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Palynoflora from the Permian Sotres Formation (Picos de Europa, Asturias, Northern Spain)

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ABSTRACT

A new spore and pollen assemblage has been discovered in the Sotres Formation (Picos de Europa, Asturias, North of Spain). The palynoflora includes: *Alisporites splendens*, *Fimbriaesporites fimbriatus*, *Gardenasporites heisseli*, *Hamiapollenites bullaeformis*, *Lueckisporites virkkiae*, *Potonieisporites novicus*, *Protohaploxypinus microcorpus*, *Vittatina costabilis*, *Vittatina saccata*, *Striatopodocarpidites* cf. *cancellatus*, *Alisporites* sp., *Endosporites* sp., *Platysaccus* sp., *Punctatisporites* sp., *Verrucosisporites* sp. and unidentified pollen grains and microspores. A Kungurian age is suggested for the fossil site, which has implications for the understanding of the Late Variscan evolution of the Iberian Peninsula.

Keywords: Palynostratigraphy, Permian, Kungurian, Picos de Europa, Iberian Peninsula.

RESUMEN

Un nuevo conjunto de esporas y pólenes ha sido descubierto en la Formación Sotres (Picos de Europa, Asturias, Norte de España). La palinoflora incluye: *Alisporites splendens*, *Fimbriaesporites fimbriatus*, *Gardenasporites heisseli*, *Hamiapollenites bullaeformis*, *Lueckisporites virkkiae*, *Potonieisporites novicus*, *Protohaploxypinus microcorpus*, *Vittatina costabilis*, *Vittatina saccata*, *Striatopodocarpidites* cf. *cancellatus*, *Alisporites* sp., *Endosporites* sp., *Platysaccus* sp., *Punctatisporites* sp., *Verrucosisporites* sp. y granos de pólenes y miosporas sin identificar. Se sugiere que este yacimiento fósil tenga una edad Kunguriense, lo cual tiene implicaciones en el conocimiento de la evolución tardivarisca de la Península Ibérica.

Palabras clave: Palinoestratigrafía, Pérmico, Kunguriense, Picos de Europa, Península Ibérica.

1. INTRODUCTION

The occurrence of Permian sediments in the Cantabrian Mountains was first confirmed by Patac (1920), based on the discovery of fossil plants at Pola de Siero (Fig. 1B). Since then, only a few descriptions of that age were published until a general stratigraphic scheme was presented by Martínez-García (1983), based on several fossil localities (Wagner & Martínez-García, 1982). The two main stratigraphic units were described as the Viñón beds (located at the base and mainly constituted of volcanic rocks and limestone) and Villaviciosa beds (at the top and consisting of red beds with limestone intercalations).

Later, in Martínez-García (1991), the post-Hercynian Permian succession was described as composed of four formations called San Tirso Formation at the base (upper Stephanian C-Autunian), Sotres Formation (Autunian), Cabranes Formation (Autunian), and Caravia Formation (at this time considered as **"**Saxonian**"** despite a lack of palaeontological argument). The Sotres and Cabranes formations were discriminated within a Viñón Group; the Caravia Formation was equivalent to the Villaviciosa Group.

Within this geological framework, different palaeobotanical studies were carried out, in which plant remains from the Villaviciosa beds were dated as Autunian (Wagner & Martínez-García, 1982). There are few palynological records from the Lower Permian in the West Peritethyan palaeogeographical domain. For the Iberian Peninsula these include: Central Pyrenees (Broutin & Gisbert, 1983; Gisbert, 1983; Lucas & Gisbert, 1995), the Ebro Basin (Arche *et al*., 2007), Guadalcanal, Sierra Morena (Broutin, 1973, 1974, 1977, 1981), Retiendas-Valdesotos, Central System (Sopeña *et al*., 1974; Sopeña, 1977, 1979; Arche *et al*., 1983), Molina de Aragón, Castilian Branch of Iberian Range (Ramos *et al*., 1976; Ramos & Doubinger, 1979), Buçaco, North Iberian Massif (Gomes *et al*., 2004). Furthermore, in Sardinia, the localities of Perdasdefogou in the North and Lu Caparoni (Ronchi *et al*., 1998) and Guardia Pisano (Pittau *et al*., 2002) in the South.

The allocation of the Sotres Formation to the basal Permian (Martínez-García, 1981; Wagner & Martínez-García, 1982) led Weil *et al.* (2010) to conclude that the time constraint was c. 10 Ma for the oroclinal bending of the Ibero-Armorican Arc, a geologically brief, thick-skinned, lithospheric-scale deformation event marking the final amalgamation of the Pangaea supercontinent.

2. GEOGRAPHICAL AND GEOLOGICAL CONTEXT

The occurrence of a succession of Permian age at Sotres (Picos de Europa, Asturias), was reported for the first time by Martínez-García (1981). The study area is located east of this village (Fig. 1C).

Martínez-García (1981) described the Sotres Formation as a carbonate and mudstone succession with volcanogenic. Shortly thereafter, it was realized that the upper part of this succession, consisting of alternating red, green and brown sandstones and calcareous shales, should be included in the overlying Caravia Formation (Martínez-García, 1991). The basal part, attributed to the Sotres Formation, is composed of a thin basal limestone conglomerate overlain by a few metres of volcanogenic siltstones with limestone lenses and alternating limestone beds and black siltstones. The Sotres Limestone is a massive homogeneous lacustrine carbonate unit of algal origin (Prado, 1972; Mamet & Martínez-García, 1995), with a complete absence of Permian marine elements.

2.1. The Sotres succession

The stratigraphic column (Fig. 2) starts with a thin bed of basal limestone conglomerates resting unconformably on Pennsylvanian limestones; it is followed by 5-8 m of volcaniclastic rocks with interbedded limestones, on top of which a thin coal seam is found occasionally.

Near the base of the formation, a few floral remains of Autunian age were recorded (Wagner *in* Wagner & Martínez-García, 1982, p. 276): *Autunia conferta* (Sternberg) Kerp, *Dicksonites leptophylla* Doubinger, *Sphenopteris* cf. *minutisecta* Fontaine & White, *Pecopteris hemitelioides* Brongniart, *Sphenophyllum* cf. *miravallense* Vetter, *Annularia stellata* (Schlotheim) Wood.

Overlying deposits are 3-6 m of black shale followed by 55-70 m of alternating limestones and black shales with volcanic debris. Spores in the basal shales were attributed to the Autunian (Neves *in* Martínez-García, 1981). This age attribution is not supported by current data as reported in the present paper.

The Sotres Formation overlies in subhorizontal position the inclined Carboniferous limestones. It is cut by several normal faults, displacing the limestones several tens of metres. This formation is also represented east of Viñón, near Villaviciosa (Martínez-García, 1983; Suárez Rodríguez, 1988), where more abundant volcanic deposits occur as well as a thicker limestone conglomerate at the base.

The Sotres Formation is also present in other localities of the Cantabrian Mountains, such as Pola de Siero (Asturias), where the Lower Permian was identified by Patac (1920), and Aniezo, near Peña Sagra (Cantabria). The corresponding outcrops are usually overlain unconformably by other Permian formations.

The limestone succession at Sotres is overlain disconformably by red-beds of the Caravia Formation which produced a dolomitic alteration of these limestones.

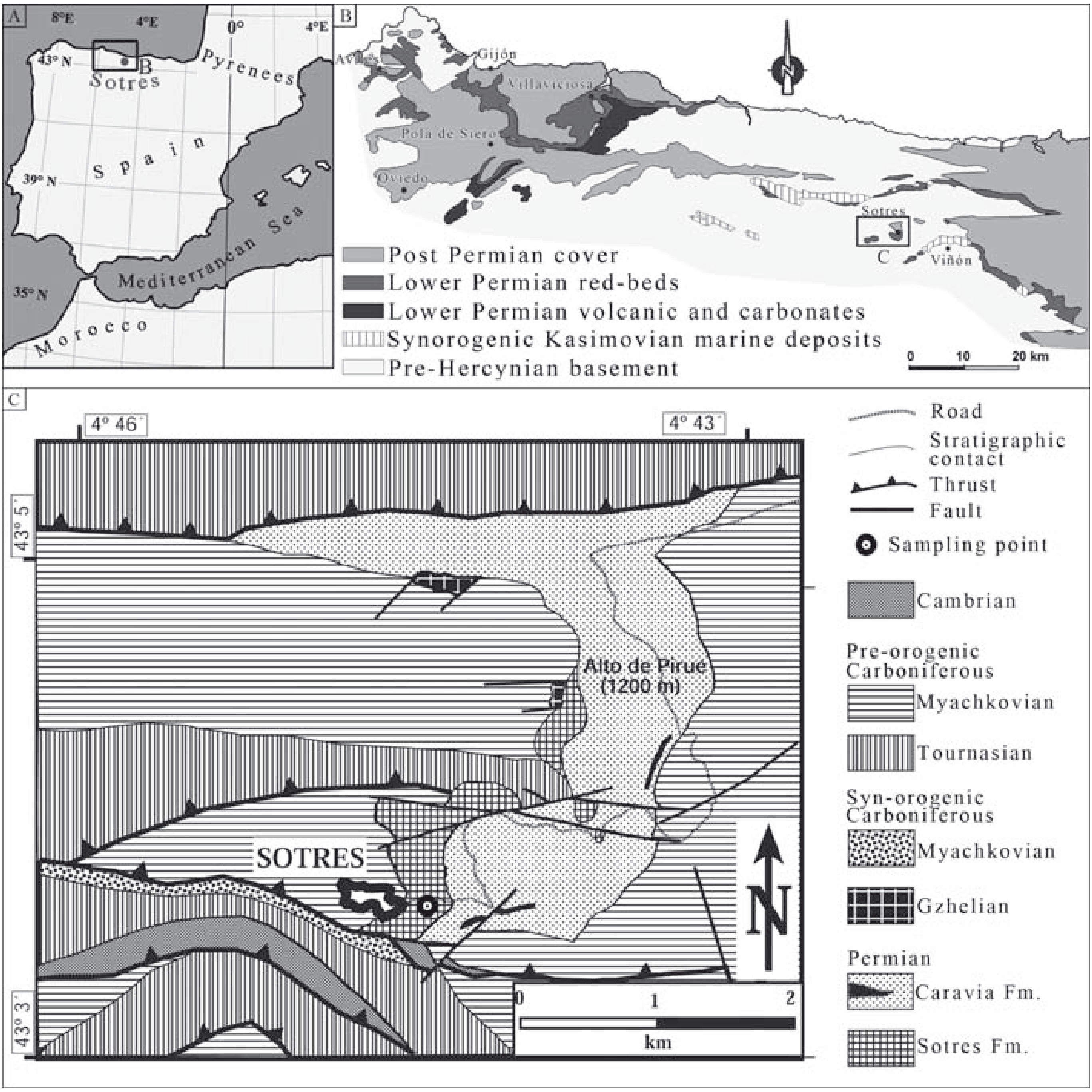

Figure 1. Studied outcrop in Sotres, Asturias (Spain). **A)** Geographical location. **B)** Geological context. **C)** Geological scheme in detail.

The Caravia Formation consists of 130-160 m of red and green shale, mudstones, and sandstones with several decimetric to metric intercalations of limestone conglomerates in a red matrix, usually with well-rounded clasts, and pisolites at the base. The Caravia Formation has been dated at Peña Sagra (Santander province, Cantabria), about 15 km to the NE, as Artinskian-Kungurian, as indicated by the fossil plant *Supaia* sp. (Kerp *in* Gand *et al*., 1997).

3. MATERIAL AND METHODS

Two samples (AS-08 and AS-09) were collected from an outcrop for palynological studies (coordinates: 43º 13’ 57.8’’ N, 04º 44’ 39.4’’ O), exposing the Sotres Formation close to Sotres village (Fig. 2).

Samples were processed in the laboratory of the University of Vigo by using standard palynological HCl-HF-HCl techniques as described by Wood *et al*. (1996). The processing was basically the first addition of HCL and HF to remove carbonate and silicate minerals. A dispersing agent

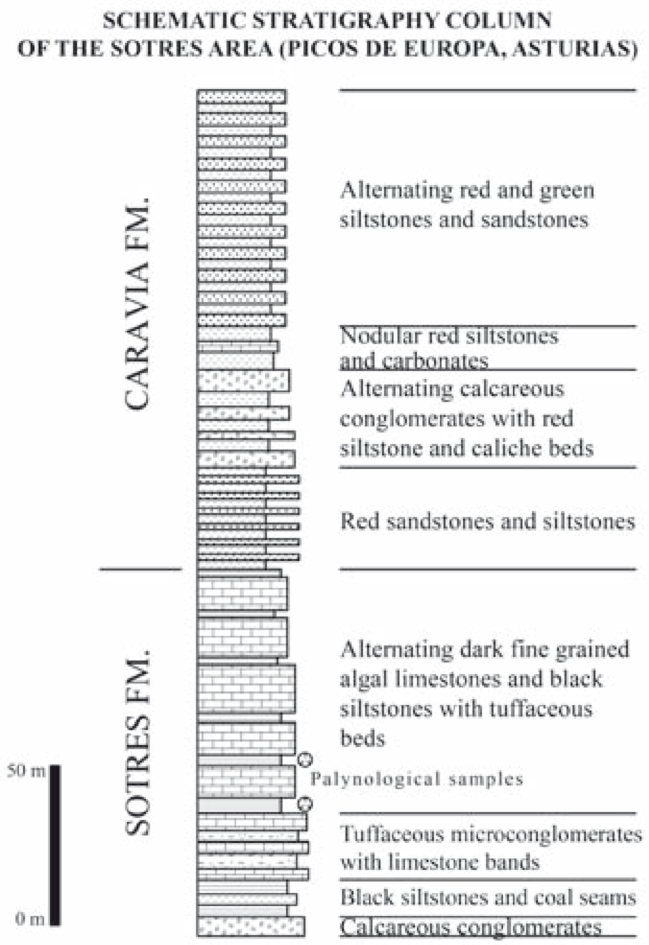

Figure 2. Stratigraphic column of Sotres Formation and Caravia Formation.

has been added subsequently to facilitate filtering. Only one sample (SAB-08) contained a miospore assemblage. The residue was mounted on glass and observed under a Confocal Microscope of Nikon Biorad, at the Cacti Labs at the University of Vigo.

4. RESULTS AND DISCUSSION

The palynomorph assemblage is poorly preserved as is usual for Permian samples in SW of Europe. The following taxa were identified (Fig. 3): *Alisporites splendens* (Leschik) Foster, *Fimbriaesporites fimbriatus* Singh, *Gardenasporites heisseli* Klaus, *Hamiapollenites bullaeformis* (Samoilovich) Jansonius, *Lueckisporites virkkiae* Potonie & Klaus, *Potonieisporites novicus* Bhardwaj, *Protohaploxypinus microcorpus* (Schaarschmidt) Clarke, *Striatopodocarpites cancellatus* (Balme & Hennelly) Bharadwaj, *Vittalina costabilis* Wilson, *Vittatina saccata* (Hart) Jansonius. Though not an abundant assemblage, it is regarded as significant.

Autunian morphotaxa include: *Potonieisporites novicus* or *Vittatina costabilis*. However, we found also *Lueckisporites virkkiae*, which is normally attributed to higher levels of the Permian (Table 1).

For a biostratigraphic assessment, a revision of the available literature is made so as to determine as accurately as possible the stratigraphic distribution of each taxon (Table 1).

It follows that this assemblage may be attributed to the Kungurian-Roadian transition (270.6 Ma), a conclusion based on the ranges of *Vittatina costabilis*, *Vittatina saccata*, *Potonieisporites novicus* and *Gardenasporites heisseli* (Table 1). The presence of *Alisporites splendens*, *Fimbriaesporites fimbriatus*, *Hamiapollenites bullaeformis*, *Lueckisporites virkkiae*, *Protohaploxypinus microcorpus* and *Striatopodocarpidites* cf. *cancellatus* is consistent with this conclusion.

The previous megafloristic data (Wagner *in* Wagner & Martínez-García, 1982; Gand *et al*., 1997) suggested Autunian (latest Carboniferous according to Wagner & Álvarez-Vázquez, 2010). Although the palynological assemblage is similar to the "A3 association" of mid-Artinskian to Kungurian age in the Autun Basin, as described by Doubinger (1974), this author already suggested the possibility of attributing the "A3 Association" to Kungurian by comparing the Permian deposits of the Estérel (Visscher, 1968) with the Austrian Alps (Potonié & Klaus, 1954; Klaus, 1963), the Assise of Kusel in the Saar-Palatinate (Helby, 1966); it could also be compared to some of the lacustrine deposits of Pugh (Turkey; Agrali & Akyol, 1967). In effect, the co-occurrence of *Potonieisporites novicus* and *Gardenasporites heisseli* leads us to suggest a Kungurian (latest Early Permian) age rather than Roadian (earliest Late Permian).

Although the Sotres Formation was attributed to Autunian on the megaflora, we thus regard it as later, i.e., the highest Early Permian, possibly Kungurian.

These new data allows a more accurate duration for the oroclinal bending of the Ibero-Armorican Arc evaluated by Weil *et al*. (2010) and it might be suggested that this deformation has been performed three times slower than previously stated.

5. CONCLUSIONS

This study is a new contribution to the poor Permian palynological records from the Cantabrian Mountains. It is the first time that Kungurian age deposits are described in this area, on the base of a palynological association. It implies that the last phase of oroclinal bending of the Ibero-Armorican Arc, as proposed by Weil *et al*. (2010), might range from latest Carboniferous to high Early Permian.

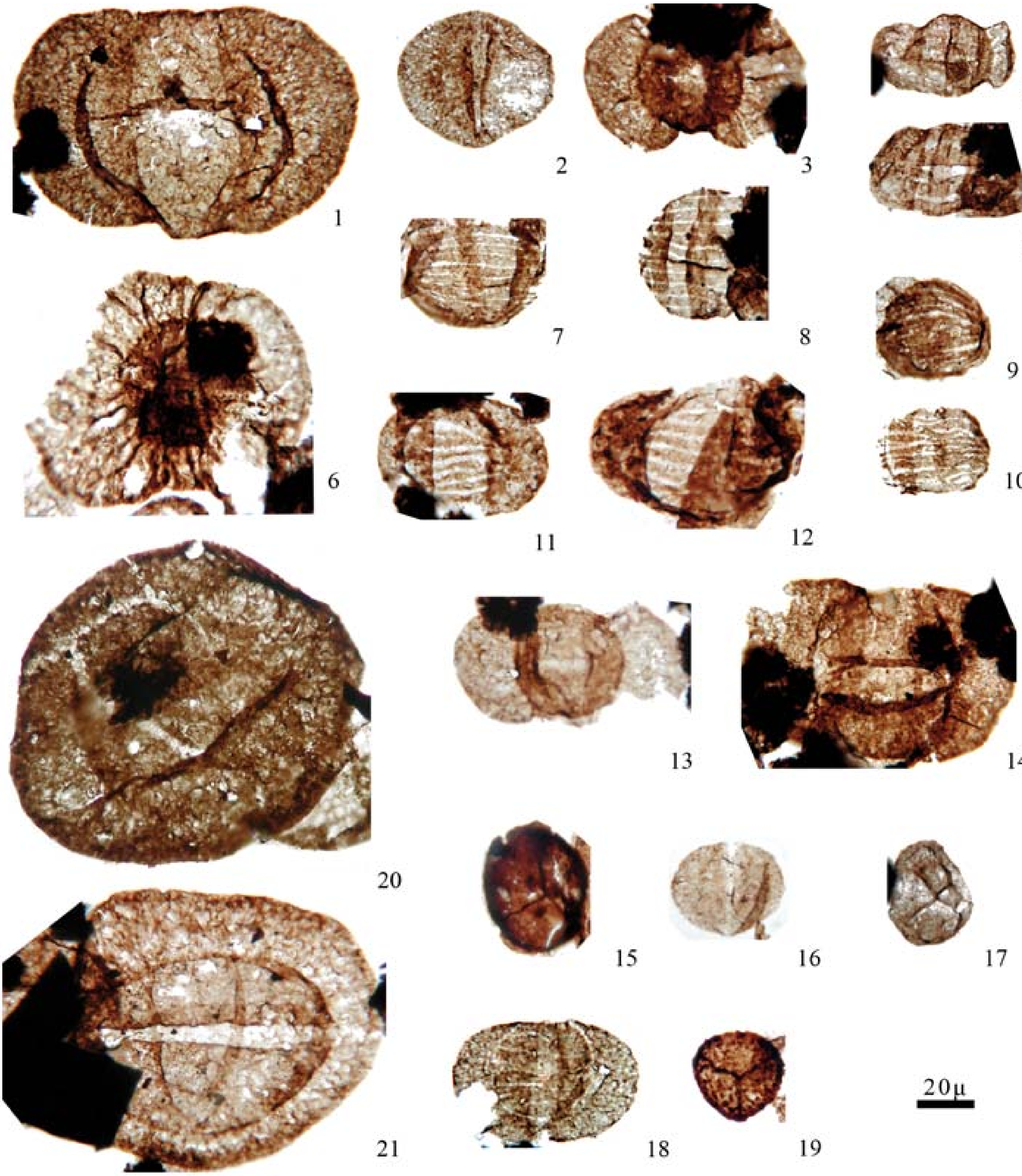

Figure 3 (x 500). **1)** *Gardenasporites heisseli* Klaus. **2)** *Alisporites splendens* (Leschik) Foster. **3)** *Fimbriaesporites fimbriatus* Singh. **4-5)** *Hamiapollenites bullaeformis* (Samoilovich) Jansonius. **6)** *Platysaccus* sp. **7-8)** *Vittalina costabilis* Wilson. **9-10)** *Vittatina saccata* (Hart) Jansonius. **11-12)** *Protohaploxypinus microcorpus* (Schaarschmidt) Clarke. **13-14)** *Lueckisporites virkkiae* Potonie & Klaus. **15)** *Endosporites* sp. **16)** *Alisporites* sp. **17)** *Punctatisporites* sp. **18)** *Striatopodocarpidites* cf. *cancellatus*. **19)** *Verrucosisporites* sp. **20-21)** *Potonieisporites novicus* Bhardwaj.

Table 1. Chronologic distribution of the AS-08 Association. The species found in the AS-08 are shown on the vertical axis, while their chronologic distribution is shown on the horizontal axis. In turns, the papers in which each taxa has been registered are displayed on the table. Number legend: (1) Arche & López-Gómez (2006): Hoz de Gallo Formation, Iberian Basin, Molina de Aragón, Spain. (2) Arche *et al*. (2007): Caspe1 borehole, Ermita Formation, Ebro Basin, NE Spain. (3) Balarino (2009): Colorado Basin, Argentina. (4) Balarino *et al*. (2012): Andapaico Formation, central foothills of San Juan, Argentina. (5) Barbolini (2010): a) Dwyka Group; b) Ecca Group, Vryheid Formation, Biozone II; c) Ecca Group, Vryheid Formation, Biozone III; d) Ecca Group, Vryheid Formation, Biozone V, northern Karoo Basin, South Africa. (6) Barbolini (2014): a) Ecca Group, Gwembe Coal Formation; b) Ecca Group, Vryheid Formation, Biozone II, Karoo Supergroup, South Africa. (7) Broutin *et al*. (1988): Buntsandadstein facies, Catalonian Pyrenees, Spain. (8) Broutin *et al*. (1990): Tarat Formation, Arlit Region, Northern Nigeria. (9) Di Pasquo *et al*. (2010): Paganzo Basin, Los Sauces area, Rioja Province, Argentina. (10) Di Pasquo & Grader (2012): Copacabana Formation Apillapampa, Cochabamba, Bolivia. (11) Doubinger (1974): Zone A3. Brive and Blanzy Basin, France. (12) Doubinger *et al*. (1987): Lodève Basin, Hérault, France. (13) Draxler (2010): Gröden Formation, Arenaria di Val Gardena, Dolomites, Italy. (14) Dunn (2001): Carboniferous-Permian boundary stratotype section, Aidaralash Creek, southern Ural Mountains, Kazakhstan. (15) Eshet (1989): Yamin Formation, Permian-Triassic boundary, Israel. (16) Gorsky *et al*. (2002): a) Illwarra, Kaiman, Samara Belt (V.2.), Voldodrad Belt (VI.3.) and Prypiat depression, Russia. b) Batirmalinskaia Formation, Russia. (17) Götz & Silantiev (2014): Kazanian stratotype section, Russia. (18) Hart (1965): Western PreUrals, Solikamsk, Russia. (19) Hochuli (1985): borehole Weiach, Northeastern Switzerland. (20) Jan (2011): Nilawahan Group of the Salt Range, Pakistan. (21) Mangerud & Konieczny (1993): Gipshuken Formation, Spikbergen, Svalbard, Norway. (22) Martínez-Blanco *et al*. (2012): borehole-254, “Paso de las Toscas”, Paraná Basin, Uruguay. (23) Modie (2007): borehole STRAT-1, CKP6, Kalahari Karoo Basin, Botswana. (24) Pérez Loinaze *et al*. (2010): San Miguel Formation, Western Paraná Basin, Paraguay. (25) Pittau & Del Rio (2002): Guardia Pisano Basin, SW Sardinia, Italy. (26) Pittau *et al*. (2002): Guardia Pisano Basin, SW Sardinia, Italy. (27) Prevec *et al*. (2010): Southern Karoo Basin, South Africa. (28) Sabina & Jha (2014): borehole 1007, Godavari Basin, India. (29) Sebban (1996): boreholes 0T6bis and OT7, Haouz Basin, Morocco. (30) Semkiwa *et al*. (1998): Mchuchuma Formation at Lake Rukwa, Southwestern Tanzania. (31) Souza & MarquesToigo (2005): Paraná Basin, Rio Grande do Sul, Brazil. (32) Stolle (2007): Mityaha-1 well, North Iraq. (33) Susnjara *et al*. (1992): Central and North Dalmatia Region, Southeastern Lika and Western Bosnia. (34) Utting (1994): Sabine Bay, Assistance, van Hauen and Trold Fiord formations, Sverdrup Basin, Canadian Arctic Archipelago. (35) Vigili *et al*. (1983): Landete Basin, Sierra Collado de Plata (Teruel) and Talayuelas (Cuenca), Spain. (36) Visscher (1968): Zechstein Basin, Agay and Le Muy (Département Var), France. (37) Visscher *et al*. (1974): “Facies de Léouvè”, Dôme de Barrot, France.

Taxa	Permian											
	Cisuralian						Guadalupian			Lopingian		
	Asselian	Sakmarian		Artinskian		Kungurian	Roadian	Wordian	Captitanian	Wuchiapingian		Changhsingian
Vittatina costabilis	19, 20, 22, 23, 24	19, 20, 22, 23, 24	19, 20, 22, 23, 24, 34	11, 19, 20, 22, 23, 24, 34	11, 20, 22, 23, 24, 34	11						
Vittatina saccata	14, 22, 24	14, 22, 24	14, 22, 24	6a, 14, 22, 24	6a, 14, 22, 24	6a						
Potonieisporites novicus	2, 14, 21, 23, 25, 26	2, 5a, 14, 21, 23, 25, 26	2, 5a, 14, 21, 23	5a, 11, 14, 21	11, 21	11						
Alisporites splendens	23	5b, 23	5b, 23	5b, 6b	6b, 24, 25	24, 25	34	34				
Hamiapollenites bulleaeformis	14	14	14	3, 4, 14	3, 4 ,14	3, 4, 18, 34	3, 4, 17, 34	34				
Lueckisporites virkkiae				5d, 24, 28, 34	5d, 10, 12, 24, 28, 31, 34	5d, 10, 12, 24, 31, 34	10, 12, 16a, 17, 24, 31, 34	10, 16a, 24, 32, 34	10, 16a, 24, 29, 32	1, 7, 16a, 29, 32, 33, 35, 36	1, 7, 16a, 29, 32, 35, 36	1, 7, 15, 16a, 29, 32, 35, 36
Protohaploxypinus microcorpus				3	3, 24	3, 24	3, 24	24	24	1, 6	1, 6	1, 6, 27
Fimbriaesporites fimbriatus					12	12		32	32			
Gardenasporites heisseli							16b	16b	16b	2, 7, 13, 16b, 33, 37	2, 7, 13, 33, 37	2, 7, 37
Striatopodocarpidites cf. *cancellatus*	9	8, 9	8, 9	5c, 30	5c, 30	5c, 30						

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