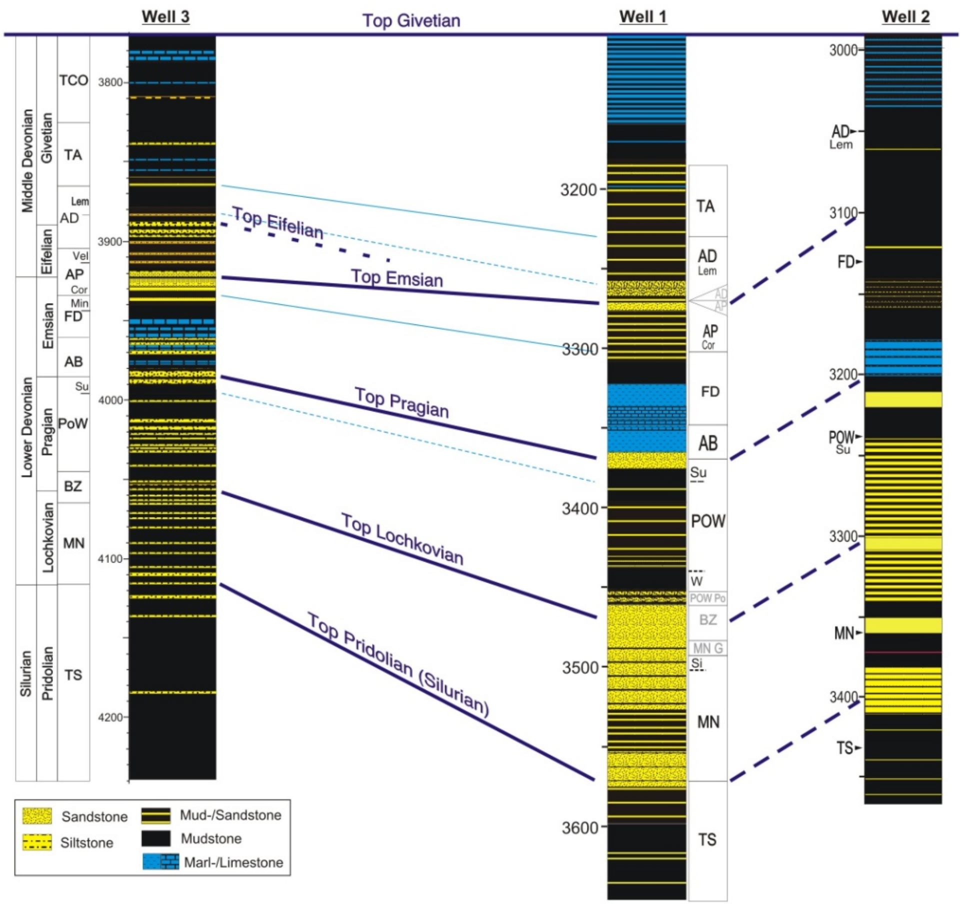


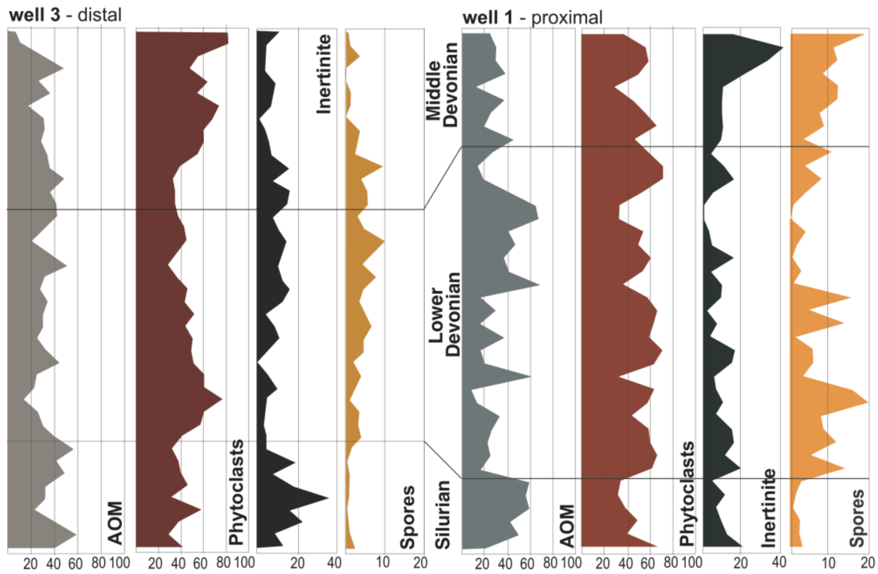
Figure 1. Palynostratigraphic correlation of three wells studied in the Reggane basin.

The Emsian (lower AP, FD, AB spore zone) is palynologically recorded in all three wells, with typical Lower Devonian spore assemblages of high diversity. The majority of spores are taxa appearing in the upper Siegenian and in the basal Emsian. The first occurence of *Camptozonotriletes caperatus* marks the base. In the upper part, the occurence of *Camarozonotriletes sextantii* confirms the upper Emsian age of the top of the interval. At the top, *Dibolisporites eifeliensis* disappears. In the Pragian (PoW, upper BZ spore zone) well preserved and highly diverse spore assemblages are recorded in the upper part, dominated by typical Pragian taxa. The rest of the Pragian contains less preserved spore assemblages, mainly comprising Lochkovian to Pragian taxa. The base is marked by the first occurence of *Dictyotriletes emsiensis* and the top by the occurence of *Dictyotriletes subgranifer*. The Lochkovian (MN, lower BZ spore zone) shows moderately to poor preserved spore assemblages dominated by typical Lochkovian taxa from *Cymbosporites paulus* and *Chelinospora cassicula* at the base to *Brochotriletes foveolatus* in the upper part. In the Pridolian (uppermost Silurian, TS spore zone) the preservation and diversity of the spore assemblages declines significantly. Based on the first occurence of *Scylospora cymba* and *Archaeozonotriletes chulus* and the absence of any Devonian taxa*,* this interval is assigned to the upper Silurian TS zone.

PALYNOFACIES ANALYSIS

In all three wells, palynofacies is dominated by phytoclasts and AOM. Palynomorphs are less common, mostly dominated by terrestrial palynomorphs (miospores). Palynofacies analysis shows a clear change at the Silurian/Devoninan boundary in both proximal and distal settings. In proximal wells 1 and 2 a rapid shift from marine AOM-dominated Pridolian samples to phytoclast-dominated samples in the lower Lochkovian is observed, whereas distal well 3 shows a gradual shift reaching its maximum in the upper Lochkovian (fig. 2, fig. 3). The major change of palynofacies at the Silurian/Devonian boundary is related to a significant fall of sea-level. This is followed by a generally increasing marine trend from the Lochkovian to Emsian and an increasing terrestrial trend from the Eifelian to Givetian. Within this general trend, four marine maxima are observed in TMI, giving evidence for four transgressive intervals, best seen in TMI_{PAL}. The terrestrial:marine Index (TMI) is the most indicative palynofacies proxy, either as TMI_{OM} (all marine organic matter vs. all terrestrial organic matter) or even better as TMI_{PAL} (all marine palynomorphs vs. all terrestrial palynomorphs). Peaks of TMI_{PAL} partially differ from TMI_{OM}. Two transgressive intervals correspond to lithological changes. In distal well 3, TMI is generally more marine and transgressive events are less clearly observed. Palaeoenvironmental analysis (after Tyson 1993) shows no significant change at the Silurian/Devonian boundary. Samples from distal well 3 mainly plot as dysoxic to anoxic shelf to basin environments, whereas samples from proximal wells 1 and 2 partially plot as slightly more oxygenated shelf environments. Proximal shelf conditions are recorded from the upper Pragian of wells 1 and 2 and the middle to upper Givetian of wells 2 and 3. Typical basin environments are recorded in well 1, corresponding to the marine maxima in TMI in the Silurian, Pragian and Emsian.

Internal variation of palynofacies trends suggests potential for additional well correlation. Three proxies were tested: The Terrestrial:Marine Index (TMI), the Opaque:Translucent Phytoclast Ratio (OT) and the Degradation Index of Phytoclasts (DI). All proxies define proximal – distal trends. TMI shows strong internal variation and high coincidence between proximal and distal wells (Fig.3). TMI shows a very high potential for well correlation, especially TMI_{PAL}. OT and DI show little internal variation and little coincidence between the wells and with TMI. No significant change is observed at the Silurian/Devonian boundary and the transgressive intervals are very poorly preserved.



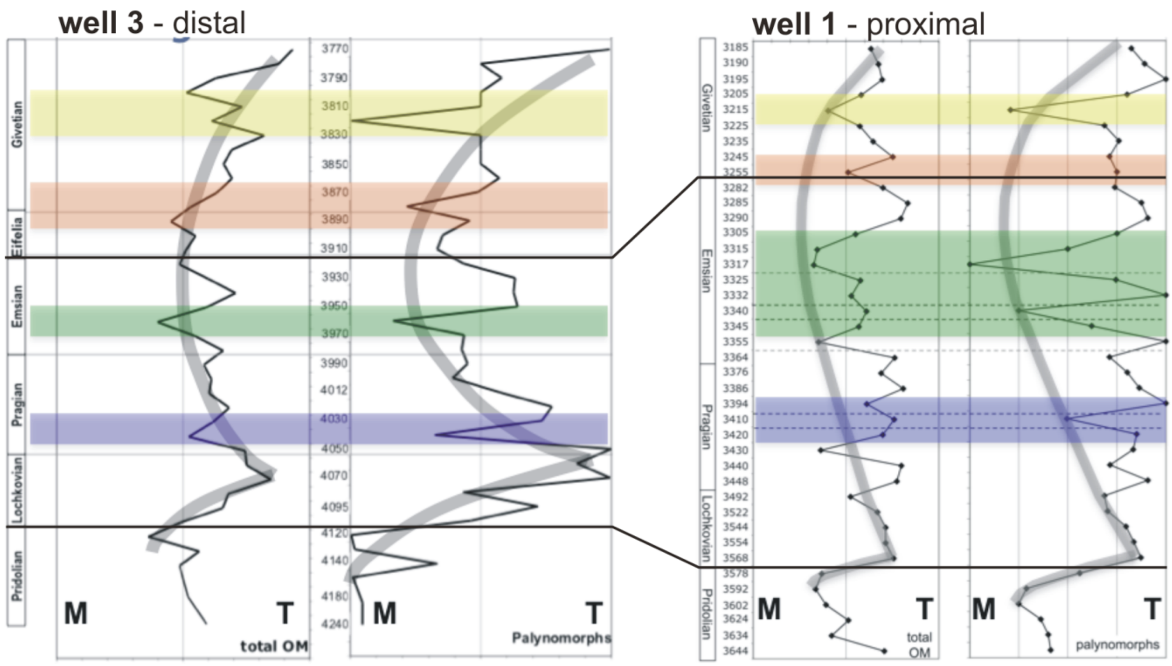


Figure 2. Palynofacies trends of main groups in high resolution studied wells 1 and 3.
Figure 3. Terrestrial:Marine Index of total organic matter and palynomorphs for studied wells.

SEQUENCESTRATIGRAPHIC INTERPRETATION

Results of palynofacies analysis were used for a sequence-stratigraphic analysis of the Lower Devonian. Previous sequence-stratigraphic interpretation are mainly based on gamma ray logs supplemented by lithology and other well logs, recognizing 3rd and partially 5th order cycles. Four sequences are proposed: one for most of the Lochkovian, two from the upper Lochkovian to top Pragian and one in the basal Emsian. In the Lochkovian to Emsian 3rd order sequences from well logs show good correlation to sequence analysis based on palynofacies. Different resolution between data sets used for sequencestratigraphic analysis limits correlation. In the upper Emsian to Eifelian, sequence analysis based on palynofacies data shows internal inconsistency between palynofacies data sets and poor correlation to well log analysis. The basal Givetian sequence boundary is again clearly observed in the palynofacies.

CONCLUSIONS

In the study area, continuous deposition took place from the Upper Silurian to the Middle Devonian in distal well 3, whereas proximal wells 1 and 2 show two gaps: a minor gap in the Lochkovian and a major gap covering the entire Eifelian. Palynostratigraphy enables good correlation from proximal to distal wells. Increasing thickness in all spore zones from well 3 to 1 supports the interpretation of a proximal - distal trend from well 1 to well 3. At the Silurian-Devonian boundary TMI shows a major shift from marine to terrestrial, providing evidence for a strong fall of sea-level. In the proximal wells, a rapid shift is observed, whereas a more gradual shift is observed in distal well 3. TMI shows four transgressive phases, which can be traced from the proximal to distal wells. Palaeoenvironmental interpretation of the organic matter shows no big change, representing mainly dysoxic to anoxic shelf and basin transitional environments, and showing less oxic conditions in distal well 3. TMI also shows good potential for additional well correlation, whereas other proxies show very little potential as correlation tools. Sequence stratigraphic analysis in the Lochkovian to Emsian shows correlation of 3rd order cycles based on well logs and on palynofacies analysis. Four sequences are recognized.

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PALYNOSTRATIGRAPHIC CORRELATION OF THE SARDHAI FORMATION (PERMIAN) OF PAKISTAN

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SUMMARY

Palynological assemblages from the Sardhai Formation shale (Permian), lying between the red-bed Warcha Formation and the Amb Formation limestones in the Salt and Khisor ranges of Pakistan contain abundant bisaccate pollen grains and few spores. In particular, well-preserved specimens of ?*Florinites balmei*, a bilaterally symmetrical monosaccate pollen grain, are common. The presence of this pollen and the stratigraphic context suggest that the Sardhai Formation correlates with the Khuff transition beds of Oman and the basal Khuff clastics of central Saudi Arabia. ?*Florinites balmei* was first described by Stephenson and Filatoff in 2000 from the basal Khuff clastics of Saudi Arabia, and it has since been reported from Oman, Kuwait, southeastern Turkey, Iraq, United Arab Emirates and Qatar. This suggests that the plant that produced ?*Florinites balmei* had a rather limited palaeogeographic distribution in the Mid-Permian which may be useful in reconstructing the problematic tectonic and palaeogeographic history of this complex region.

Keywords: Permian; Pollen; Salt Range; Khisor Range; Nilwahan Group; Zaluch Group.

INTRODUCTION

The Permian succession of Pakistan crops out in the Salt Range and Trans-Indus Khisor and Marwat ranges and partly in the Surghar Range (Fig. 1), which represent the southern side of a rift flank basin, along the northern Gondwanan coastal margin (Wardlaw and Pogue, 1995).

The succession is divided into two groups, representing two different depositional settings: the largely terrestrial Gondwana succession, represented by the Nilwahan Group, and the shallow marine Tethyan succession, represented by the overlying Zaluch Group (Wardlaw and Pogue, 1995), thus it provides information on the changing palaeoclimate and palaeogeography of the region, comprising a record of warming as the Carboniferous-Permian glaciations waned and northern Gondwana drifted northwards (Stephenson et al., 2007; 2008). Biostratigraphical dating has suggested a range of ages for Salt Range units. The brachiopods and fusulinids of the Amb Formation were assigned to the Baigendzinian Substage (upper Artinskian) by the Pakistani-Japanese Research Group (1985). The most recent age determination is that of Wardlaw and Pogue (1995), who used conodonts to correlate with the North American Mid-Permian chronostratigraphic scheme which became the basis of the standard Permian chronostratigraphy of Jin et al., (1997). The latter is primarily based on conodont correlations. Thus a Wordian age was suggested for the Amb Formation.

The age of the Wargal Formation ranges from the late Murghabian, Tethyan equivalent of Capitanian, (*Neoschwagerina margaritae* Zone) to early Dzhulfian, Tethyan equivalent of Wuchiapingian (Pakistani-Japanese Research Group, 1985). The overlying Chiddru Formation has been assigned to the late Dzhulfian by the Pakistani-Japanese Research Group (1985).

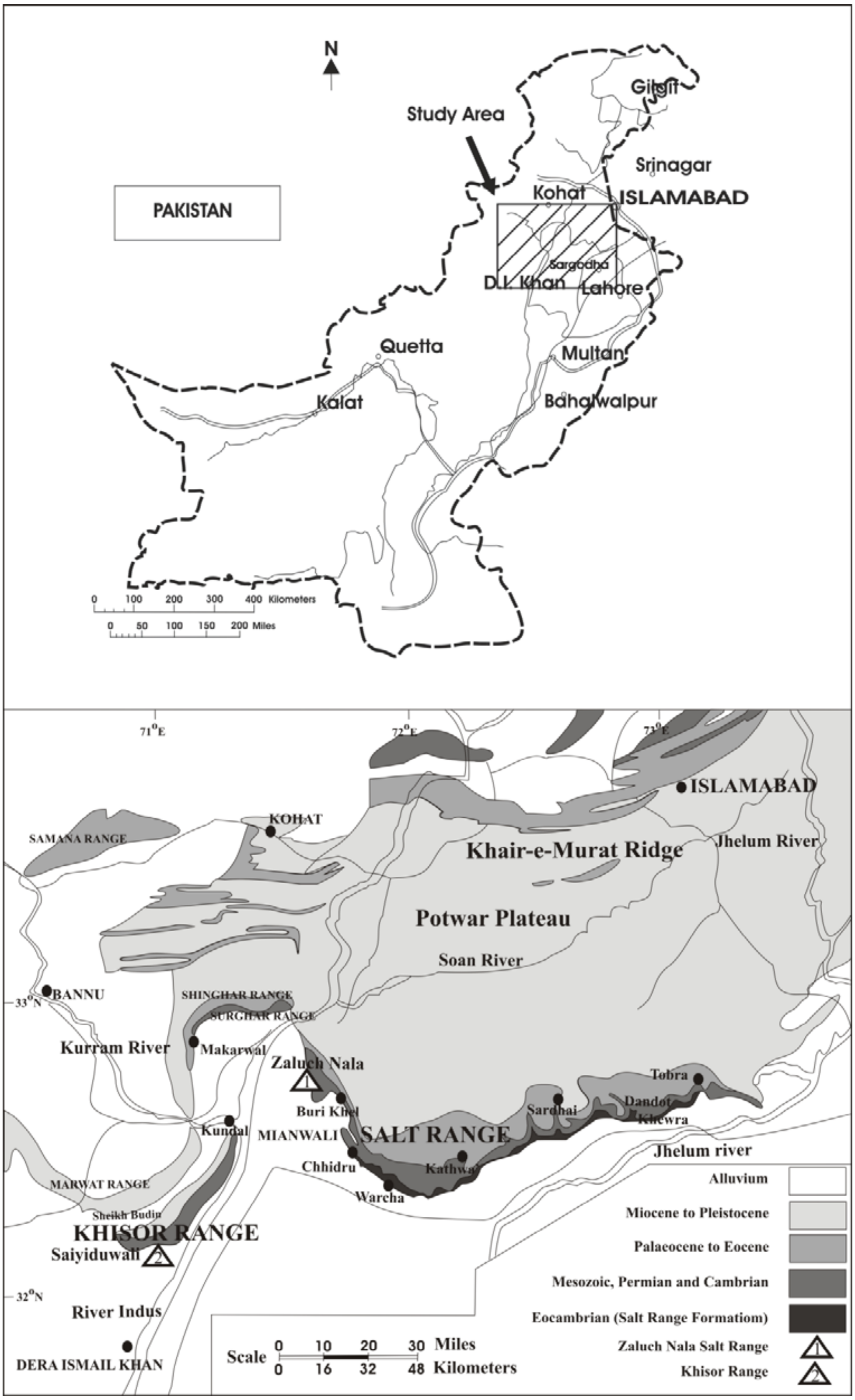

Figure 1. Location map of the study area. Showing Salt and Khisor ranges of Pakistan (Modified after Gee 1980, 1989).

Palynological study of the Permian succession is confined to the Salt Range; there are no reports of palynology from the Trans-Indus ranges. Virkki (1946) and Venkatachala and Kar (1966, 1968) studied samples from a horizon 20-25 feet above the Tobra Formation (see Balme, 1970). Balme (in Teichert, 1967) also described assemblages from the Tobra Formation at Zaluch Nala, eastern Salt Range and assigned them to the Permian (Teichert, 1967). Kemp (1975) examined two samples from the Tobra Formation at Zaluch Nala and reported the presence of *Brevitriletes* sp. cf. *B*. *unicus*, *Lophotriletes* sp. cf. *L*. *scotinus*, *Horriditriletes*- *Lophotriletes* sp. *Potonieisporites neglectus*, *Dentatisporites* sp. along with acritarchs, referable to the genus *Cymatiosphaera*, while Khan et al., (2001) reported Tobra Formation assemblages from Nilawahan Gorge, central Salt Range.

There is no palynological work on the Sardhai formation, but Balme (1970) made a detailed taxonomic survey of the carbonate dominated succession of the overlying Amb, Wargal and Chhidru formations. He recovered pollen and spores from the plant-bearing horizons of the Amb Formation at three localities in the Salt Range: Zaluch Nala, Dhodha Wahan, and near Warchha Water Tank. Balme (1970) compared the palynological assemblages from the Amb Formation of Pakistan with those of Australia and the USSR (see also Balme, 1960; Chalyshev et al., 1965).

For the present study, two samples (Fig. 2) were collected from a 22 meter-thick exposure of the Sardhai Formation in the Khisor Range at N32^{o} 11$^{//}$ 52.1$^{/}$ E 70^{o} 59$^{//}$ 18.0$^{/}$. Two more samples were collected from an approximately 30 meter-thick exposure of the same formation at Zaluch Nala, Salt Range at N32^{o} 46$^{//}$ 58.4$^{/}$ E 71^{o} 38$^{//}$ 49.4$^{/}$.

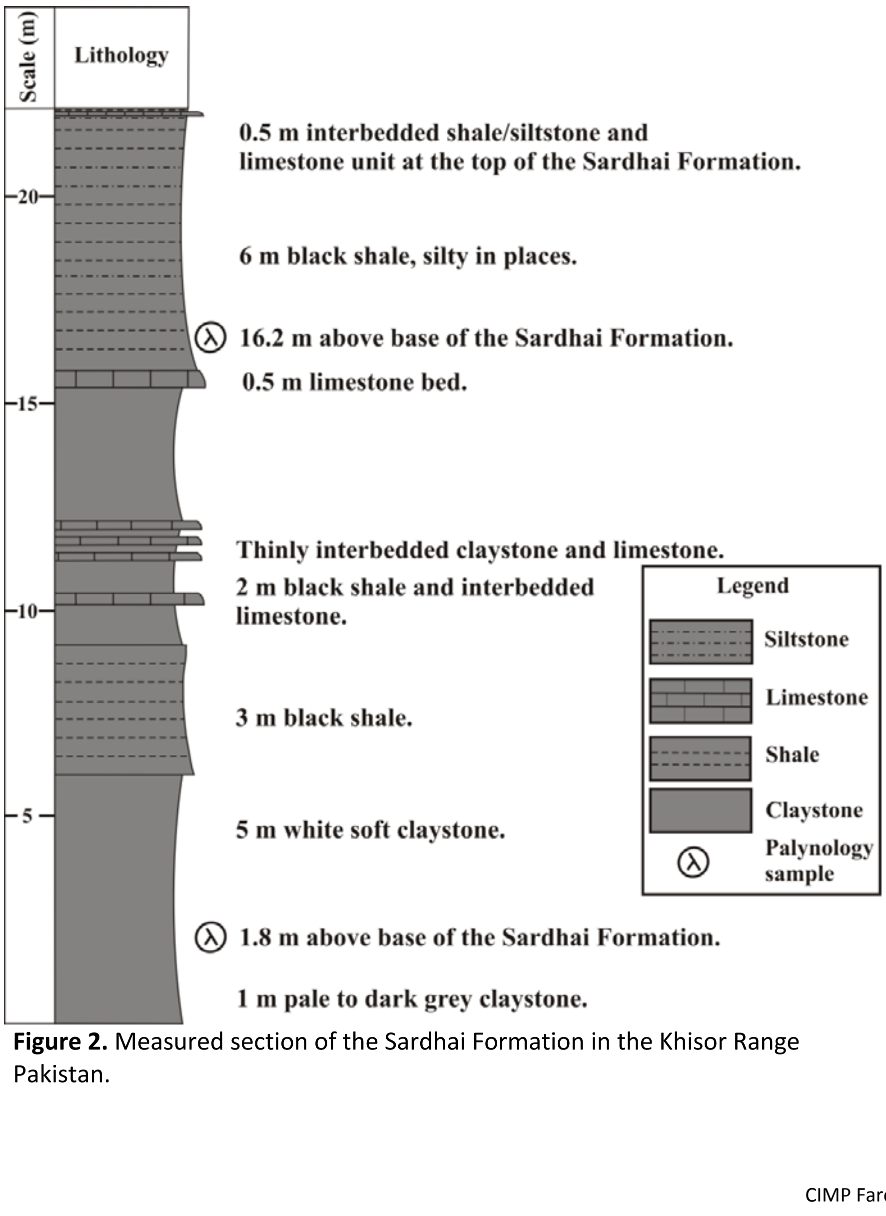

Figure 2. Measured section of the Sardhai Formation in the Khisor Range Pakistan.

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STRATIGRAPHIE ET PALYNOLOGIE DU DÉVONIAN INFÉRIEUR DU PLATEAU DU TIDIKELT D'IN SALAH (SAHARA CENTRAL ALGERIE)

STRATIGRAPHY AND PALYNOLOGY OF THE LOWER DEVONIAN OF TIDIKELT PLATEAU OF THE IN SALAH (CENTRAL SAHARA ALGERIA)

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RÉSUME

L'analyse palynologique liée avec la corrélation séquentielle a permis de déterminer la stratigraphie du Dévonien Inférieur du Tidikelt. Le Lochkovien est composé de sept cycles sédimentaires localement partiellement érodés, l'analyse palynologique a prouvé qu'il manque des sédiments du Lochkovien terminal. La miospore du Praguien étroitement comparable du miospore Praguien de Algérie. L'analyse palynologique ainsi que l'analyse séquentielle indiquent le manque des sédiments du Praguien Inférieur de l'Algérie. Toutes les sédimentations de Praguien sont d'une provenance lacustre. Si le Lochkovien avait sept cycles de sédimentation et Praguien on observe la domination du nombre de cycle (trois cycles de sédimentation). Les miospores d'Emsien sont en général analogues aux données des autres forages du Sahara. Le milieu de sédimentation est marin. On observe seulement un cycle sédimentaire.

SUMMARY

Lithologic sequences of the Tidikelt boreholes are dated by, moderately fairly preserved, well known miospores of controlled stratigraphic range. This is proving that these successions are of Lochkovian, Pragian and Emsian ages. The correlation also confirms local hiatus at Lochkovian, Pragian and Emsian peaks and at the Pragian base. These erosional formations incited by: lack of sedimentary deposits at these levels; decreasing in the number of sedimentary cycles and reducing sediments thickness of the successive cycles towards these levels. The Lochkovian deposits are of fluvial-lake origin, Pragian are of lake and Emsian of marine environments.

Keywords: Lower Devonian, palynology, Tidikelt Plateau, Algeria

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INTRODUCTION

Le travail est basé sur l'étude complexe, englobant l'interprétation sédimentologique des diagraphies γ-ray et du matériel des fragments carottés des forages étudiés et détermination palynologique des échantillons provenant de quatre forages localisés dans Tidikelt. GMD2, GMD3, GMD1, ISS1, MSR1. (Fig.1). Le forage MSR1 est situé à la limite méridionale du plateau Tademait dans la zone frontalière entre Tidikelt et Touat.

On s'est limité aux sédiments dont l'analyse palynologique a attribué l'âge du Dévonien inférieur. Les résultats de l'analyse minéralogique ont été présentés sur des méthodes de J. Czerminski(1955). Séparément pour Lochkovien, (éch.11-40), Praguien (éch.41-56) et Emsien (éch.57-59).

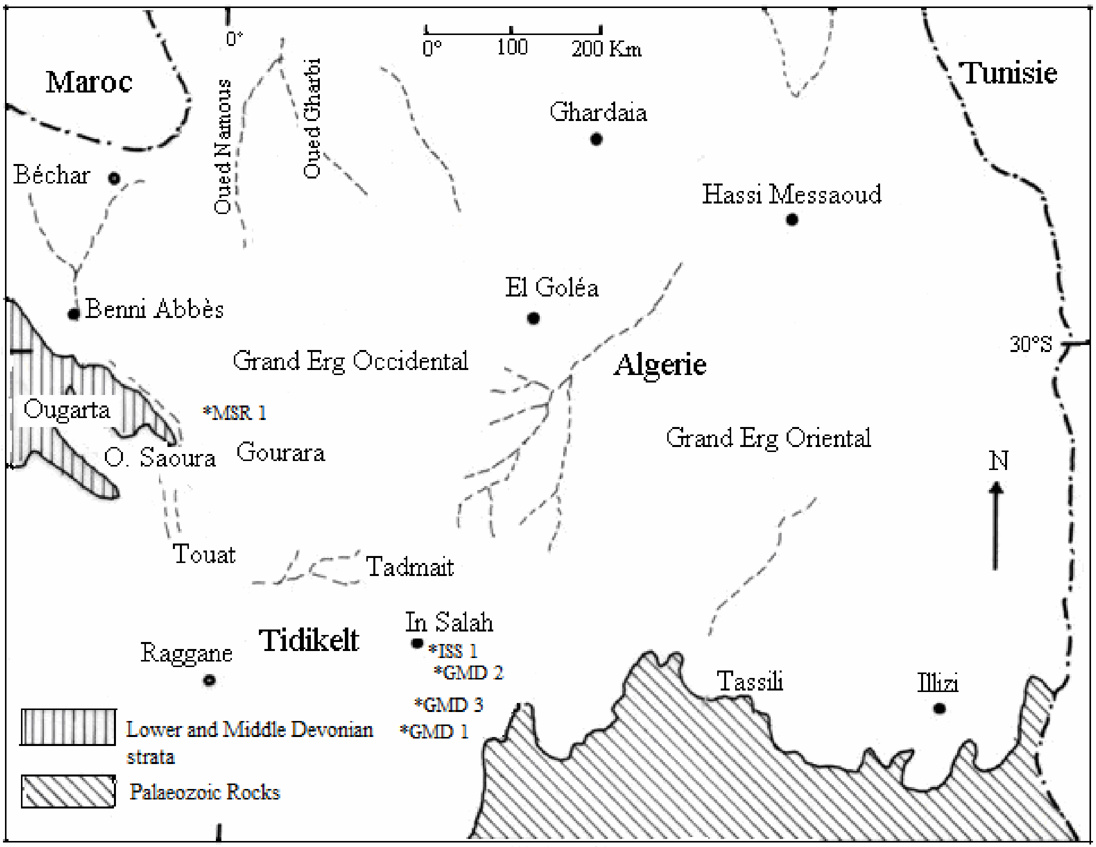

Figure 1. Carte général et de localisation des forages étudié.

CYCLES SÉDIMENTAIRES

Lochkovien dans le profil MSR1 se compose de cinq cycles sédimentaires symétriques et sixième asymétrique représenté par la séquence simple. Dans le profil GMD3 il y a six cycles symétriques et septième asymétrique représenté par la séquence simple. Dans les profils GMD1, GMD2 et ISS1, il existe sept cycles symétriques. Cela indique la lacune stratigraphique, voir l'érosion au sommet des profils MSR1 et GMD3 en relation avec les autres. Cette lacune locale est liée avec une lacune régionale beaucoup plus grande, confirmée par le manque de sédiments du Lochkovien supérieur prouvé par l'analyse palynologique

Le Praguien compte trois cycles sédimentaires. On ne peut pas dire quelle partie du profil du Praguien représente le sédiment étudié, mais on peut dire que la sédimentation n'a pas commencé partout au même temps. Si dans les forages ISS1, GMD1 et GMD3, elle commence par la séquence simple 1, dans le forage GMD2 elle commence par la séquence inverse 1 par contre dans le forage MSR1 le profil du Praguien drastiquement abrévié se commence par la séquence simple 2. Cela se traduit par abaissement différencié du terrain beaucoup plus lent dans la partie occidentale. Au cours des cycles 2 et 3 les subsidences dans la zone de forage MSR1 sont relativement les plus faibles. La plus grande subsidence au cours du Praguien existe dans la zone des forages ISS1 et GMD2. Le profil du Praguien se finit par l'érosion observée au sommet des profils MSR1 et GMD2 où manque une partie de séquence inverse 3. Encore plus grande érosion avait lieu dans les profils GMD2 où manque complètement la séquence inverse 3.

La sédimentation d'Emsien est représentée seulement par un cycle de sédimentation symétrique. Il se commence par les grès inférieurs et se finit par les grès supérieurs avec des argiles marno-sableuses au centre.

LES MILIEUX DE SÉDIMENTATION

Les milieux de sédimentation des roches étudiées ont été établis sur la base des structures sédimentaires des contenances des minéraux caractéristiques et des fossiles mais aussi selon la relation des coefficients sédimentologiques et des modes de transport, en utilisant les diagrammes de Passega(1964), et des tableaux du Visher(1969). La plus précise est la méthode de Visher, et la méthode de Moiola et Weiser(1968) avait le rôle plus limité.

Dans les profils du Lochkovien le premier cycle dans le profil ISS1, le sommet de la séquence est simple, représenté par des argiles marécageuses, mais dans le profil MSR1, les sédiments de la séquence sont inverses avec le passage des sédiments marécageux et fluviatiles. Les fragments supérieurs du profil appartiennent déjà au cycle 2. Donc dans la partie inférieure de sédiments du Lochkovien des forages ISS1 et MSR1, il n'y a pas des sédiments marins typiques pour le Silurien. Dans le profil GMD3 on observe la petite mega séquence, composée de quatre séquences simples, dont la première représentée par les grès à lamination oblique suivis par les grès à lamination et grès bien classés. C'est l'unique ingression marine inscrite dans le sédiment étudié. La deuxième séquence simple représente le passage de sédiments lacustres, et des sédiments fluviatiles.

Dans le cycle 4, on observe les passages entre les sédiments fluviatiles. Le cycle cinq représenté la méga séquence composée de trois séquences inverses. Cette méga séquence riche en spores du Lochkovien représente les sédiments lacustres. Dans le cycle six on observe le passage du milieu lacustre. Le cycle sept représente des grès de provenance lacustre. En réassumant le milieu de sédimentation du Lochkovien est fluvio-lacustre avec les passages marécageux et dunaires.

Les échantillons étudiés du Praguien se caractérisent par les transports en courant de suspension de faible énergie, caractéristiques pour le milieu lacustre ou lagunaire. La présence dans les lames minces des oncolithes semble confirmer ce milieu.

Les profils d'Emsien ont une séquence simple et inverse. Le milieu représente shelf.

ETUDE PALYNOLOGIQUE

La présence des assemblages palynologiques dans des sédiments de Tidikelt a donnée l'occasion pour les études biostratigraphiques. Les miospores du Lochkovien sont représentés *Perotrilites microbaculatus*, *Scylaspora tedikeltense*, *Dictyotriletes emsiensis* et *Apiculiretusispora synoria*. Les résultats ont été comparés avec les autres assemblages du même âge: Massa et Moreau-Benoît(1976), Richardson *et al*.(2001), Hassan Kermandji *et al*.(2008), Richardson et McGregor(1986), Richardson et Ioannides(1973).

Les miospores du Praguien sont représentés par *Camptozonotriletes caperatus, Clivosispora verrucata var. convoluta, Dibolisporites* cf. *gibberosus* (Naumora) var. *major* Kedo, *E. spinaeformis*, *Apiculiretusispora arenorugosa, Dictyotriletes subgranifer, et Verrucosisporites polygonalis,* donnent les même assemblages du Jardiné et Yapaudjian (1968), Hassan Kermandji *et al*.(2008), Massa et

Moreau-Benoît(1976), Loboziak et Streel(1989), Loboziak *et al*.(1992) et Richardson et McGregor(1986).

Les ensembles des microspores d'Emsien contiennent les représentants de taxa: *Emphanisporites annulatus, Brochotriletes Libyensis, Grandispora diampida, Dibolisporites echinaceaus, et Camarozonotriletes filatoffii.* Ces ensembles comparables avec les autres publiés précédemment concernent les microflores d'Emsien: Jardiné et Yapaudjian(1968), Moreau-Benoît *et al*.(1993), Richardson et McGregor(1986) Hassan Kermandji *et al*.(2008), Abdesselam-Rouighi(2003), Paris *et al*.(1985), Breuer *et al*.(2007), Melo et Loboziak (2003), et Streel *et al*.(1987).

LA STRATIGRAPHIE DU DÉVONIEN INFÉRIEUR DU TADEMAIT

Selon les travaux dans la zone de Tidikelt, il n'existe pas grande lacune stratigraphique entre Silurien et Dévonien. Probablement la régression du Silurien a été définitive dans l'ensemble du terrain étudié à l'exception du forage GMD3. Dans la base du Lochkovien, existe l'ingression marine locale. Le milieu fluvio-lacustre ou dunaire, fréquemment marécageux ne donne pas de la suggestion des autres conséquences de la tectonique Calédonienne que redressement du terrain suivi par la subsidence au milieu continental qui est le plus avancé dans la partie occidentale.

À la fin du Lochkovien avait lieu du nouveau le redressement du terrain en liaison avec l'érosion du Lochkovien supérieur, surtout dans la zone du forage MSR1. La subsidence du Praguien se développe en façon très lente. Cela provoque le manque des sédiments du Praguien inférieur spécialement spectaculaire dans le forage MSR1 où manquent les sédiments du cycle 1 et dans le forage GMD2 où manque la séquence inverse du cycle 1. Pourtant on ne connaît pas quand a commencé la sédimentation du cycle 1. Tous les sédiments étudiés du Praguien sont de provenance lacustre. Le milieu lacustre s'installe au terrain au fur et a mesure de subsidence.

La diminution des nombres des cycles de sédimentation du Lochkovien (sept cycles) par Praguien (trois cycles partiellement conservés) à Emsien (un cycle) est caractéristique pour les profils étudiés. Cycle d'Emsien est marin, il se commence par des grès de la transgression marine et se finit par les grès de la régression. Tous ces étages stratigraphiques sont bien documentés par des études palynologiques.

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SILURIAN TO LOWER DEVONIAN PALYNOMORPHS FROM THE BARRANCOS REGION, OSSA MORENA ZONE, PORTUGAL - PRELIMINARY RESULTS

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SUMMARY

New miospore results were obtained from the Palaeozoic stratigraphic succession present in the Barrancos region, Portugal. The studied formations comprise the Silurian carbonaceous shales intercalated with cherts and rare lenticular carbonates of the Xistos com Nódulos Formation, as well as, the dark shales that alternates with thin psammit beds of Late Silurian to Early Devonian age from the Xistos Raiados Formation. Two miospore biozones were identified: the cf. *protophanus-verrucatus* Miospore Biozone, of the Lower Wenlock (Homerian) (Richardson & McGregor, 1986) and the *Verrucosisporites polygonalis* (Po) Miospore Biozone of the Lower Pragian (Streel et al., 1987). For the first time cryptospores are reported. Rare acritarchs and chitinozoans are also present. This new preliminary data allow correlation with the graptolite biozonation already established in this region (Piçarra, et al., 1995, 1998; Piçarra, 2000) and completes previous palynological studies (Pereira et al., 1999). Even so, detailed palynostratigraphic research is needed and is currently being undertaken to better understand the complex geology of the region.

Keywords: Cryptospores, trilete spores, Silurian to Lower Devonian, Barrancos, Portugal.

INTRODUCTION

The Palaeozoic geology of the Ossa Morena Zone is well represented in the stratigraphic succession of the Barrancos region, Portugal, and comprises sedimentary rocks from Cambrian to Early Devonian age (Delgado, 1908; Perdigão *et al.*, 1982; Oliveira *et al.*, 1991, Pereira *et al*., 1999, Piçarra, 2000) (Figure 1).

In this region, the Silurian and Devonian strata are represented by two formations, the Xistos com Nódulos and the Xistos Raiados Formations (Delgado, 1908). The Xistos com Nódulos consists of black carbonaceous shales intercalated with thin black cherts and rare lenticular carbonates at the top of the succession. This formation is rich in graptolites, which allow very accurate age determinations. Seventeen Silurian graptolite biozones were identified in the Xistos com Nódulos Formation (Delgado, 1908; Romariz, 1962; Perdigão *et al.*, 1982; Gutierrez-Marco, 1982; Rigby *et al*,. 1997; Piçarra *et al*., 1995, 1998; Piçarra, 2000).

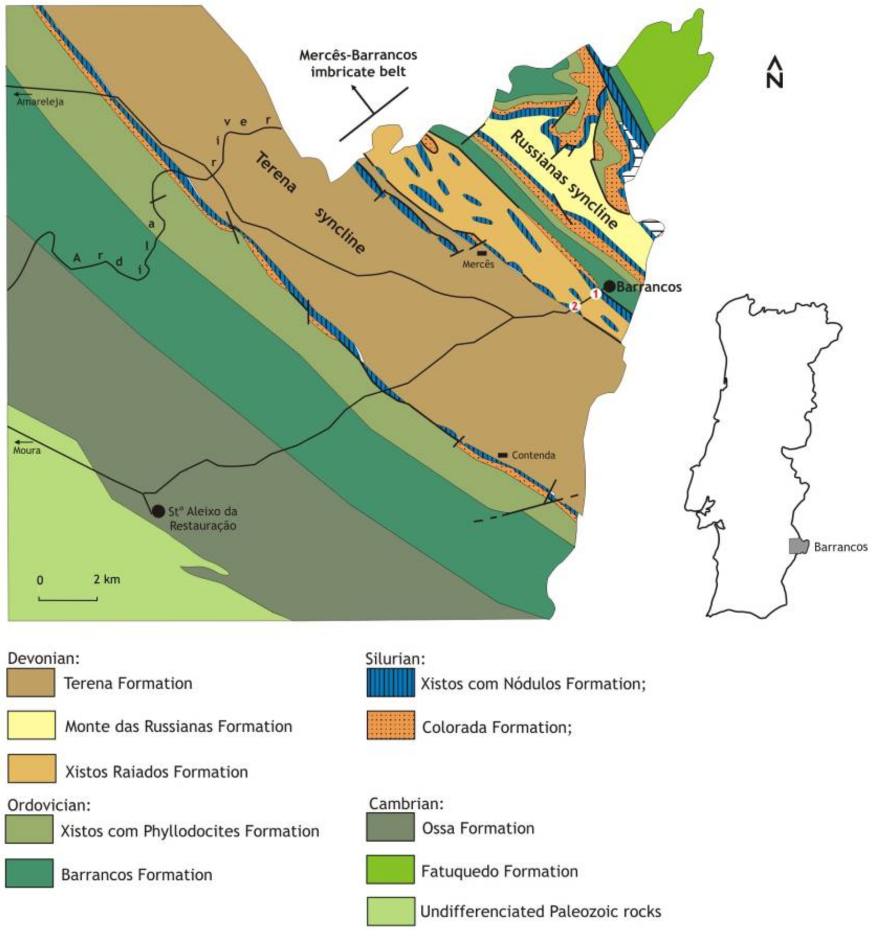

Figure 1. Simplified geological map of the Barrancos region (adapted from Piçarra et al., 1995; 1998; 2000 and Araújo et al., 2006), showing the position of the studied trenches.

The Xistos Raiados Formation is composed of dark shales that alternate with thin psammit beds. This formation has traditionally been considered Wenlock to Early Ludlow age (Delgado, 1908; Perdigão *et al*., 1982). However, more recent works indicate an age ranging from the Late Silurian (Ludlow-Prídolí) to the Early Devonian (Oliveira *et al*., 1991; Oliveira *et al*., 1993; Piçarra *et al*., 1998; Pereira *et al*., 1998, 1999).

The Xistos com Nódulos Formation reflects a euxinic sedimentary environment related to the end Ordovician glaciation, whose physical conditions remained stable throughout the Silurian. The Xistos Raiados Formation, on the other hand, indicates more shallow and oxygenated waters reflecting the beginning of a differentiated tectono-sedimentary evolution (Perdigão *et al.*, 1982; Oliveira *et al.*, 1991; Araújo *et al.*, 2006).

Palynological studies established during the last decade mostly concentrated on the upper part of the stratigraphic sequence, *e.g*. the Lower Devonian Xistos Raiados, Russianas, and Terena formations (Oliveira *et al*., 1993; Piçarra *et al*., 1995, 1998; Pereira *et al*., 1998, 1999; Piçarra, 2000). This presentation is a preliminary account of the palynological assemblages of miospores (cryptospores and trilete spores) of the Silurian to Lower Devonian strata of the Barrancos region, aiming toward a better understanding of the regional palynostratigraphy.

Produced by primitive land plants from the Ordovician to the Lower Devonian, cryptospores are here identified and reported for the first time.

Herein, we use the cryptospore definition proposed by Steemans (2000): "Alete miospores (non-pollen grains) produced by primate embryophyts. Single grains or monads, "permanent" dyads and tetrads, and sporomorphs from polyads which may or may not preserve contact areas, are included."

PALYNOSTRATIGRAPHY

Twenty-seven samples, collected in the road cut of EN 258, Km 103,7 near Barrancos and in the Eiras Altas Section (Figure 1), were processed for palynological studies.

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 and CX41 Olympus microscopes equipped with an Olympus C5050 and a SC20 digital cameras facility. All samples, residues, and slides are stored in the LNEG-LGM (Geological Survey of Portugal) at S. Mamede Infesta, Portugal.

The general miospore biozonal scheme for the Silurian to Lower Devonian used herein, follows Richardson and McGregor (1986), Burgess and Richardson (1995), Richardson *et al*. (2001), and Streel *et al.* (1987).

1. Road cut EN 258, Santo Aleixo da Restauração to Barrancos, km 103.7 (Figure 2)

This section is located in the road cut between kms 103.3 and 103.7 of the road from Santo Aleixo da Restauração to Barrancos, at the entrance of this village. The trench exposes, from northeast to southwest, a sedimentary succession that ranges from the Upper Ordovician to the Lower Devonian. It begins with the impure sandstones of the Colorada Formation (?Upper Ordovician-Lower Silurian/Rhuddanian) which is in fault contact with the black cherts of the basal part of the Xistos com Nódulos Formation. These are followed by black shales (when the weathering is very intense, the shales show pale colours) intercalated with thin black cherts and sporadic siliceous nodules (rare in the upper part), containing graptolites of Llandovery to Late Wenlock age.

The upper part of the Xistos com Nódulos Formation had four samples (BA4, 8, 9, 10) that yielded very poor to moderately preserved miospores (cryptospore and triletes spores) assigned to the cf. *protophanus-verrucatus* Miospore Biozone of the Lower Wenlock (Homerian) (Richardson & McGregor, 1986).

Also present in the assemblage are the cryptospores: *Gneudnaspora chibrikovae, Gneudnaspora chibrikovae?, Gneudnaspora plicata*?, *Imperfectotriletes vavrdovae, Pseudodyadospora petasus?*and *Quadritisporites variabilis.*

Completing the assemblage are the trilete spores *Ambitisporites avitus/dilutus* Morphon, *Ambitisporites tripapillatus, Amicosporites* sp., *Aneurospora* sp*., Archaeozonotriletes chulus* Morphon, *Emphanisporites multicostatus*, *Retusotriletes* sp., *Insolisporites anchistinus,* in association with the key species *Emphanisporites* cf. *protophanus.*

The last meters of the road-cut section expose dark shales with thin intercalations of sandstones with rare siliceous and ferruginous nodules that belong to the Xistos Raiados Formation. This part of the section was dated at the Pragian/Emsian boundary, based on miospores assigned to the upper part of the PE Biozone of Richardson and McGregor (1986), and *Dictyotriletes subgranifer* (Su) subzone of Streel *et al*. (1987).

New samples collected (BA12) in the mid part of the section yielded a very poor preserved miospore assemblage assigned to the *Verrucosisporites polygonalis* (Po) of Streel *et al*. (1987), that allows dating this part of the section as lower Pragian. The most common species present are: *Ambitisporites* sp., *A. tripapillatus*, *Amicosporites miserabilis*?, *Emphanisporites multicostatus*, and *Retusotriletes* sp., together with the guide species *Verrucosisporites polygonalis.* The cryptospores found was *Gneudnaspora chibrikovae.*

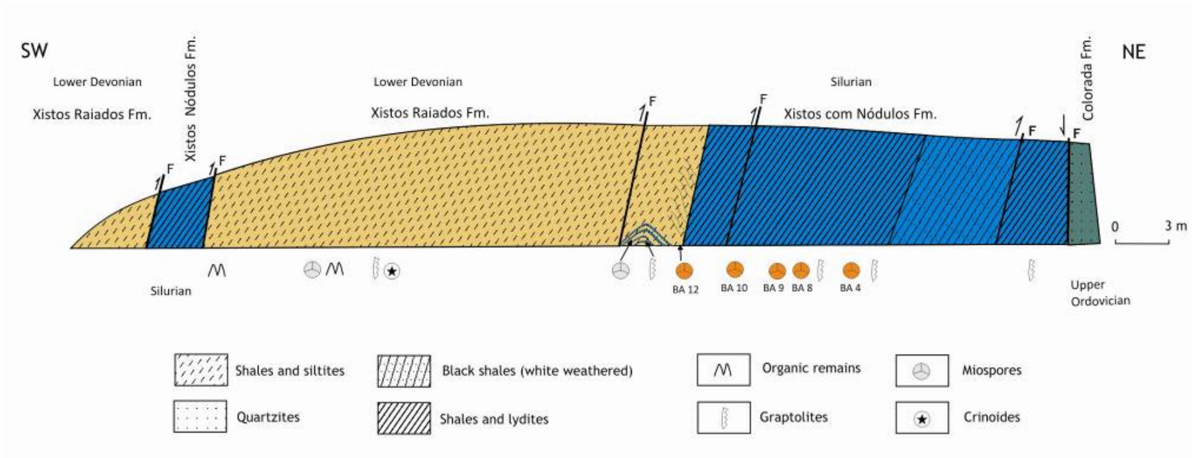

Figure 2. Scheme of the road cut EN 258, Sto Aleixo da Restauração to Barrancos, km 103,7, with location of productive palynostratigraphic samples (adapted from Oliveira, *et al*., 2000).

2. Eiras Altas Section

This section is located on the road Santo Aleixo da Restauração to Barrancos, at km 102.15, and shows the best known and complete, although condensed, Portuguese Silurian succession. The succession comprises the Xistos com Nódulos Formation and part of the Xistos Raiados Formation, and yielded 13 Silurian graptolite biozones (Piçarra *et al*., 1995, 1998; Piçarra, 2000). Here, the Xistos com Nódulos Formation consists of intensively weathered black shales that gradually pass to the base of the Xistos Raiados Formation, which is marked by the first occurrence of thin bedded dark shales and siltstones.

Twelve samples collected from the Xistos com Nódulos Formation were barren of palynomorphs, probably due to the intense weathering of the black shales as indicated by its pale colours. However, because of the importance of the section, a new sampling campaign was undertaken, and these samples are currently undergoing analysis.

CONCLUSIONS

Palynostratigraphy constitutes an important tool for precisely dating the Silurian to Devonian sequences of the Barrancos region. It is important and necessary that the correlation between the data obtained from palynology and the graptolite biozonations established in this region (Piçarra, *et al*., 1995, 1998; Piçarra, 2000).

The preliminary results obtained in this study allow the recognition of two miospore biozones in one of the studied sections (road cut EN 258, Sto Aleixo da Restauração to Barrancos, km 103.7):

The first one is the cf. *protophanus-verrucatus* Miospore Biozone of Richardson & McGregor (1986), and was obtained from the Xistos com Nódulos Formation, placing part of the studied section in the upper part of the Wenlock Series (Homerian stage), and confirming previous studies based on graptolites that assigned this section to the *?lundgreni* Graptolite Biozone (Piçarra, 2000).

The second one is the *Verrucosisporites polygonalis* (Po) Miospore Biozone of Streel *et al*. (1987), and comes from the Xistos Raiados Formation, and thus is assigned to the Lower Pragian. This new data completes previous studies that revealed miospores of the *Dictyotriletes subgranifer* (Su) subzone of Streel *et al*. (1987) of the Pragian/Emsian boundary (Pereira *et al*., 1999) (Figure 2). All of this information indicates that almost the entire Pragian Stage is represented in Xistos Raiados Formation, despite the complexity of local tectonism. A more detailed palynostratigraphic study from this road cut and other sections of the Barrancos region are currently underway.

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INITIAL BIOSTRATIGRAPHICAL RESULTS FROM A ?MOSCOVIAN/KASIMOVIAN PALAEOBOTANICAL SITE IN SANTA SUSANA BASIN (ALCÁCER DO SAL, PORTUGAL)

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SUMMARY

The Vale de Figueira locality is a ?Moscovian/Kasimovian palaeobotanical site in the Santa Susana basin (Alcácer do Sal, Portugal) which has been known for over a century. Most of the palaeobotanical collections from the Santa Susana basin held in Portuguese museums derive from this locality. The paleoflora described in several papers indicates a late "Westphalian D – early Cantabrian" age for the site. Here we present the first palynological results from the Vale de Figueira locality which suggests assignment to the Angulisporites splendidus-Latensina trileta (ST) Miospore Biozone of Clayton et al., 1977, 2003. Further analysis of the samples from the site is underway.

Keywords: Santa Susana basin, Moscovian-Kasimovian, Palaeobotany, Spores, Portugal.

INTRODUCTION

The Santa Susana Basin is a Pennsylvanian continental basin located in SW Portugal (Alcácer do Sal). Sedimentation was controlled by a transtensive dextral tectonic style along a NNW-SSE to N-S shear zone (separating the South Portuguese Zone to the East and the Ossa-Morena Zone to the West) producing a pull-apart basin during late Pennsylvanian times (Oliveira et al., 2007, Almeida et al., 2006).

The basin extends over 15Km in length in a NNW-SSE direction and is 0.1 to 1 km wide. Significant parts of the basin are covered by Tertiary deposits, but the true extent of the basin was revealed in the 1950s by borehole data. The basin has several coal seams that were explored until 1944 (Sousa and Wagner, 1983).

PREVIOUS PALAEOBOTANICAL AND PALYNOLOGICAL STUDIES

The palaeobotanical study of this basin dates back to the 1800s when Bernardino Gomes first reported fossil plants from the basin and made the first taxonomic identifications (Gomes, 1865). Lima conducted a second palaeobotanical study of the basin (e.g. Lima, 1895/98) attributing an age to the fossil sites. Later, Carlos Teixeira worked on several Portuguese Carboniferous fossil plant sites, including the Santa Susana Basin (Teixeira, 1938/40; 1940; 1944, 1945) , revising some of the work by Gomes and Lima and comparing the assemblages with others found in Spain and elsewhere in Europe.

More recently, a series of papers by Wagner and Sousa have revised the taxonomy, stratigraphic significance and palaeobiogeography of the Iberian Carboniferous fossil macroflora including the Santa Susana assemblages (Sousa and Wagner, 1983; 1985; Wagner and Sousa, 1983a, b). These authors attributed the assemblage to the “very late Westphalian D or earliest Cantabrian”. Most of the specimens described and re-described by these workers were from the Vale de Figueira locality in the southern part of the basin. The basin’s stratigraphy has been summarily described in some of the previous palaeobotanical studies and also in some specific studies (e.g. Andrade, 1927/30; 1955; Neiva, 1943) dealing with borehole data and with the characteristics of clasts in the conglomerates.

The scarcity of studies on the basin’s stratigraphy can be explained by the paucity of continuous outcrops in the area except for some stream beds and reservoir banks. Only two brief notes were published concerning the palynology of the basin: Fernandes (1996; 2001). Both refer to samples derived from borehole cuttings (Fernandes, pers. com.) and the relatively diversified spore assemblage allowed an attribution to the Miospore Biozones *Angulisporites splendidus* – *Latensina trileta* (ST) and/or *Thymospora obscura* - *T. thiessenii* (OT) of Clayton et al., 1977, 2003.

PALYNOLOGICAL RESULTS

The Vale de Figueira paleobotanical site consists of several meters of fossiliferous silts and shales underlain by ca. 30m of fluviatile cyclic sediments grading from gravel conglomerates to shales and thin coal seams. Several samples were collected from grey shales and silts of the sequence underlying the fossiliferous levels. From the 5 samples processed by standard palynological methods, 3 provided observable (apparent low maturity) palynomorphs from which several slides were produced. The organic residues from the remaining samples consist of dark brown to black opaque organic particles which would require oxidation in order for the organic content of the samples to be fully determined.

The organic residues from the 3 selected samples were dominated by light to dark brown phytoclasts with subordinate amounts of spores/pollen. Within the spores/pollen, large (>80µm), thin walled, laevigate to finely sculptured trilete and monolete forms were clearly dominant. Most of these forms are assignable to *Wilsonites* sp., *Florinites* sp. and *Schopfipollenites* sp.

The following taxa were identified in the assemblage:

Alatisporites sp.

Crassispora kosankei (Potonié and Kremp) (Bhardwaj emend. Smith and Butterworth) di Pasquo 2002

Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944

Florinites sp.

Latensina cf. *trileta* Alpern, 1958

cf. *Lundbladispora gigantea* (Alpern) Doubinger, 1968

Lycospora pusilla (Ibrahim) Somers, 1972 cf. *Radiizonates tenuis* (Loose) Butterworth & Smith (in Butterworth et al., 1964)

Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp, 1954.

Westphalensisporites irregularis Alpern 1958

Wilsonites sp

DISCUSSION AND CONCLUSIONS

Considering the taxa found and the usage of open nomenclature in several of them, the assemblage is provisionally attributed to the *Angulisporites splendidus-Latensina trileta* (ST) Miospore Biozone of Clayton *et al*., 1977; 2003, of Kasimovian age. However, further analysis of the residue and of other samples is needed to confirm the preliminary results.

These results are consistent with the results summarily described in Fernandes (1996, 2001). There is an apparent discrepancy with the biostratigraphical results derived from the palaeobotanical data (Wagner and Sousa, 1983b) which point to an older age (*Neuropteris flexuosa/ovata - Annularia stellata - Sphenophyllum emarginatum*) – corresponding to lower OT Miospore Biozone of Clayton *et al*., 1977; 2003 (Moscovian age). Revision of the fossil plant taxa is underway and the preliminary results (Mattioli *et al*., 2009) show the existence of previously undescribed taxa from the site which may lead to a reassessment of its age. Further analysis of the palynological residues will allow a more definitive biostratigraphical conclusion.

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DEVONIAN PALYNOLOGICAL CORRELATIONS ACROSS THE EURAMERICA-GONDWANA INTERFACE

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SUMMARY

A key goniatite from Bolivia is reinterpreted and provides a chronostratigraphic tie between Euramerica and Gondwana. This reveals that key zonal palynomorphs do not appear synchronously in both areas.

Keywords: Devonian, Bolivia, goniatite, spores

International Devonian correlation is achieved using a combination of conodonts and goniatites which define a series of zones. These zones are used for inter-regional correlation with varying degrees of precision. However, their application is limited by the global distribution of both conodonts and goniatites which are normally restricted to Laurussia (plus contiguous continental fragments) and northern Gondwana (i.e. North Africa, Iran and Australia). Further south in Gondwana the invertebrate faunas become dominated by trilobites and brachiopods that are endemic in their distribution (Boucot, 1988) and stratigraphic correlations become problematic. In contrast, palynomorphs are abundant across both Gondwana and Euramerica and assemblages include a number of common species that have been used to define a series of spore zones based on the inception of single species. These have been calibrated to the geochronological standard GSSP's using classic sections in Europe (e.g. Melo & Loboziak, 2003). Such spore zones have been widely applied in South America, North Africa and Arabia. However, it must be emphasised that the major elements that make up the bulk of the spore assemblages in, for example, the Eifelian and Givetian of Euramerica and central South America are very different. In Euramerica the dominant elements in the Eifelian are the bifurcate tipped *Ancyrospora* (lycopods) and *Rhabdosporites* (aneurophytalean progymnosperms) that are succeeded in the Givetian by assemblages dominated by *Geminospora* (archaeopteridalean progymnosperms). In contrast, spore assemblages from Bolivia are dominated by laevigate and apiculate spores that are simple in construction together with coarse verrucate forms (*Verrucosisporites scurrus* morphon). *Ancyrospora* and *Geminospora* are present but never dominate the assemblage.

There are, in fact, very rare occurrences of goniatites in South America. Frequently these are poorly located or are indeed unprovenanced (i.e. acquired in street markets) but have proved very influential in providing chronostratigraphical ties that have even been extended beyond the continent. In an attempt to resolve these issues goniatites have been re-located in situ and integrated with palynological studies on the same sections. An influential goniatite discovery was that of *Tornoceras bolivanum* at Campo Redondo in Bolivia to which we have added a further *in situ* specimen. Hünicken et al. (1980) attributed a Givetian-Frasnian age to *T. bolivanum*. This age is different to the associated palynological assemblage which is late Emsian based on the occurrence of *Grandispora* spp and *Emphanisporites annulatus*. However, reinvestigation of the goniatite shows that it has affinities with *Mimotornoceras* and its age cannot be younger than early Eifelian and is attributed to the Choteč transgressive event. This gives an independent age date tie-point and thus the ability to compare spore inceptions between South America and Europe and North America. This tie-point reveals a number of significant differences in the sequence of inceptions with several delayed inceptions in South America including important taxa such as *Emphanisporites annulatus*, ancyrospores, *Rhabdosporites 'minutus'* and *Rhabdosporites langii*. In addition, comparison with spore assemblages from North America reveals that the sequence of spore assemblages recorded from the Jaab Lake No. 1 well in Canada (McGregor & Camfield, 1976) shows many similarities to Bolivia. Importantly there are also revised conodont assemblages (Uyeno & Bultynck, 1993) in the Jaab Lake No. 1 well.

These results show that we must be much more rigorous with the application of single index taxa for international correlation. But it reveals that with a more sophisticated analysis and independent age dates we will be able to map out the migration of key zonal taxa and ultimately understand the spread of Devonian plants during terrestrialisation. The next step is to locate more sections that contain both conodonts, goniatites and palynomorphs from northern Gondwana.

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NEW LOWER GIVETIAN AGE MIOSPORES OF THE PHYLLITE - QUARTZITE GROUP (SÃO FRANCISCO DA SERRA ANTICLINE, IBERIAN PYRITE BELT - PORTUGAL)

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SUMMARY

Palynostratigraphical analysis of Phyllite – Quartzite (PQ) Group shales recovered from a drill core and outcrops at the São Francisco da Serra anticline, in the westernmost area of the Iberian Pyrite Belt, yielded a moderately preserved miospore assemblage assigned to the upper part of AD miospore Biozone, subzone Lem, of lower Givetian age. This is the oldest age recognized, up to this date, for any rocks in the Iberian Pyrite Belt.

Keywords: Palynostratigraphy, miospores, lower Givetian, Phyllite - Quartzite Group, Iberian Pyrite Belt

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INTRODUCTION

The stratigraphy of the Iberian Pyrite Belt (IPB) consists of two major units; the Phyllite Quartzite Group (PQG) and the Volcano Sedimentary Complex (VSC). PQG is the detritic basement of the belt and consists mostly of interbedded phyllites, quartzites, quartzwackes and shales, with limestone lenses and nodules in the upper part of this unit. The base of the unit is still unknown and its thickness is in excess of 200m.

In the south branch of the IPB, the PQG occurs in the core of rooted anticline structures, from SE, the Pomarão Anticline (in the western termination of the Puebla de Guzmán anticline, in Spain), Rosário Anticline (where the Neves Corvo mine is located), to NW, the Lousal and São Francisco da Serra anticlines. All of these structures are being palynologically investigated. The PQG has been dated as Upper Devonian (lower Frasnian to late Strunian) by ammonoids, conodonts and palynomorphs in Portugal (BOOGAARD, 1967, FANTINET et al. 1976; CUNHA & OLIVEIRA, 1989; OLIVEIRA et al., 1997; OLIVEIRA et al., 2004, PEREIRA et al., 2004) and in Spain (González, 2005).

The aim of the present paper is to present the first palynological results from the São Francisco da Serra Anticline, which indicate the oldest age determined in the IPB stratigraphic sequence

GEOLOGICAL SETTING

The S. Francisco da Serra Anticline represents the NW termination of the IPB in Portugal (Figure 1). The axis of the anticline plunges SE, whereas its western part is fault bounded and covered by Tertiary sediments.

The stratigraphic succession of the anticline shows the classic units of the IPB: at the base the PQG consisting mostly of shales interbedded with quartzites (sometimes massive) overlain by the Volcano-Sedimentary Complex (VSC), here dominated by fine volcanoclastic sediments, minor felsic volcanics, purple shales and dark carbonaceous shales in the upper part. The thickness of the PQG is unknown and that of the VSC is approximately 100 metres. Stratigraphically above the VSC are the deep-water turbiditic sediments of the Mértola Formation of Middle Late Viséan age.

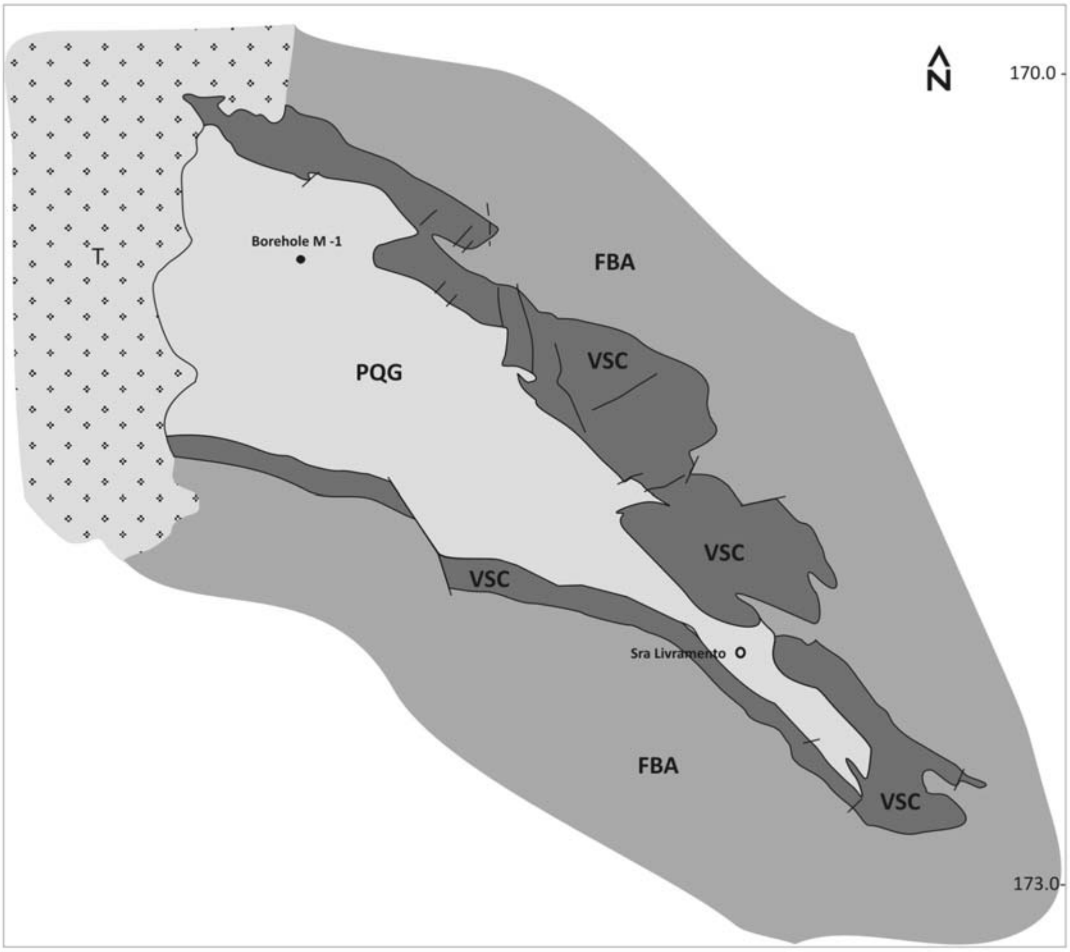

Figure 1. Simplified geology of the S. Francisco da Serra Anticline (adap. Alves et al., 1985). FBA - Mértola Formation (Flysch); VSC - Volcano-Sedimentary Complex; PQG - Phyllite-Quartzite Group; Tertiary sediments.

MATERIALS AND METHODS

Samples for this study were collected from a drill core (M1) and from outcrops located along the margins of a valley north of the Senhora do Livramento Chapel (Figure 2). Biostratigraphic research has been based on palynomorphs. 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, using a BX40 Olympus microscope equipped with an Olympus C5050 digital camera. All samples, residues and slides are stored in the LNEG-LGM (Geological Survey of Portugal) at S. Mamede Infesta, Portugal. The miospore biozonal scheme used follows the standard Western Europe Miospore Zonations (after: Clayton et al., 1977; Streel et al., 1987; Higgs et al., 1988, Clayton, 1996, Pereira , 1999, Pereira et al., 2008).

PALYNOSTRATIGRAPHY

The 'Senhora do Livramento' outcrop section and the M1 borehole were studied and sampled for palynostratigraphic investigation.

Senhora do Livramento Section

This section is located along a river valley north of the Senhora do Livramento Chapel (Figure 2) and represents the upper 100 metres of the PQG succession in this anticline. The succession consists of grey/black shales interbedded with quartzites. The quartzite beds are concentrated in two intervals. The basal interval is organised in a thinning upward succession and the beds show wave ripples and hummocky cross stratification, suggesting deposition on a shallow siliciclastic platform. The upper interval, the Senhora do Livramento Quartzites, consists of 30 metres of massive amalgamated quartzites, sometimes coarse grained, showing as dominant structures, low angle current and parallel laminations, which also indicates deposition in a shallow marine environment.

Seven samples were collected from the Senhora do Livramento measured section for palynostratigraphic research. However, all the samples were barren, probably due to the intense weathering of the shaley lithologies.

M1 Borehole

The M1 borehole (a vertical borehole 367m deep drilled by the Sociedade Mineira Riofinex, at Quinta do Poço in 1993) is located in the central part of the anticline. The succession consists of highly fractured black shales interbedded with thin-bedded quartzites. Samples from this section yielded a moderately preserved miospore assemblage assigned to the upper part of AD miospore Biozone (subzone Lem), of lower Givetian age.

The most common species present are: *Acinosporites lindlarensis, Aneurospora greggsii, Cymbosporites magnificus, Emphanisporites annulatus, E. rotatus, Grandispora protea, Retusotriletes rugulatus, Verrucosisporites premnus* and *V. scurrus* in association with the guide specie *Geminospora lemurata*.

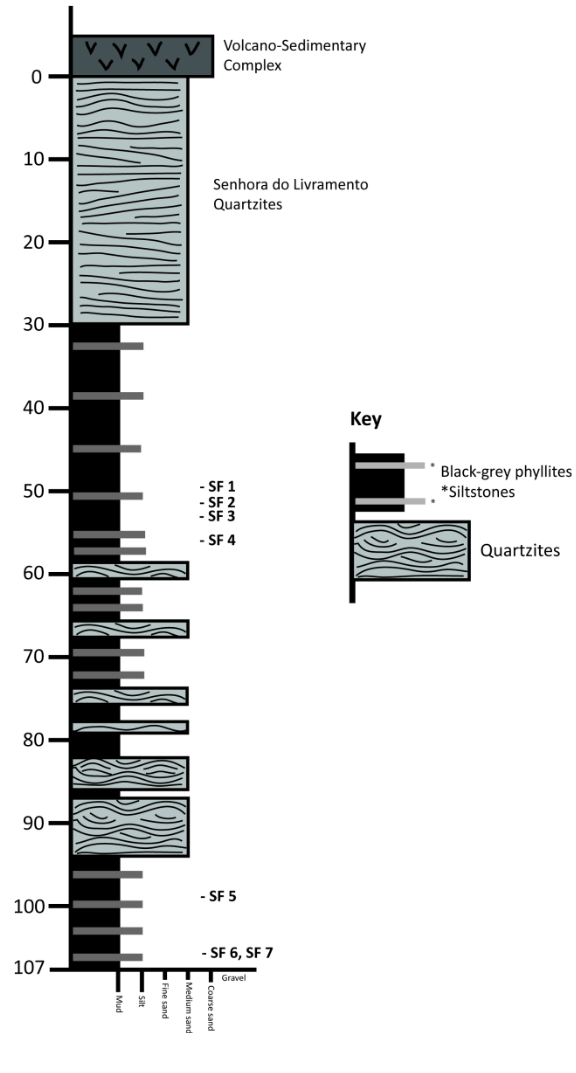

Figure 2. Senhora do Livramento section, corresponding to the upper 100 m of the PQG in the S. Francisco da Serra Anticlinal. Characters on the right refer to the samples studied.

Cristatisporites triangulatus is absent. The first occurrence of this species is at the base of the TA Biozone, confirming the position of the assemblage, as pre-TA Miospore Biozone.

Also present are reworked miospores of Lower Devonian age (e.g. *Archaeozonotriletes chulus, Brochotriletes* sp., *Camarozonotrilestes sextantii* and *Diatomozonotriletes franklini*).

CONCLUSIONS

The present research confirms the autochthonous nature of the São Francisco structure and demonstrates that the age of PQG is not yet definitively achived. Our new results suggest that the lower part of the PQG may be as old as lower Givetian in the westernmost part of the IPB. The first appearance of *Geminospora lemura* marks the base of Lem Subzone of the AD Biozone of lower Givetian age (Streel et al., 1987). According to Loboziak & Streel (1980; 1987; 1988; 1989), *G. lemurata* first occurs close to the proposed base of the Givetian stage. However, the common presence of reworked Lower Devonian miospores in many of the samples studied in this basin suggests that the PQG could extend down into the Lower Devonian.

EARLY MIDDLE DEVONIAN (EIFELIAN) PHYTOPLANKTON BLOOM ASSOCIATED WITH THE BASAL CHOTEC EVENT IN THE BARRANDIAN AREA (CZECH REPUBLIC)

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SUMMARY

A palynologic assemblage obtained from the basal levels of the Eifelian Chotec Limestone (= Basal Chotec Event) in the Prague Basin (Czech Republic), is characterized by abundant prasinophycean palynomorphs (Tasmanites/Leiosphaeridia) and rare mazuelloids and scolecodonts. The reasons for this nearly monospecific phytoplankton assemblage and it relationship to the Basal Chotec Event will be discussed.

Keywords: Lower-Middle Devonian, phytoplankton, Chotec Event, Barrandian area

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INTRODUCTION

The Basal Chotec Event in its type area, the Prague Basin (Czech Republic), occurs at the base of the Chotec Limestone (Chotec Formation, Eifelian) and its equivalents, just above the Lower-Middle Devonian boundary, which is placed at the base of the conodont *partitus* Biozone. Although generally regarded as minor, the Basal Chotec Event is globally documented by a distinct facies and faunal change (e.g., Chlupác et al., 1979; Chlupác 1983, 1985; Chlupác & Kukal, 1986).

Within the Prague Basin, the respective lithology changes from light, bioturbated skeletal wackestones/packstones of the Trebotov Limestone, to dark, crinoidal and peloidal grainstones alternating with dark laminated lime-mudstones and slightly bioturbated grey to dark wackestones of the Chotec Limestone. This level of the event approximately corresponds to the base of the conodont *costatus* Biozone, the beginning of the conodont *Pinacites jugleri,* and the junction of the conodont *Nowakia holynensis-Nowakia sulcata* biozones (Chlupác & Kukal, 1986).

During a restudy of the type locality of the Chotec Formation (the Na Skrábku quarry near Chotec village), an abundance of three-dimensionally preserved palynomorphs have been recovered from the conodont preparation residue. Light microscopy and SEM show that the majority of these well-preserved palynomorphs can be classified as prasinophycean algae. In addition, a few mazuelloids and scolecodonts have been observed, whereas acritarchs, spores and chitinozoans are thus far absent.

The prasinopyceen algae occur in a dark peloidal grainstone containing large amounts of micritized echinoderm ossicles, 20 cm above the base of Chotec Limestone. The associated conodont fauna is represented by *P. linguiformis bultyncki* Weddige, *P. costatus patulus* Klapper, and *Polygnathus* sp. aff. *P. trigonicus* Bischoff & Ziegler. The latter was also found at the base of the *costatus* Biozone in New York (Klapper, 1971) as well as in the Prague Basin (Klapper et al., 1978). Accordingly, the base of the *costatus* Biozone in the Prague Basin is drawn near to the base of the Chotec Limestone.

Presently, there are no published records of palynomorphs from this interval from Bohemia. Herein, we record the presence of *Tasmanites*/*Leiosphaeridia* prasinophytes, which occur in masses just above the base of the Chotec Limestone and probably represent a phytoplankton bloom during the Basal Chotec Event. The reasons for the accumulation of a nearly monospecific assemblage of prasinophycean phytoplankton and the possible relations/effects to this event will be discussed.

ACKNOWLEDGMENTS

This study was supported by the project VaV DE08P04OMG002 and MSM 0021620855.

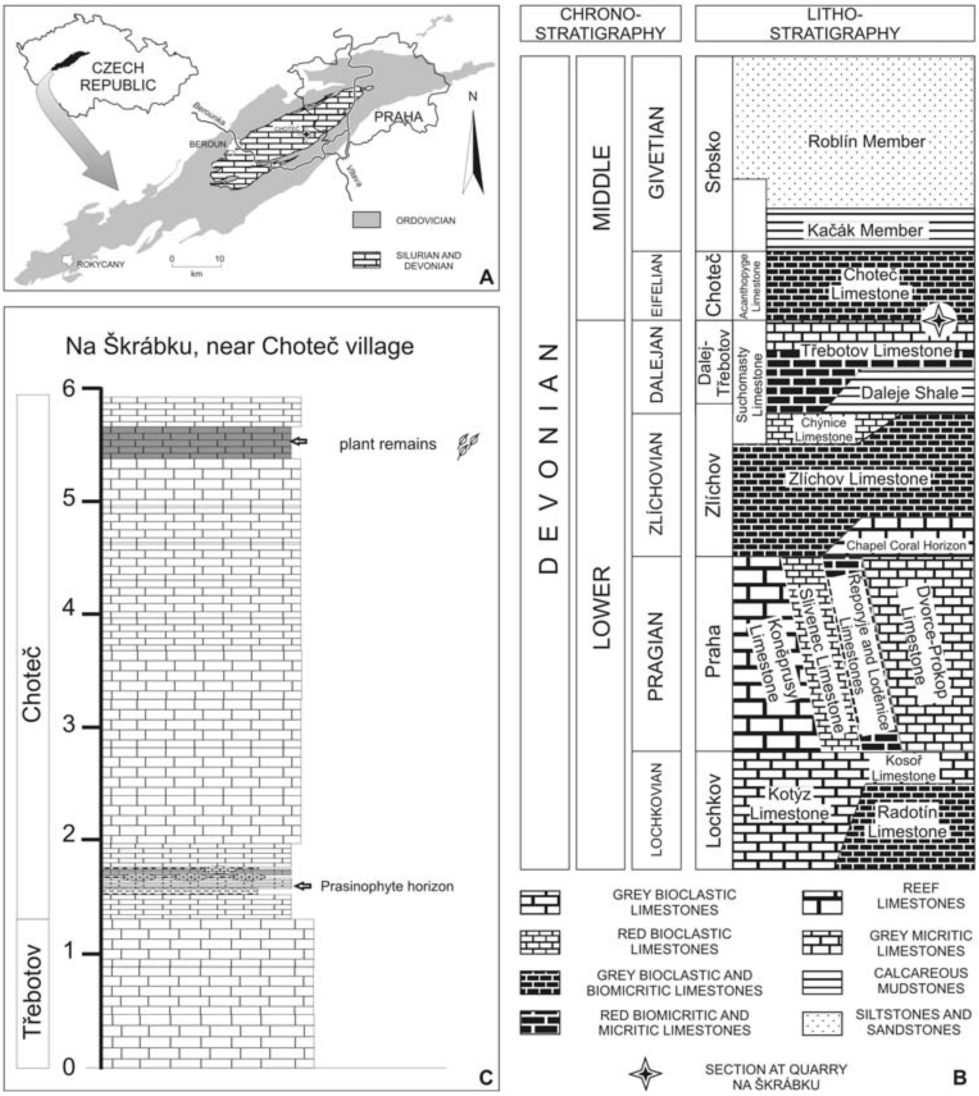

Figure 1. A: Simplified geological sketch map of the Prague Basin (Barrandian area) and the studied section in the Na Skrábku quarry near Chotec; **B:** Devonian stratigraphy of the Barrandian area (after Chlupác et al., 1998); **C:** Stratigraphic section in the Na Skrábku quarry near Chotec.

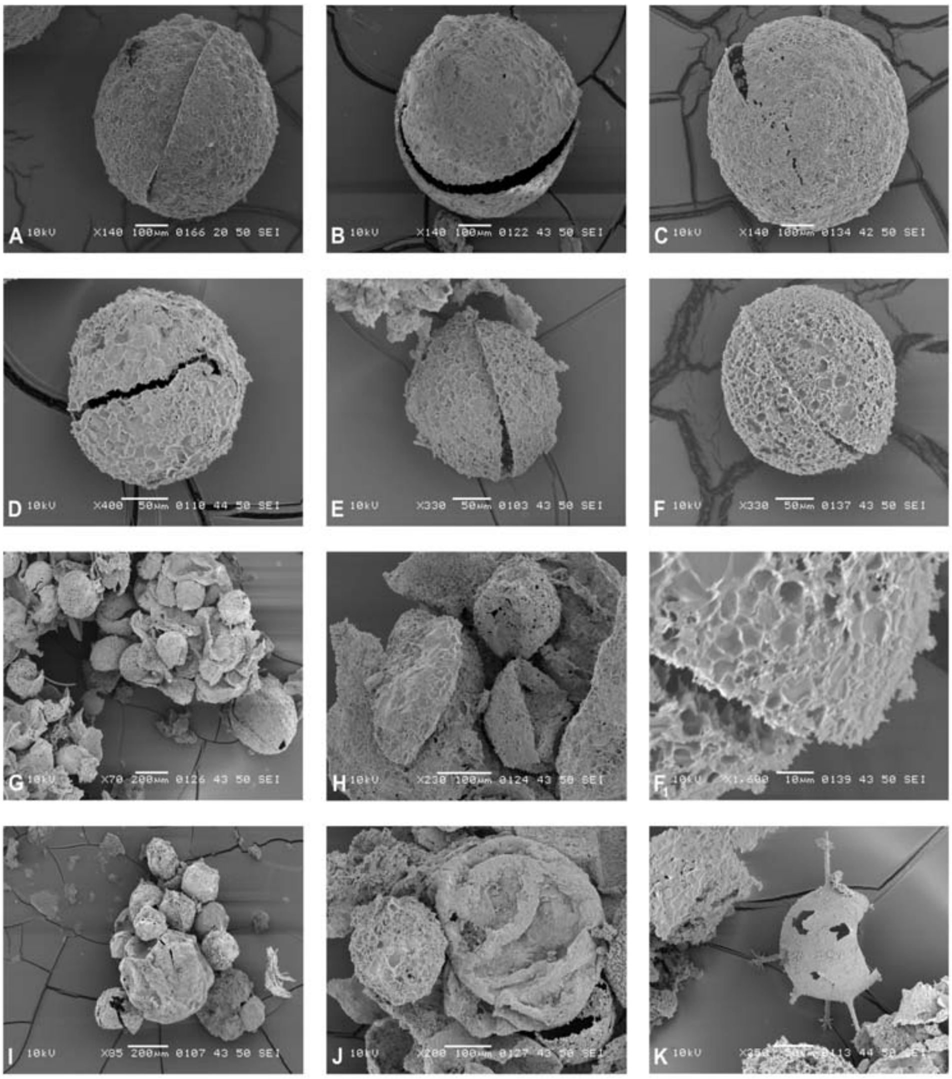

Figure 2. Palynomorphs of the Chotec Limestone. All specimens are from the prasinophyte horizon. **A-J**: *Tasmanites*/*Leiosphaeridia*; **K**: Mazuelloid.

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CARBONIFEROUS CLIMATE CYCLICITY BASED ON PALYNOLOGICAL AND SEDIMENTOLOGICAL DATA FROM DUTCH ONSHORE WELLS

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The cyclic character of many upper Carboniferous deposits can in theory be used to establish a high resolution regional cyclostratigraphical framework, which together with the available biostratigraphical schemes could enhance the resolution of stratigraphical correlations (Peppers, 1996). In this study a combination of sedimentological proxies together with palaeoecological interpretations from Westphalian B to C intervals in several Dutch onshore wells are used to establish the nature and driving factor behind the cyclothemic deposition observed in these wells.

To enable a palaeoecological interpretation of palynological signals in the late Carboniferous a link between the sporomorph and the sporomorph motherplant together with its ecology was made for the most representative sporomorph groups in the assemblages. This Sporomorph Ecogroup (SEG) technique was earlier developed and applied to Jurassic to Cretaceous deposits of the North Sea basin (Abbink et al., 2001). By means of this SEG approach a quantitative palynological signal could be used to develop a proxy to detect regional palaeoenvironmental changes. To establish a long term regional palaeoenvironmental signal, sampling for palynological analysis was restricted to subaqueous (lacustrine-marine) parts of the cyclotherms. As all palynomorphs from these settings are transported, domination by local vegetation is excluded and a more broad-scale regional environmental signal is generated. This technique is widely applied in Quartenary palynology (Faegri and Iversen, 1989) and provides a methodology to detect regional vegetation changes. The developed proxy is a ratio between the elements representing the wettest lowland SEG group and those representing a more transitional lowland environment. It is therefore suggested this proxy represents regional hydrological changes in the terrestrial part of the basin.

The periodicity of the observed palynological signal appears to be in harmony with long-period eccentricity, based on sedimentological proxies. It is thought that this cyclicity represent Milankovitch-driven base-level changes related to eustatic sea-level changes. To test this hypothesis, time-equivalent sections in Kentucky, USA were sampled recently and the same sedimentological and palynological proxies are being applied to test if similar patterns can be detected. If this is the case, this palynological technique provides a tool to apply sequence stratigraphy in Late Carboniferous terrestrial, coal bearing deposits.

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KATIAN CHITINOZOANS FROM THE RIBEIRA DA LAJE FORMATION, AMÊNDOA/MAÇÃO SYNCLINE (UPPER ORDOVICIAN), PORTUGAL

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SUMMARY

The type section of Ribeira da Laje Formation (mid Upper Ordovician, Portugal) was defined by Young (1985, 1988) in the Ribeira da Laje valley, near the Sanguinheira region, on the northern limb of the Amêndoa/Mação Syncline. The Ribeira da Laje Formation is composed of micaceous mudstones, followed by bioturbated silty sandstones, with quartzites at the top, and contains very few macrofossils. Ten samples were collected and analyzed from the type section of the Ribeira da Laje Formation, which provided moderately preserved chitinozoans assigned to the *tanvillensis* and *barbata* Chitinozoan Biozones of early to middle Katian age.

Keywords: Chitinozoans, Ribeira da Laje Formation, Upper Ordovician, Amêndoa-Mação Syncline

Young (1985, 1988) has defined the Upper Ordovician outcrops in the Amêndoa-Mação Syncline of central Portugal (Figure 1). In this region, three formations are recognized. These are the Cabeço do Peão, the Ribeira da Laje, and the Casal Carvalhal formations.

The type section for the Ribeira da Laje Formation was defined in the Ribeira da Laje valley, near the Sanguinheira region, on the northern limb of the Amêndoa/Mação Syncline (Figure 1).

The base of the Ribeira da Lage Formation is defined as the contact with the top of the conglomeratic bed of the underlying Serra de Cadaveira Member. The unit begins with micaceous mudstones followed by bioturbated silty sandstones.

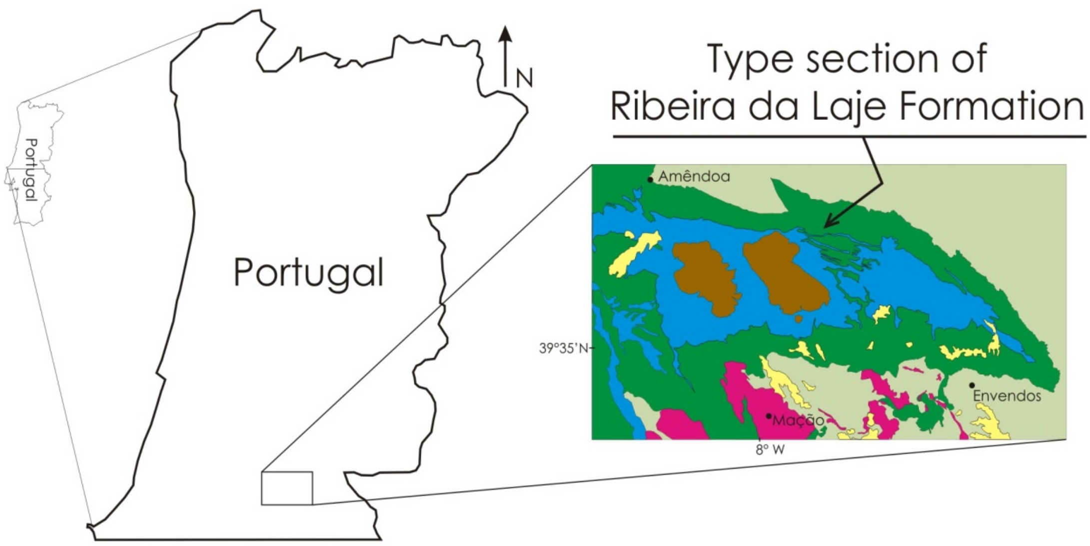

Figure 1. Localization of the Amêndoa/Mação Syncline and the type section of the Ribeira da Laje Formation (Adapted from: Geological Map of Portugal, 1/50 000 (28-A Mação), IGM, 2000).

Near the top of the sequence, there is an increase, in frequency and thickness, of discrete sandstone beds, culminating in 9 m of quartzites, and individual bed thicknesses of up to 1.5 m. The quartzites are overlain by 5 m of thinly bedded bioturbated sandstones (Young, 1985, 1988). The Ribeira da Laje Formation has very few macrofossils, and middle Ashgill age is proposed, based on correlations with the Buçaco Syncline (Young, 1985, 1988). Ten samples, constituting the basis of this study, were collected from the type section of the Ribeira da Lage Formation in the Ribeira da Laje valley (Figure 2).

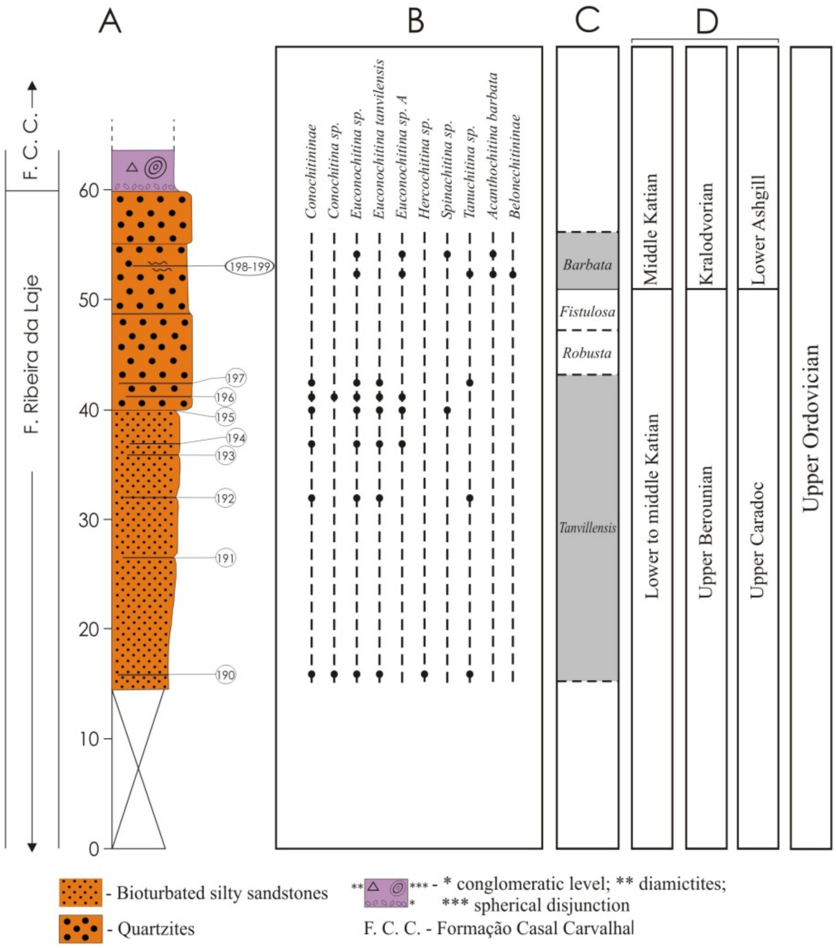

Figure 2. A. Stratigraphic log of the Ribeira da Laje Formation with the location of the studied samples (scale in meters). B. Palinostratigraphical results. C. Biozonation adapted for the North Gondwana domain (Paris, 1990, 1999; Paris and Verniers, 2005). D. Cronostratigraphic chart for the Upper Ordovician (Global Ordovician Stages, Mediterranean and North Gondwana Ordovician Stages and United Kingdom Ordovician Series (Bergström et al., 2009).

The samples were prepared using standard palynological laboratory procedures (Paris, 1981; Wood et al., 1996), and the preparations were examined with near-vertical illumination, using a Leica MZ12 stereomicroscope and a Philips-FEI Quanta 400 SEM. All samples, residues, and slides are stored in the Department of Geology, University of Trás-os-Montes and Alto Douro. Stratigraphically important and typical chitinozoan taxa are illustrated in Figure 3.

The main objective of this study was to characterize the assemblage of chitinozoans present. Two of the 10 samples proved to be barren of chitinozoans, whereas the other eight samples yielded moderately preserved specimens. Recovery rates of taxa varied between approximately six specimens/gram and 500 specimens/gram of rock.

In the studied productive samples, two key species, *Euconochitina tanvillensis* Paris *in* Robardet *et al.*, 1972 (samples 190, 192, 194-197), and *Acanthochitina barbata* Eisenack 1931 (samples 198 and 199), were recovered that allowed placement in the *tanvillensis* Chitinozoan biozone (Paris, 1990, 1999) and the *barbata* Chitinozoan biozone (Paris, 1999; Paris and Verniers, 2005) respectively. These biozones are of early to middle Katian age (Figure 2). Several other genera were also found, and they include: *Conochitina*, *Euconochitina*, *Hercochitina*, *Spinachitina*, and *Tanuchitina*. Samples 194, 195, 196, and 198, collected in the intercalated levels of the quartzites, and sample 199 from the bioturbated quartzites, contain *Acanthochitina barbata*, and, what appears to be a new species of *Euconochitina* (Figure 3).

The micaceous mudstones, as well as in the bioturbated silty sandstones of the basal portion of the Ribeira da Laje Formation contain poorly preserved brachiopods and many ichnofossils (Romão, 2000). The common presence of the chitinozoan guide species *Euconochitina tanvillensis* Paris *in* Robardet *et al.*, 1972 and *Acanthochitina barbata* Eisenack 1931, suggests an early to middle Katian [upper Berounian to Kralodvorian, Mediterranean and North Gondwana Ordovician Stages, middle Caradoc to lower Ashgill, United Kingdom Ordovician Series, (Bergström et al., 2009)] age for the Ribeira da Laje Formation. This age is somewhat older than the age (middle Ashgill) suggested by the brachiopods data and by lateral correlation with the established biostratigraphy for the Buçaco Syncline (Young, 1985, 1988).

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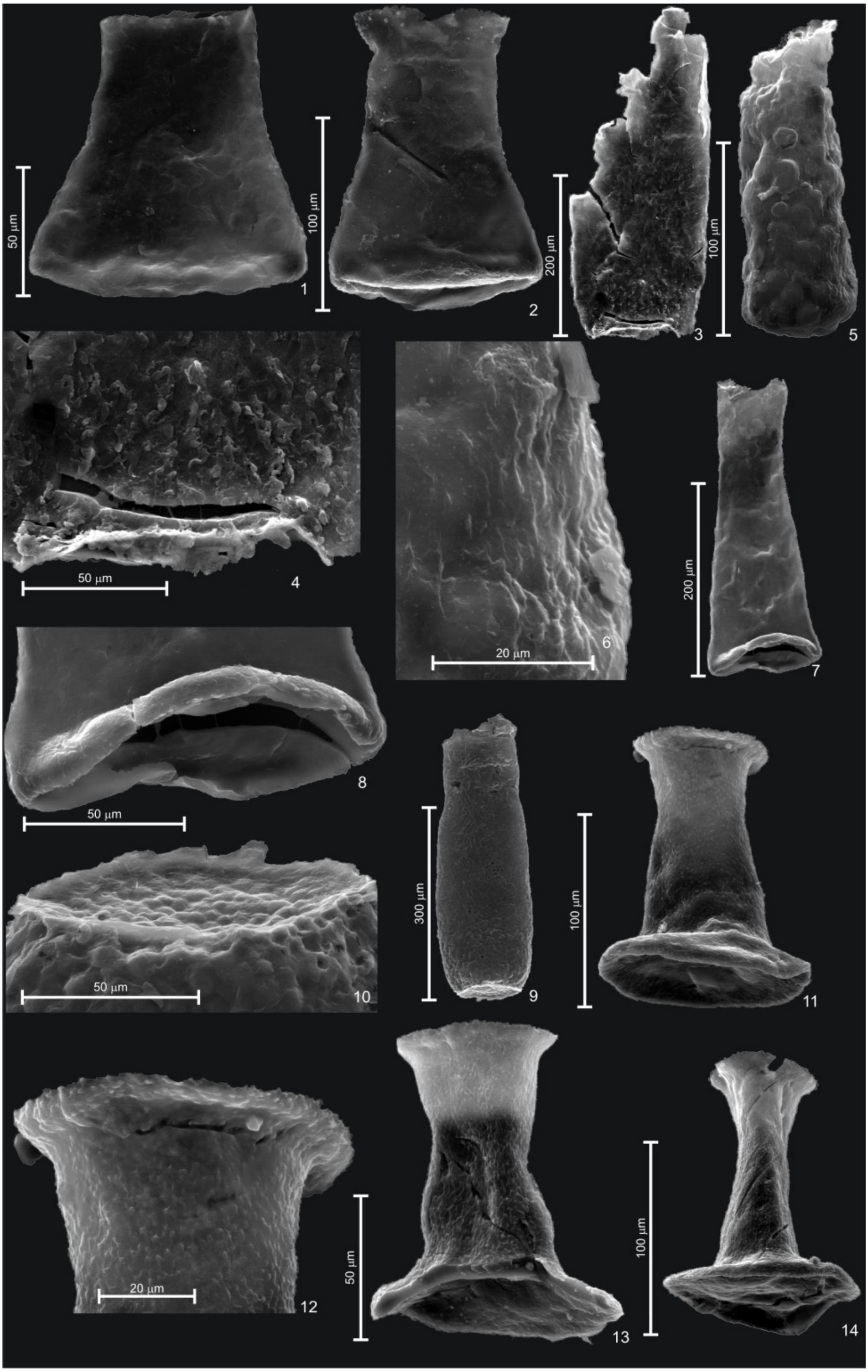

Figure 3. 1, 2. *Euconochitina tanvillensis* Paris *in* Robardet *et al.*, 1972. 3, 4. *Acanthochitina barbata* Eisenack 1931. 5, 6. *Hercochitina* sp. 7, 8. *Spinachitina* sp. 9, 10. *Tanuchitina* sp. 11, 14. *Euconochitina* sp. A.

SPORE WALL ULTRASTRUCTURE OF DEVONIAN *EMPHANISPORITES*: EVIDENCE FOR RAMPANT CONVERGENCE - BUT WHY?

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SUMMARY

Among dispersed Silurian-Devonian spore genera none are more distinctive than *Emphanisporites*. Members of this form genus possess radiating sculptural patterns on their proximal surfaces. *Emphanisporites* is widespread, diverse (with over 50 described species) and displays phenomenal morphological disparity. In an attempt to determine the parent plant(s) of this spore type, we used transmission electron microscopy (TEM) to examine numerous serial sections of several Lower Devonian species: *E. rotatus, E. annulatus* and *E. schultzi.* They all have remarkably different ultrastructural characteristics. This degree of ultrastructural variability is unexpected, and suggests that very different plant groups may have produced these spores, seemingly building their spores in different ways but converging on a common structural theme. It is possible that some of the differences may be attributable to natural variation, developmental stage or preservational vagaries, but we discount these as the main agents as all specimens are dispersed spores (i.e. most likely mature) and from the same sample. Such widespread appearances of generalized morphological types, that seemingly appear rapidly, diversify and dominate and then decline rapidly, occur throughout the dispersed spore/pollen record (e.g., grapnel-tipped spines, taeniate pollen, triprojectate pollen). Possible explanations for this phenomenon include adaptive radiations, convergence due to common (as yet unrecognized) internal or external function, and/or some other pathway of evolutionary/informational transmission (e.g. emergence).

Keywords: Devonian; spores; *Emphanisporites*; wall ultrastructure.

A LATE DEVONIAN PALYNOMORPH ASSEMBLAGE FROM BOLIVIA AND ITS IMPLICATION FOR SOUTH AMERICAN GLACIATION

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SUMMARY

A well-preserved and somewhat abundant acritarch, prasinophyte, and spore assemblage was recovered from the uppermost three meters of the Iquiri Formation and overlying 18 m+ of the lower Itacua Formation at the Bermejo West section, approximately 80 km southwest of Santa Cruz, Bolivia. Analysis of the samples, taken at approximately 1 m intervals, places the uppermost 3 m of the Iquiri Formation within the VCo-VH miospore biozone ("*Rugospora radiata*" Assemblage). The overlying Itacua Formation, consisting of diamictites, sandstone lenses, and a number of large deformed sedimentary blocks, can be assigned, in ascending stratigraphic order, to the LL, LE, and LN miospore biozones of Western Europe. However, the majority of the succession is LN miospore biozone in age. Whereas the acritarch and prasinophyte assemblages are not as biostratigraphically precise, they are, nonetheless, consistent with a Late Devonian (Famennian) age. The diamictite facies of the Itacua Formation, exposed at this location, indicates an unknown number of glaciation and deglaciation events. However, the final deglaciation for which palynologic evidence is preserved occurred during latest (LN miospore biozone) Devonian time.

Keywords: Late Devonian, Bolivia, Iquiri and Itacua formations, miospores, acritarchs, prasinophytes, glaciation

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A palynologic analysis of the uppermost Iquiri Formation and overlying diamictite facies of the Itacua Formation from Bolivia indicates a Late Devonian (late Famennian) age. Whereas the Itacua Formation has been previously considered "Devono-Carboniferous" or "Early Carboniferous" in age based on megafossil and lithostratigraphy, the recovery of a well-preserved acritarch, prasinophyte, and spore assemblage definitively dictates a Late Devonian (Strunian) age. In fact, there are no definitive Carboniferous spore or marine phytoplankton species in any of the samples examined.

The Bermejo West section is located approximately 80 km southwest of Santa Cruz, Bolivia (Figure 1). At this location, samples were taken from the uppermost three meters of the Iquiri Formation, which consists of shale with some sandstone layers, as well as the overlying 18 m+ of the Itacua Formation, consisting of diamictites, sandstone lenses, and a large deformed sedimentary block (Figure 2). The contact between the Iquiri and Itacua formations at this location is sheared, with local differential movement along what is interpreted to be an unconformity or condensation.

Three samples from the uppermost Iquiri Formation yielded a well-preserved, diverse, and abundant acritarch and prasinophyte assemblage, as well as a low diversity, but equally well-preserved miospore assemblage, indicating a late Famennian (somewhere within the VCo-VH miospore biozone) age.

The 18 samples from the overlying Itacua Formation follow a normal ascending stratigraphic succession, consisting of the LL, LE, and LN miospore biozones, suggesting the sequence spans the Strunian. Three samples from a large (1 m+) bedded and deformed block located approximately 7 m above the base of the Itacua Formation all indicate an LN miospore biozone age. Furthermore, this 'exotic' block sits just below the base of the LN miospore biozone within the Itacua Formation.

The acritarch and prasinophyte assemblage, which is more diverse and abundant than the spores in nearly all of the samples examined, indicates a Late Devonian (Famennian) age for the upper Iquiri and lower Itacua formations, thus corroborating the miospore age assignments. However, the miospores allow for a more detailed age assessment in terms of comparison to the Western European spore zones.

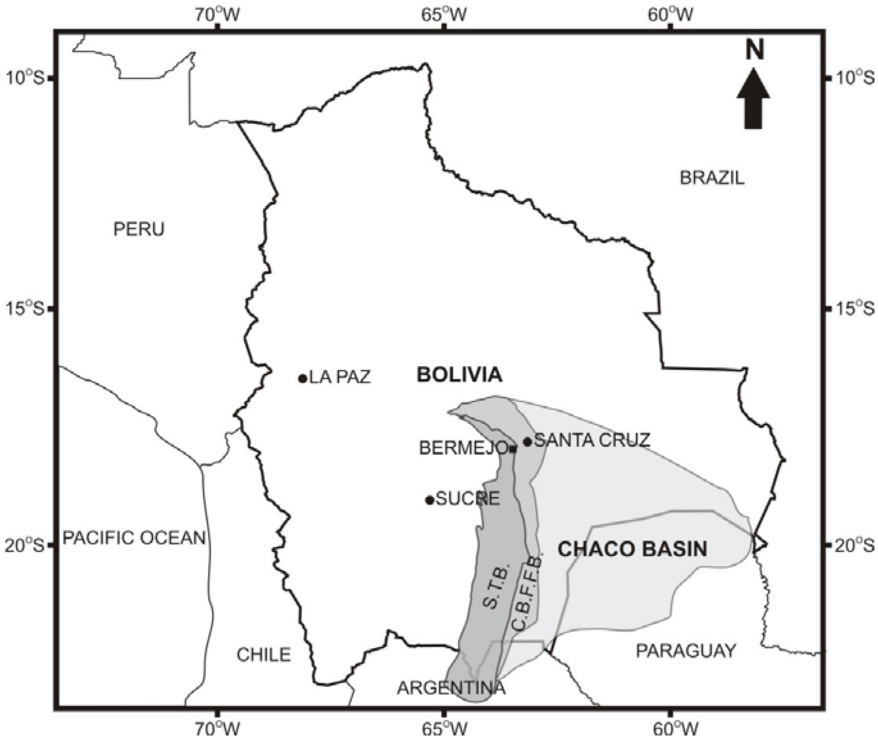

Figure 1. Outline map of Bolivia showing the sampled Devonian locality at Bermejo. Major cities are shown as black circles. Superimposed is the Chaco Basin, which is subdivided into the Subandean Thrust Belt and the Chaco Basin Foreland Fold Belt.

The acritarch and prasinophyte assemblage from the uppermost Iquiri Formation includes 29 species, whereas 38 species were recovered from the overlying Itacua Formation. The total assemblage contains the following abundant and characteristic Late Devonian species: *Cymatiosphaera ambotrocha, Daillydium pentaster, Duvernaysphaera angelae, D. radiata, Evittia geometrica, Exochoderma arca/irregulare, Gorgonisphaeridium discissum, G. ohioense, Horologinella quadrispina, Maranhites brasiliensis, M. mosesii, Pyloferites pentagonalis, Umbellasphaeridium deflandrei, U. saharicum,* and *Veryhachium polyaster*. In addition, several long ranging, as well as possibly reworked species, such as *Baltisphaeridium distentum, Muraticavea munificus, Navifusa bacilla, Polyedryxium pharaonis, Pterospermella pernambucensis, Stellinium micropolygonale, Tyligmasoma alargada,* and *Veryhachium trispinosum* complex also were recorded. The total marine microphytoplankton assemblage is thus very characteristic of the Late Devonian.

In terms of the spore assemblage, the succession of miospore biozones through the diamictitic facies of the Itacua Formation at this location follows a normal ascending stratigraphic sequence of the LL, LE, and LN miospore biozones. There is no evidence to suggest any mixing of the biozones through reworking of the spores.

Specifically, the three samples of the uppermost Iquiri Formation yielded a low diversity assemblage of miospores, including *Rugospora radiata*. The absence of *Retispora lepidophyta* in all three samples indicates this part of the Iquiri Formation falls within the VCo-VH miospore biozone. Thus, we assign these three samples to the "*Rugospora radiata*" Assemblage.

The first meter of the overlying Itacua Formation above the contact between the Iquiri and Itacua formations is tentatively assigned to the LL miospore biozones based on the presence of rare specimens of *Retispora lepidophyta*.

The next five meters are assigned to the LE miospore biozone based on the addition of rare specimens of *Indotriradites explanatus*, and an increase in the number of specimens of *Retispora lepidophyta*, such that their occurrence can be considered common in these samples.

The remaining 11+ meters of section, including the large 'exotic' sedimentary block, are placed in the LN miospore biozone. This assignment is based on the continued presence of *Retispora lepidophyta* and the first appearance of *Verrucosisporites nitidus*.

Despite the rare occurrence and sometimes lack of index spores used to define the Late Devonian European miospore biozones, the presence of some stratigraphically-useful miospores from northern Gondwana permit broad correlation with Western Europe for the sampled intervals of the upper Iquiri and lower Itacua formations at the Bermejo West locality.

According to Caputo et al. (2008), three glacial episodes have been identified in Upper Devonian and Lower Mississippian strata in South America. These are based on a variety of sedimentologic, stratigraphic, and paleontologic data. The first glacial episode, interpreted from diamictites deposited in basins in Peru, Bolivia, and Brazil, occurred during the late Famennian and corresponds to the LE and LN miospore biozones of Western Europe. The second and third glacial episodes occurred during the late mid to early late Tournaisian and late Visean respectively.

The Bolivian diamictite succession cropping out at this location records an unknown number of glaciation and deglaciation events spanning the whole of the Strunian. The final deglaciation for which palynologic evidence is preserved, indicates that it occurred during latest Devonian (LN miospore biozone) time.

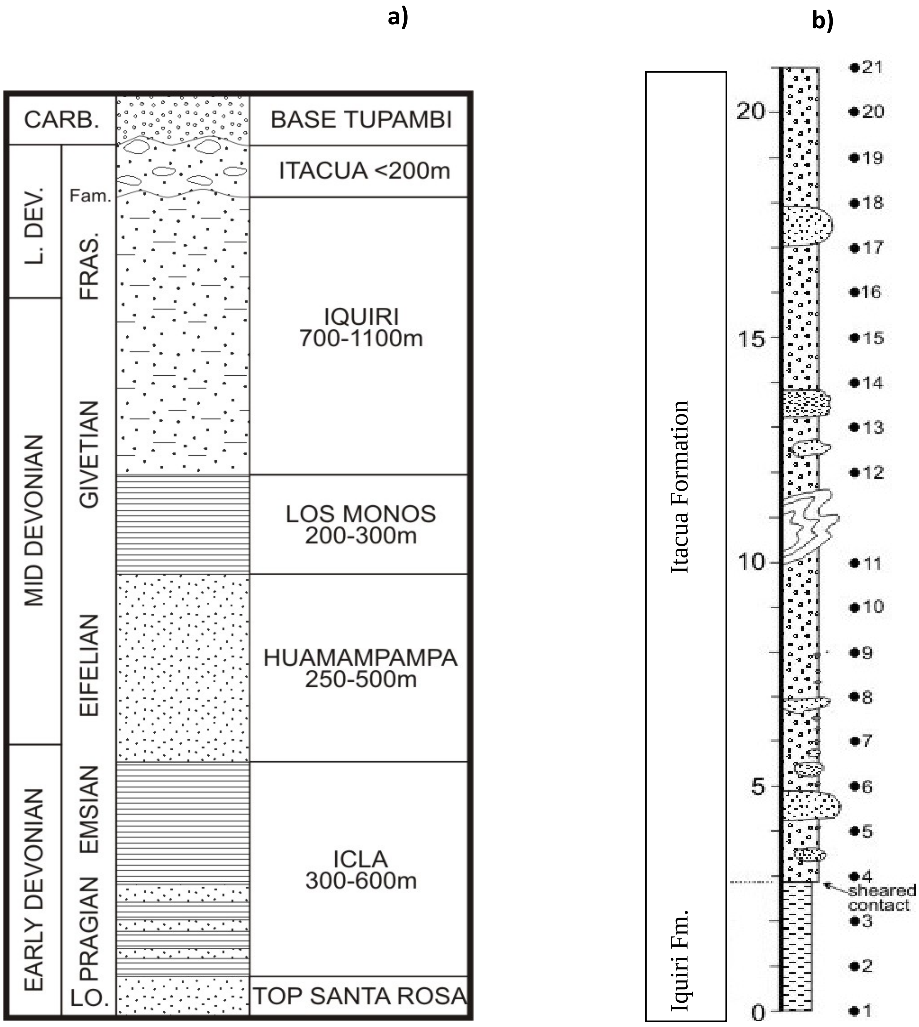

Figure 2. (a) Generalized Devonian lithostratigraphy in the Subandean Fold Belt. (b) Stratigraphic section at Bermejo West, showing formations, thickness, and sample numbers.

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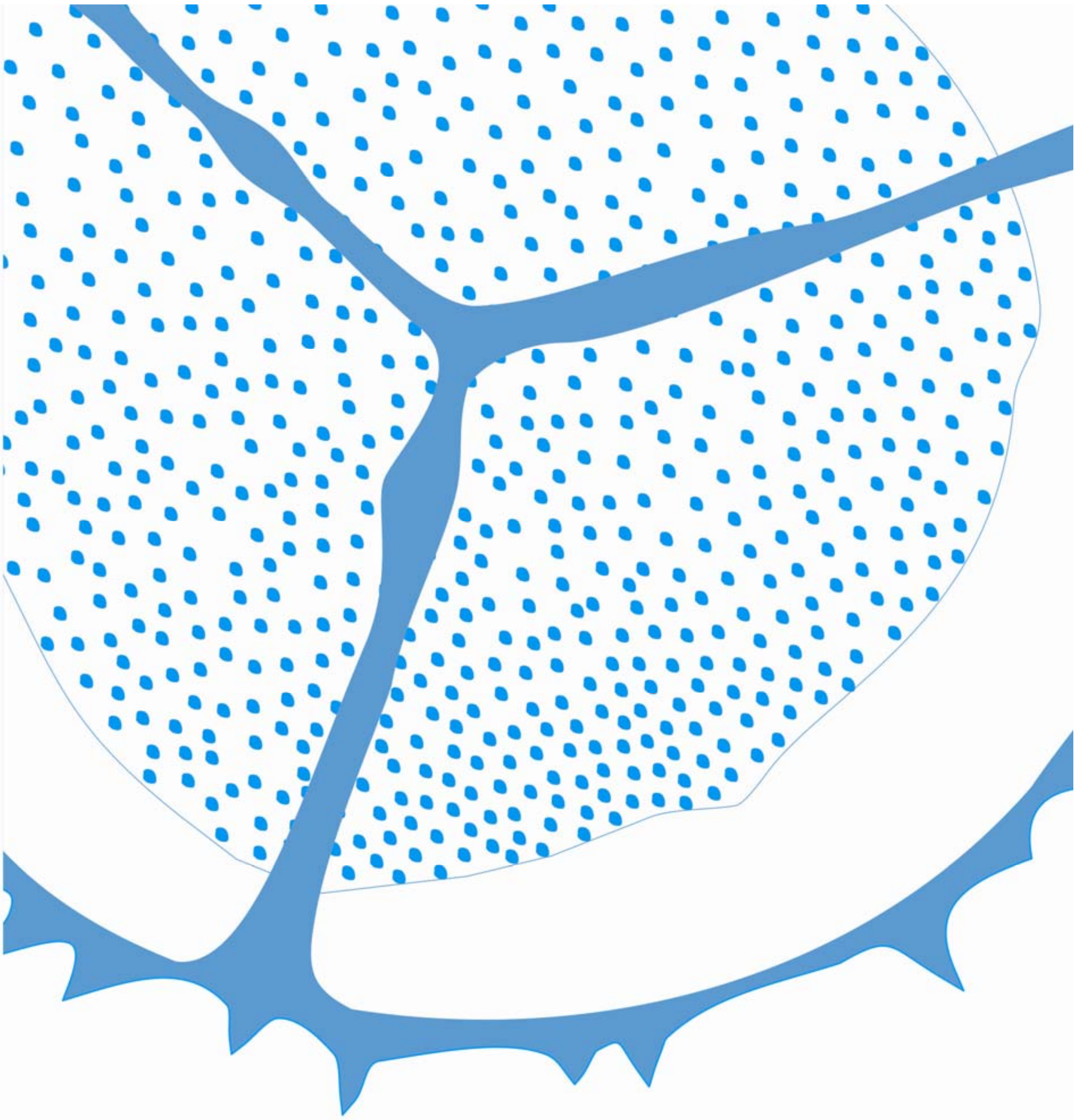

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