A PALYNOLOGICAL APPROACH TO TERRANE ANALYSIS IN THE SOUTH PORTUGUESE ZONE

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TRABAJOS DE GEOLOGIA

Lake, P. A., Oswin, W. M. and Marshall, J. E. A. (1988).—A palynological approach to terrane analysis in the South Portuguese Zone. *Trabajos de Geología,* Univ. de Oviedo, 17, 125-131. ISSN 0474-9588.

El estudio de palinomorfos procedentes de las pizarras del complejo de filitas y cuarcitas han permitido establecer una edad Givetiense Superior para dicho complejo. Datos anteriores indicaban para el mismo una edad Fameninse. Este dato puede afectar la edad, Fameniense/Turnesiense para el vulcanismo en general y para el del área al este de Río Tinto en particular. Se consideran varias explicaciones posibles para esta inconsistencia en las edades: datación incorrecta de alguna de las muestras, diacronía para el vulcanismo de la base del complejo VS, tectónica sin-sedimentaria o dislocación tectónica subsecuente.

Palabras clave: Zona Sur Portuguesa, Palinología, Devónico, Vulcanismo.

[Traducido por la revista]

Recent work in the Spanish part of the Iberian Pyrite Belt has shown there to be a potential use for palynology in elucidating the poorly defined stratigraphy. Palynomorphs have been recovered from Phyllite/Quartzite Group slates and Late Givetian ages established. This adds to previously published data which indicate Famennian ages for this Group. These ages may affect the proposed Famennian/Tournaisian timing of volcanism in general and in the east of Río Tinto area in particular. Possible explanations for this age anomaly considered are: —incorrect dating of either sample, a diachronous base to Volcano-Sedimentary Group volcanism, syn-sedimentary tectonism or subsequent tectonic dislocation.

Key words: South Portuguese Zone, Palynology, Devonian, Volcanism.

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The main obstacle to a better understanding of Pyrite Belt and South Portuguese Zone geology is the lack of a detailed, unified stratigraphy. Complex tectonics compound this problem.

Current stratigraphic schemes are based largely on lithostratigraphic subdivisions. The lack of regional lithological marker horizons hinder the development of a workable stratigraphy. Rather monotonous, similar looking sediments enclose the VS Group volcanics which are characterized by rapid lateral facies changes.

The need for well constrained biostratigraphic markers in this region is obvious. Macropalaeontology has failed to produce such indicators due to the general paucity, and deformation of fossil remains. The widespread presence of palynomorphs however suggests that a palynological approach can generate a workable biostratigraphy.

GEOLOGICAL SETTING

The South Portuguese Zone (Lotze 1945; Julivert *et al.* 1972; Julivert 1984) is the most southerly zone of the Hercynian fold belt in Iberia. It can be divided (Fig. 1) into a number of approximately east-west trending lithostratigraphic divisions (after Oliveira, *et al.*, 1986), these are (from north to south):

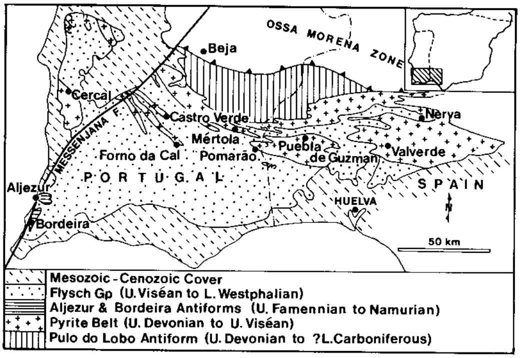

Fig. 1.—Tectono-Stratigraphic domains of the South Portuguese Zone (after Oliveira *et al.*, 1986).

(1) Pulo do Lobo Antiform.
(2) Iberian Pyrite Belt.
(3) Flysch Group.
(4) Aljezur-Bordeira Antiform.

The Pulo de Lobo Antiform (Pfefferkorn, 1968; Schermerhorn, 1971; Carvalho *et al.*, Oliveira, 1983; Oliveira, in press) contains a thick sequence of clastic sediments divisible into several formations. The basal, Pulo Formation (Pfefferkorn, 1968; Oliveira, 1983) consists of strongly deformed phyllites, minor quartzites, interbedded volcanics and basalts. No ages have been established for this formation. The overlying strata have been divided into separate groups on either side of the Pulo do Lobo Antiform (Carvalho *et al.*, 1976; Oliveira, 1983; Oliveira *et al.*, 1987). South of the fold axis the Chança Group is composed of the Atalaia Formation (sandstones and phyllites); the Gafo Formation (a turbiditic sandstone shale unit with intercalations of acid and mafic volcanics [Vale de agua volcanics] and intrusions of basic and acid dykes) and the Represa Formation (a local variation of the Gafo Formation composed of siliceous siltstones, shales and quartzwackes). North of the fold axis the Ribeira de Limas Formation (sandstones phyllites and rare tuffites); the Santa Iria Formation (a greywacke/shale turbiditic unit with sandstones and rare limestones) and the Horta da Torre Formation (shales, impure sandstones and siltstones with quartzite beds towards the top) comprise the Ferreira-Ficalho Group. The similarity between formations in both limbs would suggest minor lateral facies changes across the hinge. The Horta da Torre Formation yields palynomorphs of mid-Famennian age (Oliveira *et al.*, 1987).

The Iberian Pyrite Belt is an arcuate belt of upper Palaeozoic strata some two hundred and thirty kilometres long and up to thirty five kilometres wide. From Aznalcollar northwest of Sevilla it stretches north westwards to the Portuguese coast approximately one hundred kilometres south of Lisbon.

The stratigraphy has been divided into three main lithostratigraphic groups or «rock units» (Schermerhorn, 1971). These have been renamed as Groups to produce a more representative and stratigraphically acceptable terminology.

(1) *Culm Group:* a flysch dominated succession of Upper Viséan to Mid-Westphalian age, referred to as the *Flysch Group* in Portugal where it is well developed.

(2) *Volcanic-Sedimentary or VS Group:* an occasionally silicified, possibly cyclic bimodal suite of shallow intrusives and extrusives set within a shale dominated succession. Ages of Early Famennian to Late Viséan have been established using conodonts (Boogaard, 1967; Boogaard and Schermerhorn, 1981; Oliveira, 1983), brachiopods (Quiring, 1936); Carrington da Costa, 1943); Goniatites (Oliveira, 1983) and whole rock Rb-Sr isotope dates (Priem, 1968).

(3) *The Phyllite/Quartzite or PQ Group:* original shales, silts, quartzwackes and minor limestones, are now seen as slates, phyllites and quartzites. Limestone lenses within this succession have been dated using conodonts as Famennian (Boogaard & Schermerhorn, 1975; 1980; 1981). The basement to this sequence is not seen.

The Flysch Group (Baixo-Alentejo Flysch Group) is a turbiditic sequence of slates and greywackes. The succession can be divided into three formations; Mértola (Late Viséan), Mira (Latest Viséan-Late Namurian) and Brejeira Formations (Mid Namurian-Early Westphalian). Locally dark grey slates overlying the VS Group volcanics grade up into proximal turbidites of the Mértola Formation. In the northern part of the Pyrite Belt this boundary is often tectonised and in places (Lousal, east of Castro Verde) greywackes overly basic volcanics (Oliveira, 1983). Oliveira *et al.* (1979) cited such disconformities and the similarity of VS Group lithologies to flysch clasts and suggested the possibility of local emergence and erosion of Pyrite Belt volcanoclastics. Unconformities have yet to be proven and the main flysch sediment source area is still thought to be the Beja Geanticline further north. Detailed accounts of sedimentology and stratigraphy are given in Oliveira *et al.* (1979) and Oliveira (1983). A south-westwards progradation of both thrusting and related flysch sedimentation is seen. In the Pyrite Belt, flysch deposition has been dated as Late Viséan (Carrington da Costa, 1943; Feio, 1946; Delépine, 1957). South of Odemira in the south-west of Portugal dates as young as Westphalian A have been recorded (Delépine, 1957).

Aljezur and Bordeira Antiforms: the succession here consists of five main Formations: Tercenas, Bordalete, Murração, Quebradas and Brejeira (Oliveira, *et al.*, 1985; Oliveira *et al.*, 1986). The Tercenas Formation composes Famennian phyllites and minor quartzites of a tidal dominated shelf environment. These probably represent the western basin margin equivalents of Pyrite Belt PQ Group deposits. The overlying Bordalete Formation dated at Middle-Late Tournaisian (Oliveira *et al.*, 1985) is coeval with the Pyrite Belt VS Group but is only represented by a few tens of metres of grey to grey-black laminated shales and siltstones. In the Pyrite Belt further to the north-east equivalent deposits attain stratigraphic thicknesses of several kilometres (Schermerhorn, 1971). The Murração and Quebradas Formations consist of a relatively thin succession of marly muds, shales, limestones and minor reworked tuffites with 'phosphorite' nodules (Oliveira *et al.*, 1985) occurring near to their top. Citing available fossil evidence and restricted stratigraphic thicknesses, Oliveira *et al.* (1985) have suggested a late Viséan hiatus in the south-west Portuguese area. The subsidence which affected northern areas in late Viséan times finally reached south-west Portugal by the Westphalian when this shoal area finally subsided. The turbiditic sediments of the Brejeira Formation then overlapped onto Flysch Group sediments.

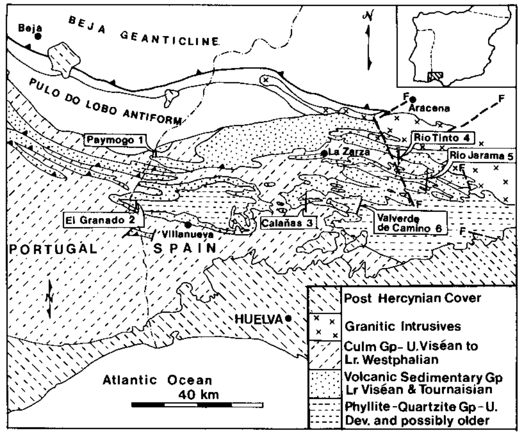

Fig. 3.—Generalized geological map of the Spanish part of the Iberian Pyrite belt (after I.G.M.E.) showing the location of numbered sections.

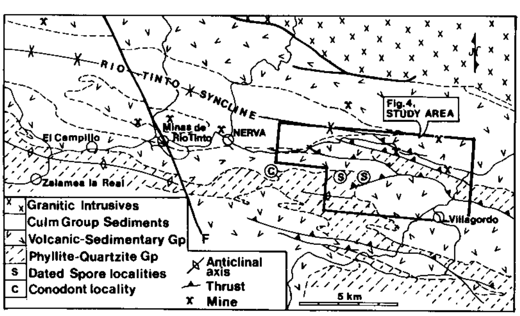

Fig. 2.—Simplified geological map of the Río Tinto area (partly after I.G.M.E. geological sheets 938 and 939). The Río Jarama research area is indicated.

A PALYNOLOGICAL APPROACH

The feasibility of a palynological approach was first realised following the discovery of datable spore assemblages in slates and phyllites from the area east of Río Tinto (Fig. 2).

Subsequently a wider ranging reconnaissance survey was carried out throughout the south Portuguese Zone. From this, six sections within the Spanish half of the Iberian Pyrite Belt were selected for further investigation (Fig. 3). These are areas where good outcrop permits structural sections to be drawn and dominant lithologies indicate a possibly high organic component. Four of these sections have so far been sampled at intervals varying between twenty and two hundred metres depending on the structure and the

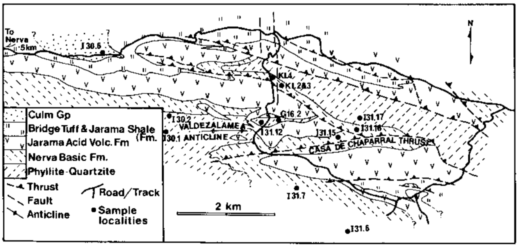

Fig. 4.–Palynological black shale-slate sample localities.

presence of suitable lithological hosts. Processing has largely been completed and detailed taxonomic work is being undertaken.

Several problems have been encountered using palynomorphs from these sections. The main difficulty is the relative scarcity of «fresh» (unoxidised) material. The combination of climate and the chemical characteristics of many of the lithotypes combine to reduce the preservation potential of organic walled microfossils in surface exposures.

A second major problem has been produced by the relatively high temperatures reached during late Hercynian orogenic activity (Schermerhorn, 1975). This is indicated by the opaque nature of palynomorphs and the high levels of vitrinite reflectance.

These problems have now largely been overcome by careful sampling of fresh material and controlled oxidation and stabilization of kerogen concentrates (Marshall, 1980).

RESULTS FROM THE RIO JARAMA AREA

Some fifteen samples were originally processed from the Río Jarama area (see Fig. 4 for sample localities). Two of these (I30.1 and I31.12) proved to contain a datable spore assemblage. Of the others three contained minor spore concentrations, five woody fragments only, whilst the rest were barren. The two productive samples I30.1 and I31.12 lie some five kilometres east-south-east of Nerva on a minor anticline related to hanging wall deformation in the Casa de Chaparral thrust (Fig. 2 and 4). Both are samples of PQ Group slates; one within fifty metres, and the other two hundred metres of the contact with Nerva Basic Formation volcanics. The Nerva Basic Formation being the lowest formation in the VS Group (see Table I).

In terms of Pyrite Belt Geology (Fig. 2) this thrust lies on the northern limb of a west-north-west trending anticline just south of the main Río Tinto synclinorium. The massive stratiform sulphides comprising the Río Tinto ore bodies occur in a structural dome of felsic volcanics within this main synclinorium.

PALAEONTOLOGY

The taxa present and their relative abundances are listed in Table II. Established species are present although spore diameters

Table I.–General stratigraphy of the area east of Río Tinto (Río Jarama) after Oswin (1986).

CULM GROUP		
VOLCANO SEDIMENTARY GROUP	UPPER JARAMA SHALE FORMATION	
	BRIDGE TUFF FORMATION	
	JARAMA ACID VOLCANIC FORMATION	MOZOS MEMBER
		SIERRA BLANCA MEMBER
		JABATILLA MEMBER
		CANOS MEMBER
	NERVA BASIC FORMATION	
PHYLLITE QUARTZITE GROUP		

TABLE II.–Miospore contents of black shale-slate samples from the area of Río Jarama (East of Río Tinto)

Samples.	I30.1	I31.12	I30.2	I31.6	I31.16
Species.					
Geminospora lemurata	A	A	P	A	P
Chelinospora concinna	P				
Calamospora atava	P	P	P		
Rhabdosporites langii	P				
Verrucosisporites premnus	P				
Grandispora velata	P				
Convolutispora cf. *disparalis*	P				
Emphanisporites rotatus	P				
Geminospora verrucosa	P				
Densosporites conncinus	P				
Calamospora pannucea	P				
Cristatisprites triangulatus	P	P			
Insculptospora confossa	P	P			
Emphanisporites annulatus	P	P			
Cirratriradites avius	P				
Retrusotriletes rugatus	P	P			
Ancyrospora cf. *langii*	P				

A = Abundant, P = Present.
Additionally K1.3, I30.6 and I30.7 contained only woody kerogen.

show a marked skew towards the lower end of published size ranges.

This would suggest that the assemblages are rather distal in relation to the probable palynomorph source area. The date for the assemblage is derived from three main taxa. The combination of abundant *Geminospora lemurata, Cristatisporites triangulatus* and *Chelinospora concinna* places the assemblage in the Optivus-Triangulatus zone of Richardson and Mc Gregor (1986) and the TCo zone of Streel *et al.* (1987). This indicates a Late Givetian/Early Frasnian date.

DISCUSSION

Elsewhere in the Pyrite Belt: Forno da Cal and Pomarão in Portugal (Boogaard, 1963; Boogaard & Schermerhorn, 1981), Cabezas del Pasto near Puebla de Guzmán and Nerva near Río Tinto in Spain (Boogaard & Schermerhorn, 1975; 1980), conodont assemblages have been recovered from limestone lenses within the PQ Group succession. In all instances these indicate a Famennian age. The nearest conodont locality to the Río Jarama area (Fig. 2) comes from south-east of Río Tinto (Boogaard & Schermerhorn, 1980). This lies in a similar stratigraphic position to the palynologically dated samples (just below VS Group volcanics and only five kilometres geographically west along strike).

The conodont and spore data are in apparent conflict. Spore data would indicate the onset of volcanism as being soon after the Givetian whilst the conodont data suggests a Late Famennian to Tournaisian event.

There are several possible explanations of this age anomaly:

1) Either sample has been incorrectly dated. This is unlikely. The conodont dates were ascertained using some four thousand individual elements whilst the spore assemblage showed a highly characteristic Late Givetian microflora. The anomaly could be explained by reworking of the spore assemblage. This again seems unlikely as normally in such circumstances at least some evidence of the younger assemblage is seen. Accepting both dates to be correct we must look for other possible reasons.

2) The onset of volcanism is highly diachronous. If volcanism commenced in the Río Jarama area in the Frasnian, some twelve million years before the similar event in the south-east Río Tinto area, this would explain

the apparent two stage disparity in the VS Group/PQ Group boundary dating in both areas.

Initial volcanic activity in the eastern part of the Pyrite Belt is dominantly basaltic (spilitised) pillow lavas. Considering the aerial extent of modern day basic lavas such a large anomaly over, only five kilometres would initially seem unreasonable. Detailed lithological mapping in this area by Oswin (1986) indicates that palaeotopography, probably associated with rifting on an east-west axis played an important role in the distribution of volcanic centres. Volcanic deposits could show highly localised facies distribution at a rift margin. The south-east Río Tinto area may represent a rift shoulder not enveloped by volcanic deposits until the adjacent basin was filled. The likelihood of a diachronous base to VS Group volcanism is therefore real although possibly more important on a regional scale.

3) Syn-sedimentary tectonism. The two stage (twelve million year) disparity between these samples could be explained by the presence of syn-depositional erosion or non deposition, generating local unconformities.

4) Subsequent tectonic dislocation. Much of the shortening within the succession is taken up by the less competent slates. This coupled with the lack of marker horizons or detailed biostratigraphic control produces great uncertainty as to the true stratigraphic position; especially where exposure is limited or highly weathered. Structural control is therefore of great importance as without this, any dates are of reduced value.

Any conclusions concerning the precise reason for the age anomaly, the commencement of VS Group volcanism or the nature of the VS/PQ Group boundary itself, must await further detailed work. More extensive sampling especially in the area inmediately surrounding Boogaard's conodont localities will facilitate local correlation between spores and conodonts.

Problems concerning the precise timing and possibly diachronous nature of VS Group volcanism will also be investigated in future work.

CONCLUSIONS

1) A stratigraphic scheme based on lithostratigraphic subdivisions is of restricted use in the Pyrite Belt as few lithological marker horizons exist.

2) The recovery of kerogens from across the Pyrite Belt indicates the potential for constructing a biostratigraphic scheme for this area.

3) Palynomorph ages indicate a Late Givetian deposition for some PQ Group slates. These are the oldest ages established to date.

4) Precise structural control is needed to satisfactorily interpret palynological data.

5) Palynological data will give the potential to assess whether local lithostratigraphies can be correlated.

ACKNOWLEDGEMENTS

We would like to express our gratitude to Dr. J. R. Andrews for editing the manuscript and much constructive criticism and Anthea Dunkley for drafting the diagrams. Thanks also to all the postgrads and staff at Southampton University Geology Department.

REFERENCES

Boogaard, M. Van Den (1963).–Conodonts of Upper Devonian and Lower Carboniferous age from Southern Portugal. *Geol. Mijnbouw*, **42**, 248-259.

—— (1967).–*Geology of the Pomarão region (Southern Portugal)*. Grafisch Centrum Deltro Rotterdam (thesis) Amsterdam.

—— and Schermerhorn, L. J. G. (1975).–Conodont faunas from Portugal and south-western Spain. Part 2. A Famennian conodont fauna at Cabezas del Pasto. *Scripta Geol.*, **28**, 1-36.

—— and —— (1980).–Conodont faunas from Portugal and south Western Spain. Part 4. A Famennian conodont fauna near Nerva (Río Tinto). *Scripta Geol.*, **56**, 1-14.

—— and —— (1981).–Conodont faunas from (South Portugal and South Western Spain. Part 6. A Lower Famennian conodont fauna at Monte do Forno da Cal (South Portugal). *Scripta Geol.*, **63**, 1-16.

Carrington da Costa, J. (1943).—O Dinanciano entre Grândola e Odemira. *Publ. Mus. Lab. Mineral. Geol. Fac. Cienc. Porto.*, **30**, 5-18.

Carvalho, D., Correia, H. A. C. and Inverno, C. M. C. (1976).—Contribuição para o conhecimento geológico do grupo de ferreira-ficalho. Suas relações com a faixa piritosa e grupo do polo do lobo. *Memórias e noticias*, **82**, 145-169.

Delépine, H. (1957).—Observations sur les goniatites du carbonifère Portugais. *Comun. Serv. Geol. Portugal*, **38**, 295-304.

Feio, M. (1946).—Note sur un gisement de fossiles Viséens dans les environs de Mértola. *Comun. Serv. Geol. Portugal*, **27**, 99-118.

Julivert, M. (1984).—Palaeogeographic and tectonic evolution of the Iberian Massif during Carboniferous time. *In Neuvieme Congres International de stratigraphie et du Carbonifère.* (Gordon Mackenzie jr. Ed.) Southern Illinois University Press, **1**, 49-68.

———, Fontbote, J. M., Ribeiro, A. and Conde, L. E. N. (1972).—Mapa tectónico de la península Ibérica y Baleares, Scale 1:1,000,000. *Inst. Geol. y Minero España Mem. Expl.*, 1-113.

Lotze, F. (1945).—Zur Gliederung der variszíden der Iberischen Meseta. *Geotektonische Forsch*, 6: 78-92.

Marshall, J. E. A. (1980).—A method for the successful oxidation and subsequent stabilisation of highly carbonised spore assemblages. *Rev. Palaeobot. Palynol.*, **29**, 313-319.

Oliveira, J. T. (1983).—The marine stratigraphy of south Portugal: A stratigraphical and sedimentological approach. In 'The Carboniferous of Portugal'. *Mem. Serv. Geol. Portugal*, **29**, 3-37.

——— (In press).—Stratigraphy and syn-sedimentary tectonism in the South Portuguese Zone. *Hercynia*, spec. issue.

———, Cunha, T., Streel, M. and Vanguestaine, M. (1987).—Dating the Horta da Torre Formation; a new lithostratigraphic unit of the Ferreira-Ficalho Group, South Portuguese Zone: geological consequences. *Comun. Serv. Geol. Portugal*, **72**.

———, García-Alcalde, J. L., Liñán, E. and Truyols, J. (1986).—The Famennian of the Iberian Peninsula. *Ann. soc. géol. Belgique*, **109**, 159-174.

———, Horn, M., Kullmann, J. and Paproth, E. (1985).—Stratigraphy of the Upper Devonian and Carboniferous sediments of South Western Portugal. *Congrés. Internat. de Stratigraphie et de Géologie du Carbonifère*, Madrid 1983. Compte. Rendu., **1**, 107-120.

———, ——— and Paproth, E. (1979).—Preliminary note on the stratigraphy of the Baixo Alentejo Flysch Group, Carboniferous of Portugal, and on the palaeographic development compared to corresponding units in Northwest Germany. *Comun. Serv. Geol. Portugal*, **65**, 151-168.

Oswin, W. M. (1986).—*Upper Devonian/Lower Carboniferous volcanism and mineralisation in the area east of Río Tinto mines, Iberian Pyrite Belt.* (Unpublished thesis, University of Southampton).

Pfefferkorn, H. W. (1968).—Geologie des Gebietes zwischen serpa und Mértola (Baixo Alentejo, Portugal), *Münst. Forsch. Geol. Paläont.*, **9**, 143 pp.

Priem, H. N. A. (1968).—*Beknopt verslag etc.* Z. W. O. Laboratorium voor isotopen-Geologie. Unpublished report, 45 pp.

Quiring, H. (1936).—Die jungtertiären eisenmanganerzvorkommen im Devon, Karbon und Pliocän von Süd Portugal. *Archiv lagerstättenforsch*, **63**, 52 pp.

Richardson, J. B. and McGregor, D. C. (1986).—Silurian and Devonian spore zones of the Old Red Sandstone continent and adjacent regions. *Bull. geol. Surv. Can.*, **364**, 1-79.

Schermerhorn, L. J. G. (1971).-An outline stratigraphy of the Iberian Pyrite Belt. *Bol. Geol. Min.*, **82**, 239-268.

——— (1975).—Pumpellyite facies metamorphism in the Spanish Pyrite Belt. *Petrologie*, **1**, 71-86.

Streel, M., Higgs, K., Loboziak, S., Riegel, W. and Steemans, P. (1987).—Spore stratigraphy and correlation with faunas and floras in the Ardenne-Rhenish regions. *Rev. Palaeobot. Palynol.*, **50**, 211-229.