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Vegetation distribution and coal-forming environments in a strike-slip basin. The Pennsylvanian Peñarroya-Belmez-Espiel Basin, southern Spain

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1 **Vegetation distribution and coal-forming environments in a strike-slip basin. The**
2 **Pennsylvanian Peñarroya-Belmez-Espiel Basin, southern Spain.**

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8 **Abstract**

9 Coal and surrounding siliciclastic beds from the Peñarroya-Belmez-Espiel coalfield, a
10 strike-slip basin at the southern Iberian Variscan realm, has been analyzed
11 palynologically. The coal seams, generated in different depositional environments,
12 provide quantitatively different palynological assemblages. Lacustrine coals are
13 dominated by lycopsids, distal alluvial plain/marginal lacustrine coals by sphenophytes
14 and tree ferns, and middle alluvial fan coals by sphenophytes, tree ferns and lycopsids.
15 The dualism between vegetation distribution and sedimentary environment in the
16 Peñarroya-Belmez-Espiel Basin suggests that tectonic was the major factor controlling
17 the occurrence and distribution of flora in coal forming environments. This hypothesis
18 is thought to offer an explanation to the variability in the composition of coals from
19 tectonically active basins like the strike-slip basin analyzed here. The biostratigraphic
20 analysis of the reported palynoflora supports a Duckmantian age.

21 **Introduction**

22 In coal-bearing environments, the best preserved macroflora does not occur inside coal
23 beds but within surrounding siliciclastic deposits, because the original plant material is

24 destroyed during coal maturation. In consequence, the analysis of coal-forming
25 vegetation is based on (1) plant remains of early diagenetic permineralized concretions
26 occurring within coal beds (coal ball), (2) dispersed spores and pollen grains correlated
27 with their respective parent plant, (3) remains of the last inhabitants of swamps
28 accumulated in fine-grained strata above coals, also named roof-shale floras, and, in
29 minor extent, (4) in situ peat-forming macrofloras buried by tuff beds (Rahmani and
30 Flores, 1984; Scott, 1987; Diessel, 1992).

31 The vegetation structure and composition of Pennsylvanian coal-bearing environments
32 has been deeply analyzed in the literature using these four methods (see, for example,
33 Schopf, 1938, 1939; Winslow, 1959; Peppers, 1970; Mahaffy, 1985; Wagner, 1989;
34 Eble and Grady, 1990; Gastaldo *et al.*, 1995; Eble and Greb, 1997; Eble, 2002, Opluštil
35 *et al.*, 2007, 2009). Despite their own limitations and inherent biases (see comment by
36 Scott, 1977; Phillips *et al.*, 1985; DiMichele *et al.*, 1991), they all agree that lycopsids
37 dominated Lower and Middle Pennsylvanian coal-forming environments and filicopsids
38 replaced these since the Middle - Late Pennsylvanian transition onward (Phillips *et al.*,
39 1974, 1985; DiMichele and Phillips, 1996; DiMichele *et al.*, 2001). Climate change, and
40 more specifically, the influence of climate on the hydrologic regime controlling the
41 wetland ecology has been suggested as the most likely factor favoring this vegetational
42 shift (Phillips and Peppers, 1984; Cecil, 1990; Winston, 1990; DiMichele and Phillips,
43 1996). The climatic factor has been also alluded as responsible for the vegetational
44 variations detected within a given coal bed (DiMichele *et al.*, 1988). This pattern of
45 vegetation structure and composition of Pennsylvanian coal-forming environments is
46 mostly based on, and applies to, large paralic basins. In continental, tectonically active
47 settings, such pattern is more difficult to apply. The co-occurrence of coal-swamps
48 dominated by significantly different plant assemblages or/and the existence of drastic

49 floristic changes within a single coal deposit (Coquel, 1976; Nowak and Górecka-
50 Nowak, 1999. Oplušti *et al.*, 1999, 2007) require additional explanation. The interaction
51 between tectonic uplift and subsidence, understood as the relationship between
52 accommodation, denudation and sedimentation rates, produces in these basins a highly
53 variable stratigraphic architecture characterized by a fragile equilibrium between
54 aggradation, progradation and retrogradation of depositional devices. This produces the
55 permanent spread and retreat of alluvial, fluvial and lacustrine sedimentary
56 environments and the consequential shift in the extent and location of areas suitable for
57 peat accumulation.

58 In this study we focus on three coal beds from the Peñarroya-Belmez-Espiel (PBE)
59 coalfield, a Pennsylvanian strike-slip basin to the SE of the Iberian Variscan Massif.
60 The palynological analysis of these three coal beds, generated in different sedimentary
61 sub-environments, and their respective floor and roof siliciclastic beds, provides
62 information on the response of the coal-forming vegetation to changing environmental
63 settings. Additionally, the biostratigraphic analysis of the palynoflora recovered sheds
64 light on previous debate concerning the age of the PBE Basin (see, for example,
65 Álvarez-Vázquez, 1999; Coquel, 2005).

66 **Setting**

67 The convergence tectonic process that resulted in the Upper Palaeozoic Pangea
68 amalgamation affected the Iberian Variscan Massif since Devonian times (Matte, 1986).
69 In the latest stages, the convergence process derived in a transtensional tectonic regime
70 that mostly affected the bordering terranes of the two mega-continent involved
71 (Stampfli and Borel, 2002). In the southern Iberian Variscan Massif this tectonic
72 scenario produced strike-slip basins aligned with the main Variscan structures. These

73 basins, of Pennsylvanian to Early Permian age, laid over different basements according
74 to their respective location, and are all filled with continental deposits of alluvial, fluvial
75 or/and lacustrine facies (Figs. 1, 2). Intercalated within the sedimentary pile, some of
76 them also include volcanic rocks of different nature, interpreted in relation to the very
77 early stages of the Pangea break-up (Quesada *et al.*, 1990; Arche and López-Gómez,
78 1996; Colmenero *et al.*, 2002).

79 The PBE strike-slip basin is a Pennsylvanian trough 50 km long, 1 km wide, controlled
80 by two major NW-SE Variscan faults (Gabaldón and Quesada, 1986; Wagner, 1999). Its
81 location is related to the Badajoz-Córdoba shear zone, the major suture bounding the
82 Central Iberian (CIZ) and Ossa-Morena (OMZ) zones. The basin is bordered to the NE
83 by autochthonous early Paleozoic rocks of the CIZ, and is thrust to the SW by
84 alloctonous Viséan-Serpoukovian rocks of the Guadiato Basin, indistinctly assigned to
85 OMZ or CIZ (Fig. 1).

86 The stratigraphic record of the PBE Basin consists of a multiple repetition of alluvial,
87 lacustrine and coal seam deposits, all commonly showing evidences of frequent and
88 abrupt facies and thickness changes. When complete, the alluvial fan sequences include
89 a base with breccias, conglomerates and sandstones that evolve to fine conglomerates
90 and scarce coarse sandstones of the medial alluvial fan. Toward the top, the fine-grained
91 distal alluvial fans deposits pass distally into lutite-rich sequences of the floodplain and
92 lacustrine environments (Quesada, 1983; Andreis and Wagner, 1983; Gabaldón and
93 Quesada, 1986). The largest and more efficient alluvial fan systems occurred at the NE
94 margin of the basin. Their distal facies interfingered with small, subsidiary alluvial fans
95 fringed at the opposite margin. Between both alluvial fan systems narrow, very shallow,
96 weather-dependent lakes occurred (Wagner, 2004).

97 The PBE coal seams occur intercalated in lacustrine facies or within alluvial plain
98 flooded deposits, and also embedded into middle fan sequences. The coal rank varies
99 from bituminous in the SE sector to per-bituminous and anthracitic in the NW sector of
100 the basin. Reasons explaining the overheating of the NW coals are yet to be known, but
101 they are more likely related to the effect of a yet unknown thermal focus (Wagner,
102 2004).

103 The mining activity in the PBE Basin commenced in the second half of the XVIII
104 century, and was active until 2012. During this time coal has been extracted from
105 several underground and open-pits mines scattered throughout the basin. The last
106 operating mine was the La Ballesta open-pit, located at the southeasternmost end of the
107 coalfield (Fig. 1). The samples analyzed in this study are from this mine.

108 The palaeobotanical record of the PBE Basin is abundant and has been studied in detail
109 by Álvarez-Vázquez (1995, 1999) and Wagner and Álvarez-Vázquez (2010). These
110 authors proposed a Langsettian-late Duckmantian age for the NW sector (anthracitic
111 coals) and a late Duckmantian-early Bosovian? age for the SE sector (bituminous
112 coals). In a palynological analysis conducted at the San Antonio open-pit (SE sector)
113 Coquel in Quesada and Garrote (1983) and Coquel (2005) suggested a Langsetian–early
114 Duckmantian age.

115 The coal beds analyzed in this study are named 9, 14 and 15 according to the mine
116 nomenclature. They are representative of lacustrine (coal bed 9), distal alluvial plain /
117 marginal lacustrine (coal bed 14) and middle fan (coal bed 15) environments. The
118 palaeogeographic model and palaeoenvironmental reconstruction in Figure 3 shows the
119 location of the coal beds analyzed.

120 **Methodology**

121 The selected coal samples were disaggregated and oxidized with fuming nitric acid for
122 4, 10 and 25 minutes. The siliciclastic samples were processed at laboratory following
123 the standard techniques described by Wood *et al.* (1996), which include reaction with
124 cold hydrochloric acid (36%) for removal of carbonates, hot hydrofluoric acid (40%) to
125 dissolve silicates and hot hydrochloric acid (36%) to eliminate fluorides and remains of
126 carbonates. The resultant residue was oxidized with fuming nitric acid for the same time
127 intervals employed with the coal samples. Coal and siliciclastic residues were
128 neutralized and mounted in slides using Cellosize as dispersing agent and Elvacite as
129 mounting medium.

130 The biostratigraphic analysis was based on the biozonal scheme by Clayton *et al.*
131 (1977). The quantitative palynological analysis was performed with those slides
132 mounting the residue oxidized for 10 minutes, as they proved to contain the lowest
133 proportion of non- and over-oxidized material. Relative abundances of spore/pollen taxa
134 were determined on the basis of counts of 250 specimens per slide. The species
135 identified were assigned at generic scale to major parent plant groups according to the
136 information and compilations provided by Smith and Butterworth (1967), Balme
137 (1995), Dimitrova *et al.* (2005, 2010), Traverse (2008). Where assignment to a specific
138 parent plant group resulted problematic, the affinity was scored as “unknown”.

139 **Palynological data**

140 The coal and siliciclastic samples collected at the La Ballesta open-pit have provided
141 well to very-well preserved palynological assemblages consisting of miospores, pollen
142 grains, phytoclasts and amorphous organic matter (AOM), in addition to reworked but
143 generally well preserved miospores and acritarchs. A total of 40 miospore species, in 28
144 genera, and 4 pollen grain species, in 2 genera, have been identified. The spore/pollen

145 assemblages are dominated by Lower-Middle Pennsylvanian species characterized by
146 disparate stratigraphic ranges. Assignment of the reported taxa to their respective parent
147 plants, permits identification of four major taxonomic groups: lycopsids, sphenopsids,
148 ferns and gymnosperms (Table 1). Selected miospore and pollen taxa are illustrated in
149 Figure 4.

150 **Discussion**

151 In biostratigraphic terms, the samples analyzed can be assigned to the Duckmantian NJ
152 miospore biozone of Clayton *et al.* (1977) given the co-occurrence of the index species
153 *Microreticulatisporites nobilis* and *Florinites junior* in the lowermost assemblage, the
154 abundance of *Crassispora kosankei* in the subsequent samples, and the absence of
155 characteristic Bolsovian taxa (Fig. 5). This age assignment is compatible with the latest
156 Duckmantian macrofloral-based age proposed by Álvarez-Vázquez (1995, 1999), but
157 partially disagrees with the palynological determinations from the San Antonio open-pit
158 (Coquel in Quesada and Garrote, 1983; Coquel, 2005). Based on the occurrence of
159 *Sinusporites sinuatus* (as *Punctatisporites sinuatus*) and *Felixites playfordii* (as
160 *Chaetosphaerites pollenisimilis*), two species that apparently disappear near de
161 Langseian-Duckmantian boundary, this author suggested a late Langsetian–early
162 Duckmantian age. However, this assemblage, as occurs with the palynoflora studied
163 herein, commonly includes reworked Viséan - Namurian miospores whose preservation
164 and color are similar to that of the “hosting” assemblage. Considering that the first
165 appearance of these two species are in accord with the age of the reworked material, and
166 that the two index species of the NJ Biozone were also recovered in the San Antonio
167 open-pit, it is possible to assume a Duckmantian age for this assemblage. In
168 consequence, palynological and macrofossils data from the SE sector of the PBE Basin
169 are entirely compatible.

170 The analysis of the ranges of abundance of the four major taxonomic groups reported in
171 the La Ballesta open-pit reveals drastic differences between coals seams and
172 surrounding beds, with no clear pattern of occurrence (Fig. 6). This, and the absence of
173 palynological correlation also detected between the floor and roof of a given coal seams,
174 can be interpreted in sedimentological terms. Palynomorphs from the surrounding beds
175 represent allochthonous particles supplied by the sediment flows that precede and
176 follow peat accumulation. The allochthonous character of these palynomorphs, and more
177 specifically, of those from the roof beds, works against the idea that roof floras can
178 provide information about plant communities growing in peat-forming environments
179 (Jenning, 1986; Teichmüller, 1989). The caution advised by Scott (1977, 1978),
180 DiMichele *et al.* (1991) or DiMichele and Phillips (1994) in relating roof floras and
181 mire environments, must be particularly taken into account when studying basins
182 governed by highly variable environmental conditions, like the tectonically dominated
183 PBE Basin.

184 The palynological content of the three coal beds studied is also heterogeneous, being
185 particularly noteworthy the variations in the abundance of lycopsids spores (Fig. 6).
186 Analyzing the palynofacies of these coal beds in terms of sedimentary environments we
187 detected correlation between the reported and expected flora (Fig. 3). The lacustrine
188 assemblage, coal bed 9, is dominated by flooding-tolerant lycopsid trees, well adapted
189 to waterlogged peat mires (Phillips, 1979; DiMichele and Phillips, 1988). Coal bed 14,
190 containing sphenophytes and, in minor extent, tree ferns as principal component, was
191 deposited in a distal alluvial plain or marginal lacustrine setting. Both environments are
192 better drained and hardly colonizable habitats for lycopsids, but more prone to be filled
193 by sphenophytes and tree ferns (Martín-Closas and Galtier, 2005). Finally, coal bed 15,
194 a thin clastic-rich coal resting on a sandstone bed of the alluvial fan, is co-dominated by

195 sphenophytes, tree ferns and lycopsids, including also a considerable abundance of
196 small ferns. A middle alluvial fan subject to intermittent flooding from active channels
197 would give rise to such floral assemblage, which involves the partial colonization by
198 lycopsids.

199 Interestingly, the changing floral assemblages reported represent not only vegetation
200 from different environments within a continental basin, but vegetation dominating coal
201 seems developed in different setting. This is in clear contrast to large paralic basins,
202 floristically much more monotonous. There, lycopsids dominate virtually all peat-
203 forming environments (DiMichele and Phillips, 1994; DiMichele *et al.*, 2001). Reasons
204 explaining this discrepancy may be related to the degree of environmental instability,
205 which largely depends on the type of basin and tectonic regime. In strike-slip basins
206 such the PBE Basin, pulsating tectonic activity constantly produce the establishment of
207 conditions suitable for coal generation in different part of the basin, i.e., in different
208 depositional environments, but each one with a distinct levels of sediment supply and
209 water table. The composition and structure of vegetation in each of these cases must be
210 necessarily different.

211 **Conclusions**

212 Coals from the PBE strike-slip basin were generated in different depositional settings,
213 accumulating different floral remains. Those from lacustrine environments were
214 dominated by lycopsids, those from the distal alluvial plain or marginal lacustrine
215 settings include sphenophytes and tree ferns as principal components, and those
216 generated in middle alluvial fan areas were co-dominated by sphenophytes, tree ferns
217 and lycopsids (Figs. 3, 6).

218 The qualitative and quantitative analysis of the palynoflora recovered from coal beds of
219 the La Ballesta open-pit suggests that nature of vegetation was not the critical factor in
220 the generation of the PBE coals. When conditions favorable for peat accumulation were
221 reached, peat accumulated regardless of the nature of the available flora, contrary to
222 what occurs in large Lower/Middle Pennsylvanian paralic basins, dominated almost
223 invariably by lycopsid trees.

224 In tectonically active basins, like the PBE, the climate factor plays a secondary role in
225 the coal generation processes. For strike-slip basins we propose tectonic as the major
226 factor controlling the origin of coal. Tectonic governed the generation and location of
227 coal-forming environments, and hence the nature, distribution and availability of the
228 coal-forming flora.

229 Additionally, the biostratigraphic analysis of the palynoflora reported here provides a
230 Duckmantian age for the coals from La Ballesta open-pit compatible with previous
231 macrofloral findings.

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403

404 **Figure captions**

405 **Figure 1:** Geological sketch of the southern Iberian Variscan Massif showing the
406 location of Carboniferous and Lower Permian outcrops, and detail of the Peñaroya-
407 Belmez-Espiel Basin indicating the sample collecting site. Numbers and Abbreviations:
408 1, Viar Basin; 2, Villanueva del Río y Minas Basin; 3, Peñaroya-Belmez-Espiel Basin;
409 4, Sierra de San Pedro Basin; 5, Guadalcanal Basin; 6, Puertollano Basin; CIZ, Central
410 Iberian Zone; OMZ, Ossa Morena Zone; SPZ, South Portuguese Zone. Modified from
411 Colmenero *et al.* (2002).

412 **Figure 2:** Chronostratigraphic chart showing the distribution and types of
413 Carboniferous and Lower Permian deposits from the southern Iberian Variscan Massif.
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415 deposits; C, Volcanic rocks; D, Limestones and calcareous sandstones; E, Shales; F,
416 Sulfides; G, Conglomerates; H, Coal; I, Coastal deposits; J, Graywackes and shales
417 (Culm); K, Erosion and/or no deposition. Modified from Colmenero *et al.* (2002).

418 **Figure 3:** Three-dimensional reconstruction of the PBE Basin indicating the distribution
419 of the major floristic groups and the theoretical location of the coal beds analyzed.

420 **Figure 4:** Selected palynomorphs from the coal and siliciclastic samples of the La
 421 Ballesta open-pit. Sample/slide codes and England Finder microscope coordinates are
 422 cited in brackets. England finder coordinates were determined with the software
 423 England Finder Calculator (González, 2012). 1, 2. *Calamospora microrugosa*
 424 (Ibrahim) Schopf, Wilson and Bentall 1944 (Coal14/a-O66/0 and Coal14/c-B34/4). 3.
 425 *Granulatisporites granulatus* Ibrahim 1933 (Roof15/b- W50/1). 4, 5. *Crassispora*
 426 *konsankei* (Potonié and Kremp) Smith and Butterworth 1967 (Coal14/d-W36/4 and
 427 Coal14/a-F61/2). 6. *Verrucosisporites cerosus* (Hoffmeister, Staplin and Malloy)
 428 Butterworth and Williams 1958 (Coal14/b- M65/2). 7. *Raistrickia saetosa* (Loose)
 429 Schopf, Wilson and Bentall 1944 (Floor9/b-M59/2). 8, 9. *Savatrisporites nux* (
 430 Butterworth and Williams) Smith and Butterworth 1967 (Floor9/b-L46/3 and Roof15/b-
 431 O66/6). 10. *Cirratriradites saturni* (Ibrahim) Schopf, Wilson and Bentall 1944
 432 (Roof15/b-V61/0). 11, 12. *Densosporites annulatus* (Loose) Smith and Butterworth
 433 1967 (Coal14/b-U44/4 and Coal14/c-Y63/2). 13. *Vestispora tortuosa* (Balme) Spode
 434 1967 (Coal15/d-X49/1). 14. *Endosporites ornatus* Wilson and Coe 1940 (Coal14/b-
 435 X36/4). 15. *Laevigatosporites minor* Loose 1934 (Coal14/d- C45/3). 16.
 436 *Laevigatosporites vulgaris* Ibrahim 1933 (Coal14/d -C44/4). 17. *Lycospora pusilla*
 437 (Ibrahim) Schopf, Wilson and Bentall 1944 (Coal14/d-F35/1). 18. *Florinites junior*
 438 Potonié and Kremp 1954 (Roof15/b-R61/0). 19. *Florinites mediapudens* (Loose)
 439 Potonié and Kremp 1956 (Roof15/b-U38/0). 20. *Florinites pumicosus* (Ibrahim) Schopf,
 440 Wilson and Bentall 1944 (Roof15/4b-G64/0).

441 **Figure 5:** Vertical ranges of selected miospore and pollen species recorded from the La
 442 Ballesta coal and siliciclastic samples, with reference to the biozonal sequence of
 443 Clayton *et al.* (1977). The orange interval indicates the age range indicated by the
 444 miospore and pollen content.

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446 palynomorphs recovered from the La Ballesta coal beds and their floor and roof
447 siliciclastic beds. Scale bars = 1 m.

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453

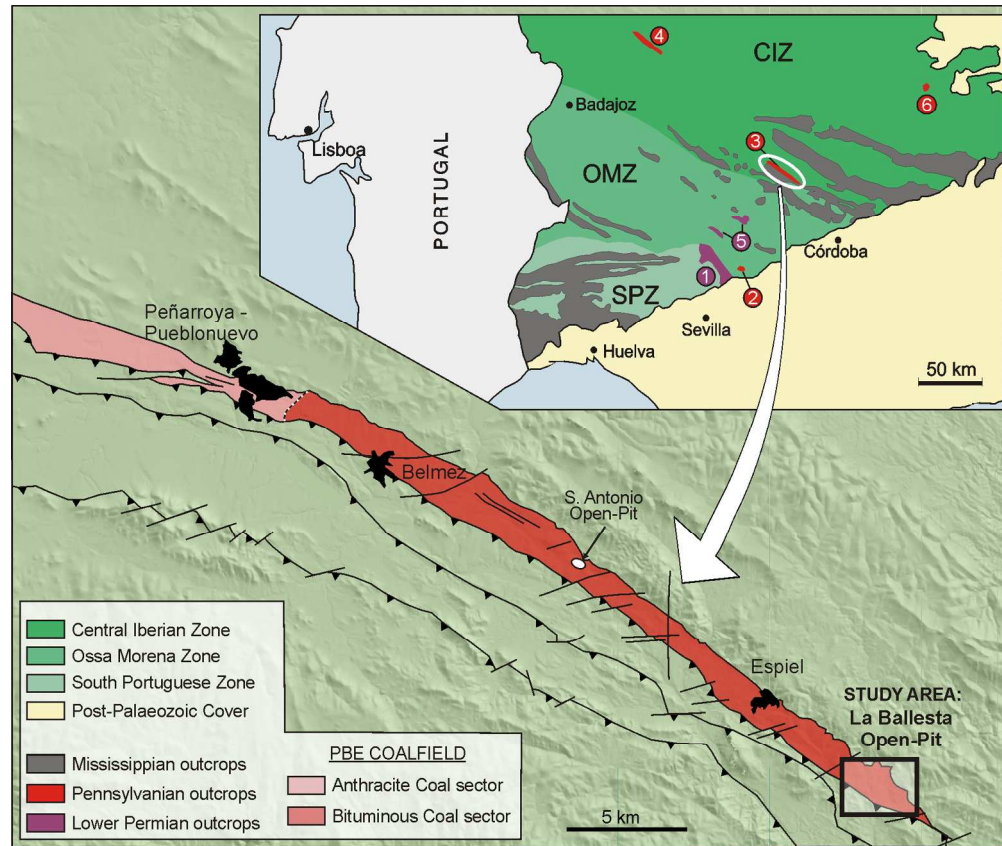


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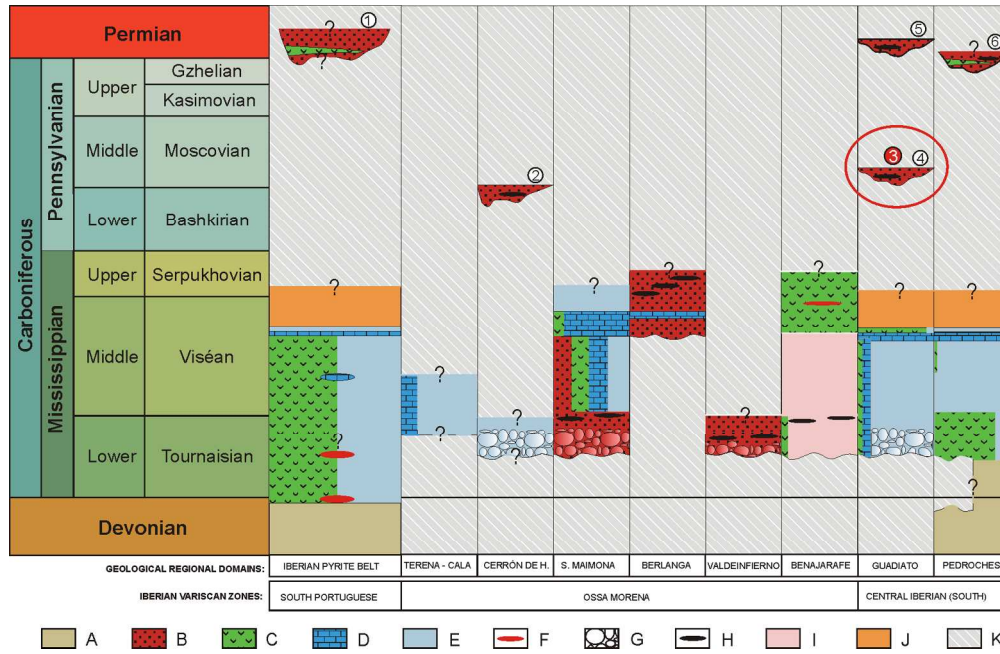


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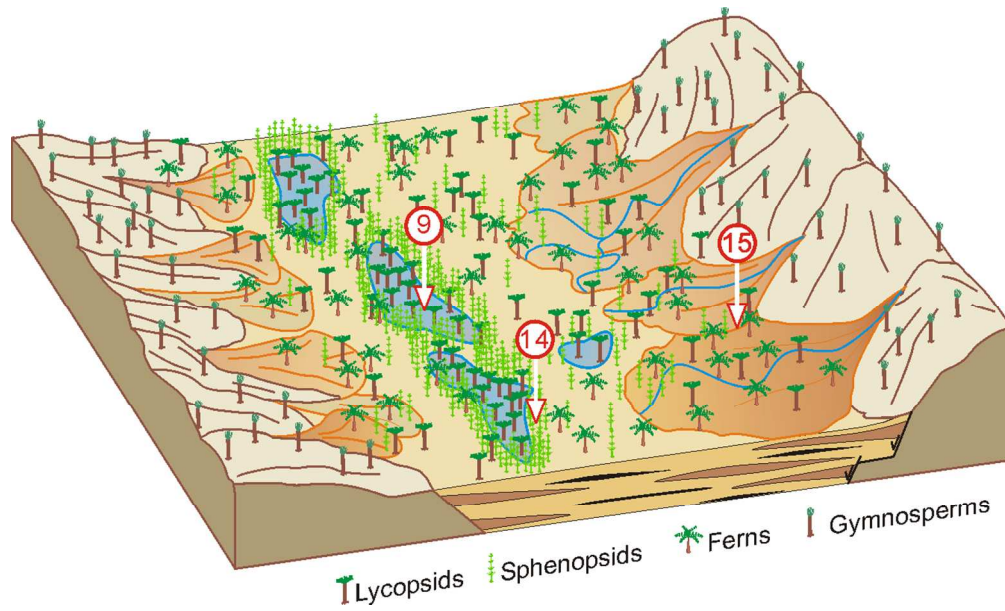


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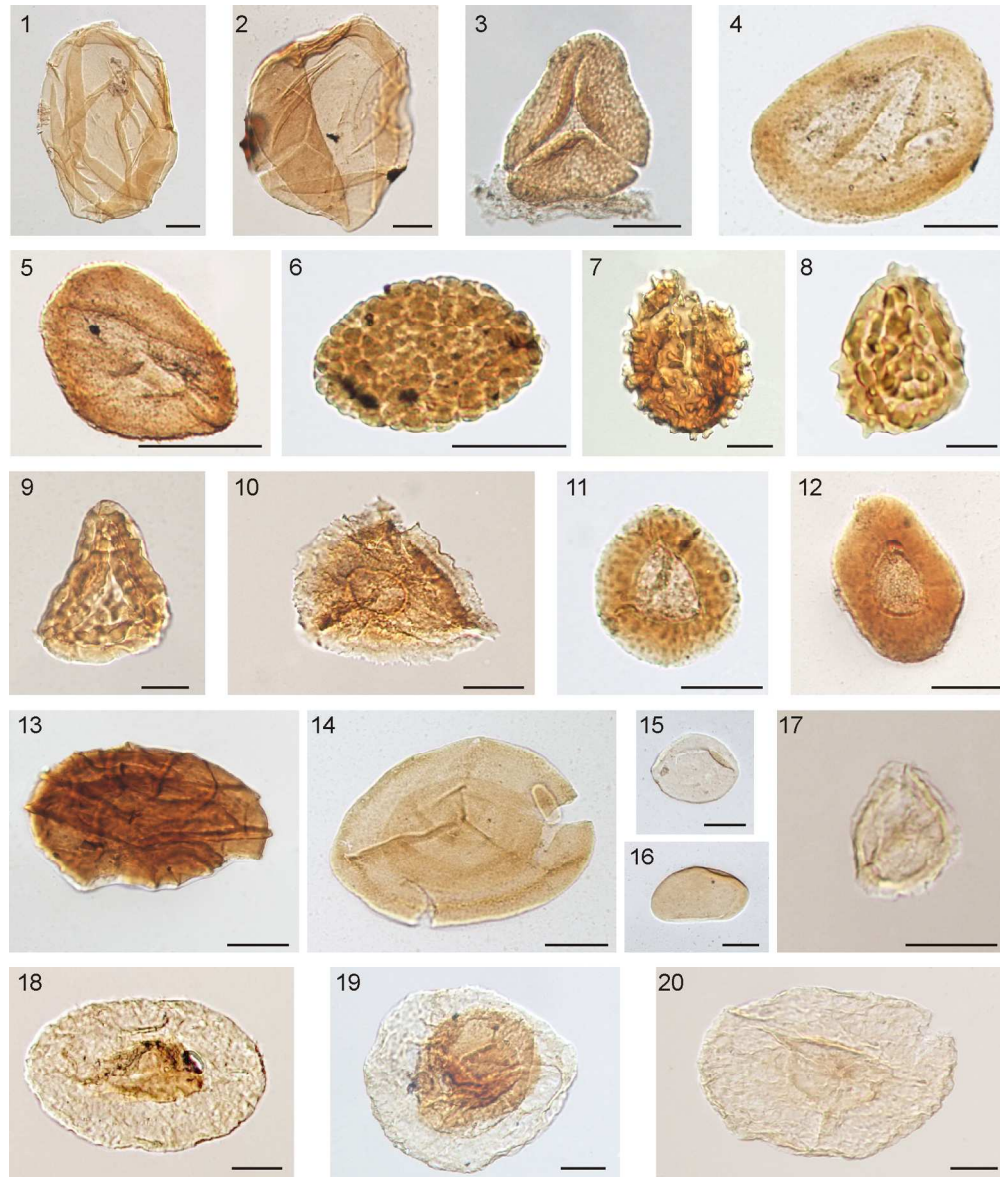


Figure 4: Selected palynomorphs from the coal and siliciclastic samples of the La Ballesta open-pit. Sample/slide codes and England Finder microscope coordinates are cited in brackets. England finder coordinates were determined with the software England Finder Calculator (González, 2012). 1, 2. *Calamospora microrugosa* (Ibrahim) Schopf, Wilson and Bentall 1944 (Coal14/a-O66/0 and Coal14/c-B34/4). 3. *Granulatisporites granulatus* Ibrahim 1933 (Roof15/b- W50/1). 4, 5. *Crassispora konsankei* (Potonié and Kremp) Smith and Butterworth 1967 (Coal14/d-W36/4 and Coal14/a-F61/2). 6. *Verrucosisporites cerosus* (Hoffmeister, Staplin and Malloy) Butterworth and Williams 1958 (Coal14/b-M65/2). 7. *Raistrickia saetosa* (Loose) Schopf, Wilson and Bentall 1944 (Floor9/b-M59/2). 8, 9. *Savatriporites nux* (Butterworth and Williams) Smith and Butterworth 1967 (Floor9/b-L46/3 and Roof15/b-O66/6). 10. *Cirratriradites saturni* (Ibrahim) Schopf, Wilson and Bentall 1944 (Roof15/b-V61/0). 11, 12. *Densosporites annulatus* (Loose) Smith and Butterworth 1967 (Coal14/b-U44/4 and Coal14/c-Y63/2). 13. *Vestispora tortuosa* (Balme) Spode 1967 (Coal15/d-X49/1). 14. *Endosporites ornatus* Wilson and Coe 1940 (Coal14/b-X36/4). 15. *Laevigatosporites minor* Loose 1934 (Coal14/d- C45/3). 16. *Laevigatosporites vulgaris* Ibrahim 1933 (Coal14/d -C44/4). 17. *Lycospora pusilla* (Ibrahim) Schopf, Wilson and Bentall 1944

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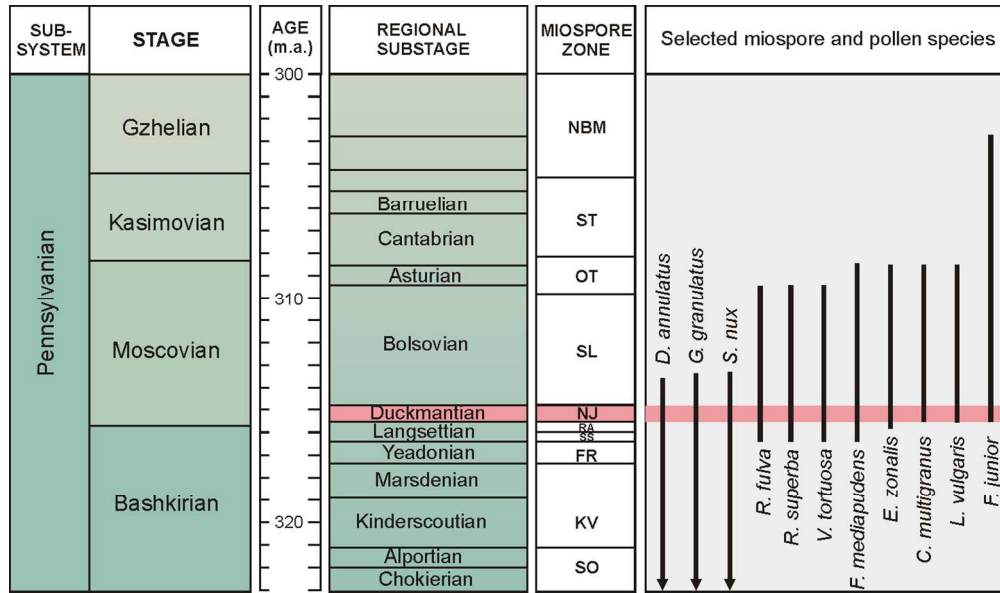


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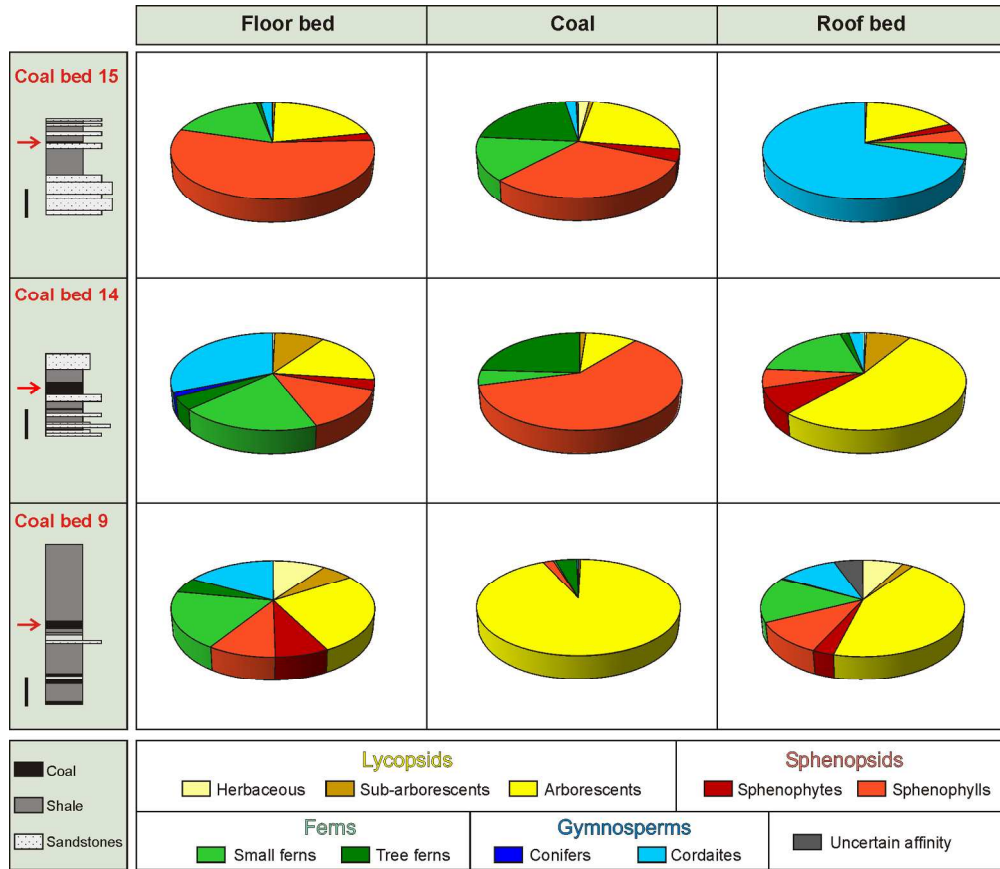


Figure 6: Quantitative distribution of major floristic groups indicated by the palynomorphs recovered from the La Ballesta coal beds and their floor and roof siliciclastic beds. Scale bars = 1 m.

		MIOspore and POLLEN TAXA									
			Floor 9	Coal bed 9	Roof 9	Floor 14	Coal bed 14	Roof 14	Floor 15	Coal bed 15	Roof 15
Lycopsiids	Her	<i>Cirratiradites saturni</i> (Ibrahim) Schopf, Wilson and Bental 1944	c			r			r		r
		<i>Cristatisporites splendidus</i> Artüz 1957			r	r					
		<i>Densosporites annulatus</i> (Loose) Smith and Butterworth 1967	c	r		c	r	u	r		
	Sub-arborescents	<i>Densosporites sphaerotriangulatus</i> Kosanke 1950			r	r					
		<i>Endosporites ornatus</i> Wilson and Coe 1950				r	r	u	r	r	r
		<i>Endosporites zonalis</i> (Loose) Knox 1950	r	r			r	r	r	r	
Arb	<i>Crassispora konsankei</i> (Potonié and Kremp) Smith and Butterworth 1967	v	c	v	a	c	v	a	c	c	
	<i>Lycospora pusilla</i> (Ibrahim) Schopf, Wilson and Bental 1944	u	v	c	r	r	a	r	a	c	
Sphenopsids	Sphenophylls	<i>Calamospora microrugosa</i> (Ibrahim) Schopf, Wilson and Bental 1944	c	u	a	a	c	c	v	a	u
		<i>Calamospora mutabilis</i> (Loose) Schopf, Wilson and Bental 1944				u	r		r	u	
		<i>Laevigatosporites minor</i> Loose 1934	r	r	r	u	a	r	r	u	r
		<i>Laevigatosporites vulgaris</i> Ibrahim 1933		r		r	v		r	a	
	Ste	<i>Vestispora tortuosa</i> (Balme) Spode 1967	c	r	u	u	r	c	u	u	u
Ferns	Small Ferns	<i>Apiculatisporis abditus</i> (Loose) Potonié and Kremp 1955			r						
		<i>Dyctiroleles densoreticulatus</i> Potonié and Kremp 1955					r				
		<i>Dyctiroleles medioreticulatus</i> (Ibrahim) Smith and Buterworth 1964				r					
		<i>Granulatisporites granulatus</i> Ibrahim 1933	r			u		r	u		
		<i>Granulatisporites microgranifer</i> Ibrahim 1933								r	
		<i>Leiotriletes priddyi</i> (Berry) Potonié and Kremp 1955	r		r	r	r	r	u	r	
		<i>Lophotriletes gibbosus</i> (Ibrahim) Potonié and Kremp 1954				r		r			
		<i>Raistrickia fulva</i> Artüz 1957		r	u			u	r	u	r
		<i>Raistrickia saetosa</i> (Loose) Schopf, Wilson and Bental 1944	u		u	c		u			u
		<i>Raistrickia superba</i> (Ibrahim) Schopf, Wilson and Bental 1944	u				r		u	u	r
		<i>Reticulatisporites carnosus</i> (Knox) Neves 1964					r		r		
		<i>Reticulatisporites polygonalis</i> (Ibrahim) Smith and Butterworth 1964			r	r			u	u	
		<i>Reticulatisporites reticulatus</i> (Ibrahim) Ibrahim 1933			r	r			u	u	r
	<i>Savatisporites nux</i> (Butterworth and Williams) Smith and Butterworth 1967	c	r	c	c	r	c	a	u	u	
	<i>Verrucosporites cerosus</i> (Hoffmeister et al) Butterworth and Williams 1958	u	r			u	r		u		
	<i>Verrucosporites sifati</i> (Ibrahim) Smith and Butterworth 1964				u	r					
	Tree Ferns	<i>Cyclogranisporites multigranus</i> Smith and Butterworth 1967	r	u	r	u	a	u	r	a	
		<i>Microreticulatisporites concavus</i> Butterworth and Williams 1958	r			u					
		<i>Microreticulatisporites nobilis</i> (Wicher) Knox 1950	u								
	Gymnosperms	Conifers	<i>Florinites junior</i> Potonié and Kremp 1954	c	r	r	u	r	u	r	u
<i>Florinites mediapudens</i> (Loose) Potonié and Kremp 1956				r	u	c		r	u	r	a
<i>Florinites pumicosus</i> (Ibrahim) Schopf, Wilson and Bental 1944			a		c	a		r	r		v
<i>Monoletes ellipsoides</i> (Ibrahim) Schopf 1938					r	u					
Uncertain affinity	<i>Alatisporites pustulatus</i> Ibrahim 1932					r	r	r		r	
	<i>Auroraspora? pickerillensis</i> McLean 1993									r	
	<i>Cingulizonates loricatus</i> (Loose) Butterworth and Smith 1964						r				
	<i>Discernisporites irregularis</i> Neves 1958	r	r	c	r			r	r	r	
	<i>Mooreisporites fustis</i> Neves 1958									r	
	<i>Punctatisporites solidus</i> Hacquebard 1957		r					r			
	<i>Secarisporites remotus</i> Neves 1961					r					
	<i>Tripartites</i> sp.						r				

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