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## ► To cite this version:

Philippe Steemans, Nisan Sariaslan, Borja Cascales-Miñana, Martin R Langer, Wilfried Meienbrock, et al.. A diverse Early Devonian palynoflora from the Waxweiler Lagerstätte (Klerf Formation, Rhenish Massif, Western Germany): palaeobotanical implications. *Palynology*, 2023, 47 (2), pp.2150904. 10.1080/01916122.2022.2150904 . hal-03896264

**HAL Id: hal-03896264**

**<https://hal.science/hal-03896264v1>**

Submitted on 13 Dec 2022

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# **A diverse Early Devonian palynoflora from the Waxweiler Lagerstätte (Klerf Formation, Rhenish Massif, western Germany): palaeobotanical implications**

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## **ABSTRACT**

The Lower Devonian Klerf Formation is an exceptional *Konservat-Lagerstätte*, exposed at multiple sites in the Waxweiler region in the Eifel area, western Germany. It has been studied for its various fossils, mainly arthropods, fishes, plants, molluscs, brachiopods, and crinoids. At Waxweiler, the sediments are palaeoecologically interpreted as a prograding deltaic depositional system elongated from NW to SE in the Ardenno-Rhenish area. The Klerf Formation has, however, not been studied in full detail in terms of its microflora and microfauna. Our study of the sediments of the formation from two different quarries in the Waxweiler area yielded fairly diverse miospore assemblages dominated by abundant organic matter of varying degrees of coalification. The miospore assemblages are

mainly composed of classical Lower Devonian taxa of the Old Red Continent (Laurussia). These belong, among others, to the genera *Ambitisporites*, *Apiculiretusispora*, and *Retusotriletes*. Biostratigraphically more important species recovered include *Acinosporites lindlarensis*, *Apiculiretusispora brandtii*, *Cymbosporites asymmetricus*, *Diatomozonotriletes franklinii*, *Emphanisporites annulatus*, *Verruciretusispora dubia* and *Verrucosisporites polygonalis*. In addition, *Emphanisporites foveolatus*, which is known only from a limited area in the Ardenno-Rhenish region, is also identified, indicating an earliest Pragian to middle Emsian age for the composite section. These assemblages are found to be accompanied by reworked phytoplankton to a much lesser extent. Our results reveal a much larger palaeobotanical diversity from the Rhineland outcrops than previously known, indicating a well-developed *Psilophyton*-type vegetation with related plants. The results further suggest a likely presence of plants such as *Leclercqia* and *Pertica*.

**Keywords:** Devonian, miospores, early land plants, *Psilophyton*, Rhenish Massif, Klerf Formation, Germany.

## 1. Introduction

The west German Eifel Mountains are part of the Rhenish Massif and constitute the peneplain remains of a Variscan truncated upland formed by uplifting and erosion of the Variscan mountains. Most of its rocks comprise Devonian slates, sandstones and limestones, that were deposited along the southern margin of the Old Red Sandstone Continent (western part of Laurussia), a mountain chain that was formed by the Caledonian Orogeny during the Silurian. Situated at the interface between marine and terrestrial ecosystems, the Lower Devonian Eifel sediments comprise transitional facies of erosional debris washed in from the northern Laurussian continent, and shallow marine Rhenish facies deposited in estuaries and lagoons. Based on the analyses of sediments and fossil biotas, a low relief deltaic complex with a variety of sub-environments was inferred (e.g., Fuchs 1982; Schweitzer 1983; Poschmann and Franke 2006; Kanzler 1985; Rebske et al. 1985; Stets and Schäfer 2002). The sub-environments reported include deltaic floodplains, interdistributary bays, ephemeral lakes, lagoons, fluvial channels, crevasse splays and point bars, indicating a limited marine, brackish- to fresh-water, tidally influenced shallow-water setting. Despite being folded and overthrust in the Variscan Orogeny, the Lower Devonian sediments preserve an exceptionally rich record of diverse biotas including e.g. fungi, algae, psilo- and filicophyta, bivalves, annelids, brachiopods, ostracods, eurypterids, arthropods, crinoids, cephalopods, trilobites, fishes, and bryozoans (for an extensive list, see Franke, 2006). Compared to reports on the biostratigraphy and palaeoecology of the Lower Devonian Eifel Mountains macrofossil assemblages, palynological studies on the microflora of the region are rare

(e.g. Riegel 1973, 1975, 1982; Schultz 1968; Huwe et al. 2003). Furthermore, such studies mainly focus on the Ardenne, the western extension of the Eifel in Belgium and Luxembourg (Leclercq, 1960; Strel 1986; Strel et al. 1987, Steemans and Brasseur 1999; Steemans et al. 2000) or the Hunsrück Mountains south of the Eifel region (Brocke et al. 2017).

Over the past years, special attention has been paid to the *in situ* spore fossil record, especially among Early Devonian plants (e.g. Wellman 2017; Bek 2017, 2021; Cascales-Miñana et al. 2022). This interest comes from the fact that *in situ* spores provide the sole evidence to link plant macrofossils to dispersed spores, and consequently an unequivocal way for discerning parent plants. Isolated spore diversity further provides important information for vegetation reconstruction (e.g. Gibson and Wellman 2021). Hence, the detailed investigation of the palynoflora from the Eifel region provides new insights into the Rhineland vegetation during the late Early Devonian.

Among the key localities for Lower Devonian biotas of the Eifel mountains are outcrops at Waxweiler (Köppen Quarries, Rhineland-Palatinate), where the Emsian-aged Klerf Formation is found in a prograding deltaic depositional system (Fuchs 1982; Stets and Schäfer 2002). The Klerf Formation takes its name from the Luxembourg locality "Clervaux" and was first described by the German palaeontologist Rudolf Richter (Richter 1919; see also Gosselet 1885). It is widely exposed in the Waxweiler area, where its outcrops are among the most diversified in the Rhenish Massif in terms of fossil content (e.g. Schweitzer 1982, 2000; Rebske et al. 1985; Anderson et al. 1998; Basse and Franke 2006; Dunlop and Poschmann 1997; Poschmann et al. 2005; Poschmann 2006; Poschmann and Franke 2006; Poschmann and Tetlie 2006; Braddy et al. 2008; Poschmann and Gossman 2014; Poschmann et al. 2016; Poschmann 2021). They are composed of dark grey to black thinly laminated, organic- and metal-rich shales and siltstones that have been slightly metamorphosed during the late and post-Caledonian tectonic phases. Waxweiler can be considered a "*Konservat Fossil-Lagerstätte*", with a high disparity and abundance of various fossils including early fish (jawless heterostracans, jawed placoderms, see Blicek 2018).

Here we document the palynological microfloral assemblages from Waxweiler in light of recent studies concerning the stratigraphic, palaeogeographic and ecological distribution of early land plants with the objective to provide a better understanding of the palaeoenvironmental context of the region in the frame of early land plant evolution in a deltaic depositional system.

## 2. Materials and methods

Samples for this study were collected from two quarries in the Waxweiler region (Figure 1). These sediments consist of the above-described deltaic complex deposits manifested in the alternation of

sub- to supratidal facies. The Klerf Formation has been assigned to the lower Emsian (Lower Devonian; e.g. Solle 1956; Braddy et al. 2008; Poschmann and Gossmann 2014; Dejonghe et al. 2017). In ascending order, eleven samples were collected from the Köppen quarry in Waxweiler (locality 1 in Fig. 1). All of them provided palynomorphs WAX1-11. Two additional samples were collected from the Köppen quarry in Merlscheid (locality 2 in Fig. 1), of which one provided palynomorphs (Eifel II-1). The stratigraphical position between the two quarries is unclear, but all samples provide palynomorphs of a same assemblage that is described below. The samples were processed in the palynological laboratory of the Palaeontology research team of the UMR 8198 CNRS unit Evo-Eco-Paleo at the University of Lille (France). Following standard procedures, palynomorphs were extracted from fine-grained samples such as shale and siltstone, using standard palynological techniques. This involved cold hydrochloric (HCl), cold hydrofluoric (HF) and hot hydrochloric (HCl) acid maceration to remove carbonates, silicates, and fluorosilicates, respectively. The organic residues were sieved through 15 µm nylon meshes. Nine of the processed samples contain palynomorphs, with most abundant land-plant derived spores, but also few acritarchs and scolecodonts, in varying abundances and states of preservation, but generally moderately to poorly preserved. Each palynological slide was observed using a ZEISS Axioskop optical microscope equipped with x40, x63 and x100 objectives. All rock samples, palynological slides and residues are stored in the palaeontological collections of the of the UMR 8198 CNRS of the University of Lille (France). Additional palynological slides are also stored in the collections of the University of Liège (Eddy Laboratory). Palynological constituents have been recorded and identified to species level wherever possible. The relative abundances have been recorded as "rare, common or abundant" to shed more light on the environmental setting (Table 1). For the identification and biostratigraphic correlation, we followed e.g. Breuer and Steemans (2013), Richardson and McGregor (1986), and Streel et al. (1987).

### **3. Results and discussion**

#### ***3.1. Assemblage composition, biostratigraphy and sedimentology***

A total of 28 species and 14 genera of miospores were identified from the samples analyzed (Table 1; Plate 1). In addition to the miospores, numerous phyto- and zooclasts have been observed. The description of these elements is not the within the aim of the present study. Among the identifiable palynomorphs are also very few acritarchs (Plate 1).

The preservation of the palynomorphs, including the miospores, varies from sample to sample

and ranges from moderate to poor. In terms of palynofacies, the samples show numerous types of organic matter of differing degrees of coalification, dominating the other main components in the assemblages. However, there are still sufficient numbers of miospores in most of the samples (Table 1). These miospores are usually brown to dark brown in color, and many of them are fragmented.

Most of the miospore taxa identified belong to the genera *Ambitisporites*, *Apiculiretusispora*, and *Retusotriletes*. The majority of these are typical forms dominating the Early Devonian assemblages of the Old Red Sandstone Continent. However, biostratigraphically more important species have also been identified (Figure 2). They include: *Acinosporites lindlarensis*, *Apiculiretusispora brandtii*, *Cymbosporites asymmetricus*, *Diatomozonotriletes franklinii*, *Emphanisporites annulatus*, *Emphanisporites foveolatus*, *Verruciretusispora dubia* and *Verrucosisporites polygonalis*. The last is a well-known worldwide-distributed species appearing in the lowest part of the Pragian (Richardson and McGregor 1986; Steemans 1989; Streel et al. 1987). The remaining taxa are typical of lower/middle Emsian strata, except for *A. brandtii*, which appears close to the Pragian/Emsian boundary, either just above or just below. According to the authors, *E. annulatus* appears at the Pragian/Emsian boundary (Richardson and McGregor 1986) or just above (Breuer and Steemans 2013). *Emphanisporites foveolatus* and *Verruciretusispora dubia* both characterise the FD Opper Biozone (Streel et al. 1987) above the AB Opper Biozone in the lower and middle Emsian. *Emphanisporites foveolatus* is the eponymous species of the Interval Zone Fov, the lowest biozone of the Opper Biozone FD. *Verruciretusispora dubia* has been very rarely recorded from Gondwana, but it is known from Saudi Arabia (Breuer and Steemans 2013) from the *lindlarensis*-*sextantii* up to the *svalbardiae*-*eximius* zones, which are respectively correlated with the upper part of the FD Biozone up to the upper part of the AP Biozone of Streel et al. (1987). Therefore, the Waxweiler samples correspond to the early/middle Emsian. However, both species, in particular *B. foveolatus*, are not well known outside the Ardenno-Rhenish area.

Besides locally known taxa, a species outside of NW Gondwana observed for the first time, *Cymbosporites asymmetricus*, appears higher in the Emsian of Saudi Arabia (Breuer and Steemans 2013), but also in the late Pragian of Brazil (Mendlowicz Mauller et al. 2007). The poor quality of the available material and incomplete data on the stratigraphical distribution of the taxon do not allow to provide more precision. *Cymbosporites asymmetricus*, *Apiculiretusispora brandtii* and *Rhabdosporites minutus* (the eponymous species of the ORSC Min Interval Zone) seem to be related and have been included in the same morphon (Breuer and Steemans 2013) making long distance correlations difficult.

The miospore assemblages are representatives of typical shallow-water habitats (e.g. Cascales-Miñana et al. 2016; Daners et al. 2017) with autochthonous open marine phytoplankton (acritarchs) being absent in the slides. The assignment to this environment is supported by abundant

sedimentological and palaeontological evidence showing e.g. fine-grained, parallel bedded slabs and well preserved imprints of *Undichna* trails. Evidence for endogenic bioturbators is lacking but the association with *Diplichnites* trackways influenced by currents also points to a very shallow depositional environment, possibly influenced by tides and situated on a deltaic floodplain (Poschmann and Franke 2006).

### **3.2. Palaeobotanical associations**

The miospore assemblages also give insights into the palaeovegetation. *Acinosporites lindlarensis* is a miospore that can be related, at least, to two *Leclercqia* macroplant species: *Leclercqia complexa* and *Leclercqia uncinata* (Xu et al., 2011; Bek, 2017). Likewise, the miospore *Apiculiretusispora brandtii* has been related to the plant species *Psilophyton charientos* and *P. forbesii* (Gensel 1980), but also to *Pertica dalhousii* (Edwards and Richardson 1996). Evidence of the presence of *Pertica* is indirectly provided by *Apiculiretusispora plicata* (Granoff et al. 1976; Edwards and Richardson 1996). However, arguably, the most interesting fact is that *A. plicata* is also documented from *Rhynia gwynne-vaughanii* (Wellman 2017), a plant that has never been found outside of the Rhynie chert assemblage, despite the fact that *A. plicata* is widely distributed around the world. The same context is observed for the miospore *Emphanisporites rotatus*, also globally known, that has recently been related to *Horneophyton lignieri* (Cascales-Miñana et al. 2022). Other spore taxa with implications for vegetation reconstruction are *Retusotriletes rotundus*, documented from the plant genera *Crenaticualis* and *Sawdonia* (Gensel 1980; Hotton et al. 2001), and *Retusotriletes* cf. *triangulatus*, documented from *Asteroxylon*, *Psilophyton* and *Tricherophyton* (Gensel 1980; Wellman 2017; Neregato and Hilton 2019).

### **3.3. Reconstruction of vegetation and palaeoenvironmental interpretation**

The current knowledge of the Lower Devonian (early Emsian) deposits of the Eifel region shows a fairly diverse flora formed by at least 17 plant species belonging to 11 genera (see Schweitzer 1990, table 3, for details). This flora includes six cosmopolitan genera and one endemic genus. Concerning widely distributed genera, the flora is composed of *Taenioocrada* (Göppert) Kräusel & Weyland, *Zosterophyllum* Penhallow, *Distichophytum* Mägdefrau, *Sawdonia* Hueber, *Drepanophycus* Göppert, and *Psilophyton* Dawson. Endemicity is represented by *Tursuidea* Schweitzer. Interestingly, numerous taxa of the Emsian flora constituents are monospecific, including *Stockmansella langii*

(Stockmans) Fairon-Demaret, *Sartilmania jabachensis* (Kräusel & Weyland) Fairon-Demaret, *Sawdonia spinosissima* Schweitzer, *Distichophytum mucronatum* Mägdefrau, *Drapnophycus spinaeformis* Göppert, and *Tursuidea paniculata* Schweitzer. The species diversity is completed by *Taeniocrada*, *Renalia* and *Psilophyton* with two species each: *Taeniocrada decheniana* (Göppert) Kräusel & Weyland and *T. dubia* Kräusel & Weyland, *Renalia graberti* Schweitzer and *R. major* Schweitzer, as well as *Psilophyton arcuatum* (Halle) Schweitzer and *P. burnotense* (Gilkinet) Kräusel & Weyland (= *Psilophyton goldschmidtii* Halle). *Zosterophyllum* is present with three species: *Zosterophyllum rhenanum* Kräusel & Weyland, *Z. spectabile* Schweitzer and *Z. fertile* Leclercq). To this list some tentative taxonomic assignments can be added, such as ?*Protobarinophyton* sp. and "*Drepanophycus*" *gaspianus*.

According to current plant classification, the (early) Emsian flora of the Eifel contains many different basal forms of tracheophytes (Capel et al. 2021, 2022). Such forms include rhyniopsids (e.g. *Renalia*), paratracheophytes (former Rhyniaceae, Gerrienne et al. 2006, i.e. *Stockmansella*) and zosterophylloids (e.g., *Sawdonia*), barinophytoid-like plants, as well as basal euphyllophytes (former trimerophytes *sensu* Banks 1968, i.e. *Psilophyton*) and lycopsids (i.e. *Drepanophycus*). Hence, the floristic composition of this Rhineland flora is characterized by an important richness of zosterophylloids and the absence of well-defined rhyniopsids such as typical rhyniopsids, i.e. *Cooksonia*-like plants.

Rhyniopsids experienced a great diversification through the earliest Early Devonian although many taxa do not extend into the Pragian (middle Lower Devonian; Capel et al. 2021). Interestingly, the closely coeval Emsian flora of Wépion (Belgium) is more dominated by rhyniopsids and *Psilophyton*-like plants than by zosterophylls (see Gerrienne 1993, for summary), which likely reflects the phytogeographic importance of the Rhineland flora. Moreover, in a larger framework, the Emsian floras of the Rhineland represent the early steps of the Eophytic turnover from which extant floras turn from a zosterophylloid-dominated to a lycopsid-dominated vegetation. This scenario suggests an early Eophytic character to the described Rhineland assemblage. However, the findings of our study suggest the presence of a well-developed *Psilophyton*-type vegetation and related plants. It further reveals a hidden diversity from the Rhineland outcrops, with a likely presence of *Leclercqia* and *Pertica*. Moreover, the presence of *in situ* spores from the Rhynie chert, a plant diversity interpreted as belonging to hot springs environment (Channing and Edwards 2009), would suggest a more complex palaeoenvironment than the coastal and shallow waters context previously proposed to the Rhineland flora by Schweitzer (1990, fig. 11).

Of particular interest for biostratigraphy, palaeogeography and palaeobotany is *Emphanisporites foveolatus*, a taxon that is only known in a small area of the Ardenno-Rhenish region and in the Emsian of Poland (i.e. Lanninger 1968; Rebske et al. 1985; Riegel 1973, 1975, 1982;



Stemans 1989; Streef et al. 1987; Turnau and Karczewska 1987; Turnau et al. 2005). This species could be the witness of a phytogeographic province, more or less equivalent to the S-Z province (Stemans and Lakova 2004).

### ***3.4. Reworking observed in the samples***

All acritarchs identified in this study are of late Cambrian to Early Ordovician age and therefore, reworked. Reworked acritarchs are common in the Ardenne (Belgium) and the Siegerland (Germany) (Vanguestaine 1979; Stemans 1989). Schematically, in the Ardenne, it has been observed on the northern side of the Dinant Synclinorium that reworked Silurian acritarchs are abundant and Cambro-Ordovician specimens are rare. On the contrary, on the southern side of the Dinant Synclinorium, the Cambro-Ordovician acritarchs dominate the assemblages (Stemans 1989). Furthermore, Stemans (1989) noted that reworked acritarchs in Belgium have been eroded from at least seven different horizons, ranging from the Cambrian to the Early Devonian. The studies in Belgium suggest at least two different sources of sediments to the basin. A northern source, the Brabant Massif, would have delivered Silurian sediments, and a southern source, the "Mittel Deutsche Schwelle", would have provided reworked palynomorphs from Cambro-Ordovician sediments into the basin (see also Vanguestaine 1979). The results obtained in the Waxweiler locality only include patchy observations, with very few acritarchs recorded, that are clearly reworked from Cambro-Ordovician sediments.

Reworking of late Cambrian-Early Ordovician acritarchs and their subsequent deposition in the Waxweiler sediments are indicative for active erosional surfaces during the Early Devonian. These findings are in line with studies obtained from sedimentary petrography, provenance analysis of minerals and zircon ICP-MS laser ablation ages (Wierich 1999; Schäfer et al. 1997; Stets and Schäfer 2002, Franke and Dulce 2017), showing (1) that the exhumation of the basement of the Rhenish Massif lead to substantial erosion and reworking, and (2) that synorogenic clastic sediments in the prograding Ardenno-Rhenish delta are derived from the northern continent Baltica to be ultimately deposited in the Rheno-Hercynian Belt of Germany in the Rhenish Massif (Franke and Dulce 2017).

## **4. Conclusions**

The new palynological analysis from the Devonian Klerf Formation deposits at Waxweiler revealed assemblages from deltaic and nearshore coastal settings comprising abundant phyto- and zooclasts,

together with palynomorphs, mostly miospores and rare acritarchs. The poorly to moderately well-preserved taxa provide the following results:

- (1) The assemblages from the Waxweiler outcrops reveal a much more diverse palynoflora than those formerly known from the Lower Devonian of the German part of the Rhenish Massif, comprising 28 miospore species from 14 genera, indicating a well-developed *Psilophyton*-type vegetation and related plants, with a likely presence of *Leclercqia* and *Pertica*.
- (2) Some of the spores found in this study (e.g. *Apiculiretusispora plicata* and *Emphanisporites rotatus*) have been found *in situ* in the sporangia of plants previously regarded to be exclusive of the Rhynie Chert (e.g. *Rhynia gwyne-vaughanii* and *Horneophyton lignieri*). These plants have been described to be associated with hot spring systems, and would be indicative of a more complex palaeoenvironment than what was previously considered to represent the Rhineland flora, or, on the other hand, indicate that some of the typical plants of the Rhynie chert had a much wider geographical distribution.
- (3) *Emphanisporites foveolatus* could correspond to a phytogeographic province; more or less equivalent to the S-Z phytogeographic province of Steemans and Lakova (2004).
- (4) Very few acritarchs recovered from the samples are all of Cambro-Ordovician age, and thus clearly not *in situ*, and represent reworked material derived from older sediments. This finding is in line with scenarios of active erosional surfaces, petrographic provenance studies and laser ablation ages of zircon minerals.
- (5) Future examination of the abundant phyto- and zooclasts, in terms of detailed palynofacies analysis, could provide interesting results.

## Acknowledgements

We acknowledge the useful comments and suggestions by Paweł Filipiak and an anonymous referee, as well as from the chief-editor James Riding. We are grateful to Agemar Siehl (Bonn) for literature information on the source area, to Sylvie Régner (Lille) for her support in the palynological laboratory, and to Christoph Steinhoff and Georg Heumann (Bonn) for assistance with the microscopy. P.S. is a Senior Research Associate of the Belgium NFSR. B.C.M. and T.S. were supported by EARTHGREEN project (ANR-20-CE01-0002-01) and N.S. and M.R.L. by the University of Bonn.

## Declaration of Interest

No potential conflict of interest was reported by the authors.

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### Figure, Plate, and Table Captions :

**Figure 1.** Location of the Waxweiler study area in the central area of the Ardenno-Rhenish massif, Germany. (a-b) A: Amsterdam, B: Brussels, F: Frankfurt, H: Hamburg, P: Paris; (c), geological map of the Waxweiler area showing the position of the sampling sites (red stars; locations of the quarries at Waxweiler – WAX: 1 and Merlscheid - EIFEL II: 2, respectively); modified after Streel et al. (1987) and Kanzler (1985). 1: Primary Quartzite; 2: Clayey Klerf beds; 3: Klerf beds; 4: Ems-Quartzite; 5: Wiltzer beds; 6: Floodplain deposits; coordinates for the sampling sites).

**Figure 2.** Biostratigraphic comparison chart (a-b: *annulatus-bellatulus*).

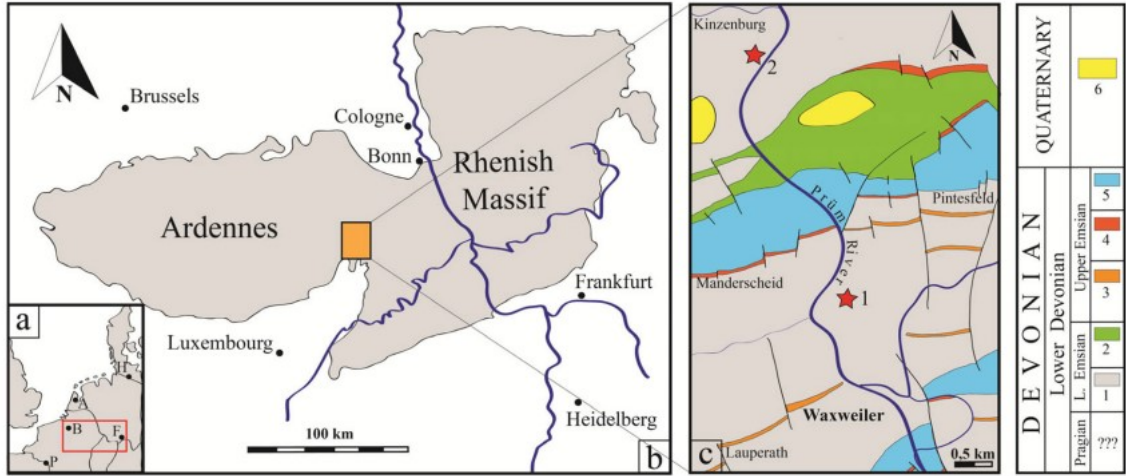
**Plate 1.** Spores and acritarchs found in this study. Identification followed by sample number and England Finder Graticule Coordinates.

1. *Cymbosporites asymmetricus* WAX1, SF-92;
2. *Apiculiretusispora brandtii* WAX1, SF-96;
3. *Emphanisporites annulatus* WAX11-1, Q-72;
4. *Verruciretusispora dubia* WAX1, SF-135;
5. *Acinosporites* cf. *apiculatus* EIFEL II-1-1, H-46-2;
6. *Verrucosisporites polygonalis* WAX11-1, D-58-3;
7. *Diatomozonotriletes franklinii* EIFEL II-1-1, M-53;
8. *Emphanisporites foveolatus* WAX11-1, R-69-3-1;
9. *Acinosporites lindlarensis* WAX11-1, V-70-2;
10. *Apiculiretusispora brandtii* WAX11-1, J-74-3;
11. *Apiculiretusispora plicata* WAX11-1, F-70-3-3;
12. *Acinosporites* cf. *apiculatus* WAX11, SF-159;
13. diacrodian acritarch (late Cambrian to Early Ordovician) WAX11, SF-445;
14. cf. *Vavrdovella areniga* (Vavrdova 1973) Loeblich and Tappan 1976 (Early Ordovician) WAX11, SF-102;

15. *Cymatiogalea* sp. (late Cambrian to Early Ordovician) WAX11-1, E-50-2-1;
16. *Acanthodiacrodium-Coryphidium* transient (Early Ordovician) WAX3, SF-78.

**Table 1.** Distribution of species within the samples, geographical coordinates of individual sampling sites and information on the relative abundance of individual taxa (based on individual counts). R: Rare (1-2 individuals); C: Common (4-10 individuals); A: Abundant ( $\geq 20$  individuals); abundance information in italics represent unusual occurrences).







1 ———



2 ———



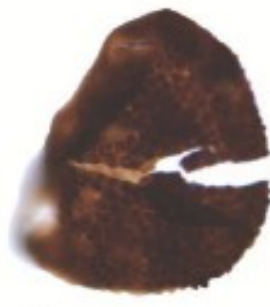
3 ———



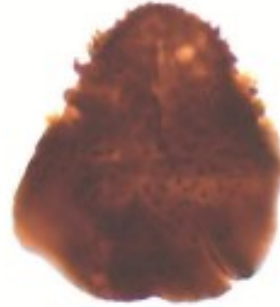
4 ———



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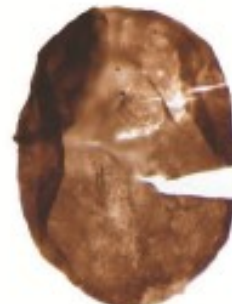
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12 ———



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14 ———



15 ———



16 ———



| Sample number  | WAX1                             | WAX2                             | WAX3                             | WAX4                             | WAX5                             | WAX6                             | WAX7                          | WAX8                             | WAX9                          | WAX10                            | WAX11                            | Eifel II-1                       |
|--|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|-------------------------------|----------------------------------|-------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Location of site   | 6°21'31.67"E<br>50°<br>5'59.45"N | 6°21'32.04"E<br>50°<br>5'59.34"N | 6°21'32.32"E<br>50°<br>5'59.16"N | 6°21'32.51"E<br>50°<br>5'59.03"N | 6°21'32.17"E<br>50°<br>5'59.00"N | 6°21'32.41"E<br>50°<br>5'58.87"N | 6°21'32.71"E<br>50° 5'58.58"N | 6°21'33.43"E<br>50°<br>5'58.22"N | 6°21'33.97"E<br>50° 5'57.84"N | 6°21'23.86"E<br>50°<br>5'56.22"N | 6°21'23.14"E<br>50°<br>5'56.27"N | 6°20'41.38"E<br>50°<br>6'56.18"N |
| Species  |                                  |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  |                                  |                                  |
| <i>Acinosporites cf. apiculatus</i><br>Streel, 1967                  | C                                |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  | R                                |                                  |
| <i>Ambitisporites avitus</i><br>Hoffmeister, 1959                    |                                  |                                  |                                  |                                  |                                  |                                  |                               |                                  | R                             |                                  | R                                | C                                |
| <i>Aneurospora sp.</i>   | R                                |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  |                                  |                                  |
| <i>Apiculiretusispora brandtii</i><br>Streel, 1964                   | A                                |                                  |                                  |                                  |                                  |                                  | R                             |                                  |                               | A                                | C                                |                                  |
| <i>Apiculiretusispora plicata</i><br>Streel, 1967                    | A                                |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               | A                                | C                                | R                                |
| <i>Apiculiretusispora sp.</i>  | C                                |                                  | A                                |                                  |                                  |                                  |                               |                                  | R                             | A                                | R                                | C                                |
| <i>Archaeozonotriletes chulus</i><br>Richardson and Lister, 1969     | R                                |                                  | R                                | R                                |                                  | R                                |                               |                                  |                               | R                                | R                                | R                                |
| <i>Cymbosporites asymmetricus</i><br>Breuer et al., 2007             | C                                |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  |                                  |                                  |
| <i>Cymbosporites sp.</i>   | R                                |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  |                                  |                                  |
| <i>Diatomozonotriletes franklinii</i><br>McGregor and Camfield, 1982 | R                                |                                  | R                                |                                  |                                  |                                  |                               |                                  |                               | R                                | R                                |                                  |
| <i>Dibolisporites echinaceus</i><br>Richardson, 1965                 | R                                |                                  | R                                |                                  |                                  |                                  |                               |                                  |                               | R                                | R                                |                                  |
| <i>Dibolisporites eifeliensis</i><br>McGregor, 1973                  |                                  |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               | R                                |                                  | R                                |
| <i>Dibolisporites wetterdorfensis</i><br>Lanninger, 1968             |                                  |                                  | C                                |                                  |                                  |                                  |                               |                                  |                               | R                                | R                                | R                                |
| <i>Dictyotriletes sp.</i>  |                                  |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  | R                                |                                  |
| <i>Emphanisporites annulatus</i><br>McGregor, 1961                   | R                                |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  | R                                | R                                |
| <i>Emphanisporites biradiatus</i><br>Stemans, 1989                   |                                  |                                  | R                                |                                  |                                  |                                  |                               |                                  |                               |                                  | C                                |                                  |
| <i>Emphanisporites foveolatus</i><br>Schultz, 1968                   |                                  |                                  |                                  |                                  |                                  |                                  |                               |                                  |                               |                                  | R                                |                                  |
| <i>Emphanisporites mcgregorii</i>                                    |                                  |                                  |                                  |                                  |                                  |                                  | R                             |                                  |                               |                                  | R                                |                                  |

