

1 Palynology of surface sediments from caves in the Zagros Mountains (Kurdish Iraq):  
2 patterns and processes.

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7

8 Abstract

9 Cave palynology has been widely used to reconstruct past vegetation in areas where  
10 other conventional sources of pollen are scarce. However, the mechanisms involved  
11 in pollen transport, deposition and accumulation in caves are still poorly understood,  
12 mostly because of the number of interplaying factors that affect these processes. In  
13 this paper we explore some of these factors further by assessing differences in  
14 pollen assemblages in transects of surface samples from six caves in the Zagros  
15 Mountains of Kurdish Iraq. Simple sac-like caves show a clear pattern in pollen  
16 distribution with anemophilous taxa declining from the highest percentages near the  
17 front of the cave to lower percentages at the rear of the cave and entomophilous  
18 taxa showing the opposite trend. There is a tendency for this pattern to be most  
19 marked in caves which are narrow in relation to their length. It is less clear at  
20 Shanidar Cave, most probably because of the geometry of the cave but also  
21 because of the disturbance and mixing of the superficial sediments caused by the  
22 large numbers of people visiting the cave. Only one of the sampled caves shows a  
23 different pattern, which is likely to reflect its geomorphological complexity and,  
24 consequently, its air circulation. Other factors, such as the presence of a cave

25 entrance flora, are considered but here they seem to have little influence on the  
26 pollen assemblages, contrary to that found in temperate-zone caves.

27

28 Keywords: Caves, Palynology, Taphonomy, Zagros Mountains, Vegetation

29

30 1. Introduction:

31 The central Near East has always been an area of particular interest for archaeology  
32 and prehistory because it is a location through which European, Asian and African  
33 populations interchanged. It is also a hearth of early domestication of plants and  
34 animals (Solecki, 1963). In comparison with Europe, however, the history of  
35 vegetation and climate change in this critical region has been the object of relatively  
36 few studies with most of them undertaken in Turkey, Iran and Syria (e.g. Van Zeist  
37 and Bottema, 1977; Van Zeist and Woldring, 1978; Bottema and Woldring, 1984;  
38 Van Zeist and Bottema, 1991; Bottema, 1975, 1995; Litt *et al.*, 2009, 2011, 2012,  
39 2014; Kaplan, 2013; Pickarski *et al.*, 2015; Beug and Bottema, 2015; Van Zeist and  
40 Bottema, 1977; Djamali *et al.*, 2008; 2009; 2011; Nickewski and van Zeist, 1970;  
41 Deckers *et al.*, 2009). For many years, the only pollen-based palaeoenvironmental  
42 work in Iraq was by Arlette Leroi-Gourhan on the Shanidar Cave deposits (Solecki  
43 and Leroi-Gourhan, 1961; Leroi-Gourhan, 1968, 1975, 1998, 2000). Shanidar Cave  
44 is an important Mousterian site located in the Zagros Mountains in the northeast of  
45 the country. This site is particularly important because a substantial number of  
46 Neanderthal skeletons were recovered in the 1950s and 1960s (Solecki, 1963). The  
47 context of one of these skeletons, Shanidar IV, was studied palynologically by Leroi-  
48 Gourhan (1975). The area around the skeleton contained clumps of pollen of spring

49 flowers, which led Leroi-Gourhan (1975) and Solecki (1975, 1977) to the conclusion  
50 that complete flowers were deposited with the body as part of a funerary ritual. This  
51 interpretation caused considerable controversy (e.g. Sommer, 1999) but the political  
52 situation in Iraq prevented reassessment of the cave deposits at Shanidar for many  
53 years.

54 As part of the re-excavation and reassessment of the archaeology of Shanidar Cave  
55 (Reynolds et al. 2016) we have conducted pollen taphonomic work at Shanidar and  
56 other caves in the High Zagros with the aim of reaching an understanding of the  
57 processes leading to the pollen assemblages reported by Leroi-Gourhan (1975) and  
58 of the palynological sequence in the cave (Leroi-Gourhan 1968, 1975, 1998, 2000).  
59 Our preliminary reassessment of this remarkable find suggests that other processes  
60 than those suggested by Leroi-Gourhan (1975) may have been implicated in forming  
61 the clumps of pollen that she linked with complete flowers (Fiacconi and Hunt 2015).  
62 Shanidar Cave is, however, a major tourist destination, visited by hundreds of people  
63 a day during the spring and early summer, and the superficial deposits in the cave  
64 have been much disturbed by visitor footfall. It is therefore necessary to examine the  
65 taphonomic signature of other similar caves which are not affected by visitor  
66 presence, but are close to Shanidar Cave, in order to better evaluate the hypotheses  
67 of Leroi-Gourhan (1975) and Solecki (1975, 1977).

68

## 69 2. Pollen taphonomy in cave environments

70 In the last few decades, cave palynology has been widely used to reconstruct the  
71 past vegetation at local and regional scales, especially in arid and semi-arid areas  
72 where other depositional environments suitable for preserving pollen are scarce (e.g.

73 Gale et al., 1993; Carrion et al., 1999; Hunt et al., 2011; de Porras et al., 2011;  
74 Edwards et al., 2015). However, the mechanisms involved in pollen transport,  
75 deposition and accumulation inside caves are still under investigation because of the  
76 number of interconnected factors that can affect them. These include

- 77 • environmental setting of the cave, including issues such as aspect and exposure  
78 to prevailing winds (e.g. Weinstein, 1983) and properties of vegetation outside  
79 the cave (e.g. Coles & Gilbertson, 1994; de Porras et al., 2011);
- 80 • geomorphology of the cave, including number and size of entrances, complexity  
81 of the cave network and air-circulation patterns (e.g. van Campo & Leroi-Gourhan,  
82 1956; Coles et al., 1989; Coles & Gilbertson, 1994; Simpson & Hunt, 2009);
- 83 • inputs of pollen via drip waters and fluvial processes (e.g. Peterson, 1976; Coles  
84 et al., 1989; Genty et al., 2001);
- 85 • presence of cave entrance-flora (e.g. Hunt & Gale, 1986; Coles et al., 1989;  
86 Coles & Gilbertson, 1994)
- 87 • activities of animal and human vectors (e.g. van Campo & Leroi-Gourhan, 1956;  
88 Bottema, 1975; Bright & Davis, 1982; Davis & Anderson, 1987; Coles et al., 1989;  
89 Hunt & Rushworth, 2005; Fiacconi & Hunt, 2015).

90 Experimental studies undertaken during the last fifty years in caves in different areas  
91 of the world, and especially in Spain, have shown the presence of some general  
92 patterns in pollen distribution in this kind of environments even if the local  
93 characteristics can have a strong influence in the final pollen assemblages. In  
94 general, those studies (van Campo & Leroi-Gourgan, 1956; Burney & Burney, 1993;  
95 Coles & Gilbertson, 1994; Prieto & Carrión, 1999; Camacho et al., 2000; Navarro et  
96 al., 2001; Navarro et al., 2002; Hunt & Rushworth, 2005; de Porras et al., 2011)  
97 identified:

- 98 • the importance of the cave morphology, with small cave mouths and narrow
- 99 shapes related to lower pollen concentration
- 100 • a decline of anemophilous/airfall pollen with distance from the cave mouth
- 101 contrasting with greater importance of animal-transported pollen near the back of
- 102 the cave;
- 103 • higher pollen concentrations in caves with high human and animal presence;
- 104 • good agreement between cave assemblages and those on open-air sites nearby;
- 105 • generally good representation of the vegetation at a local scale but often an
- 106 under-representation of arboreal pollen and over-representation of fern spores;
- 107 • the positive impact of dryness in pollen preservation;
- 108 • the relevance of post-depositional processes such as differential preservation.

109 Clearly, the influence of these factors is quite variable. In this paper we explore  
110 some of them further by assessing differences in pollen assemblages in transects of  
111 surface samples from six caves in the Zagros Mountains of Kurdish Iraq. Most of  
112 the caves studied are simple phreatic remnants in morphology, none have  
113 streamways, all have little or no entrance flora and all have comparatively low levels  
114 of ingress of drip-water. They are therefore relatively simple systems in which to  
115 explore factors such as aspect and the influence of animal vectors relative to  
116 deposition of windblown pollen. The present study aims to understand the  
117 mechanisms involved in pollen transport and deposition in this kind of environment  
118 and the influence of the factors mentioned above on the composition of the related  
119 pollen assemblages.

120

121 3. Environmental setting

122

123 The study area is located in the northern part of Iraq within the Irano-Anatolian  
124 phytogeographic region (Guest and Al-Rawi, 1966). This region is species-rich, with  
125 altitudinal and topographic influence on the composition of the vegetation, which is  
126 characterised by zones of forest, steppe, halophytic and psammophytic vegetation  
127 (Fig. 1a). The caves studied in this paper are located within the mountain-forest zone,  
128 situated in the western slopes of the Zagros Mountains. The zone lies altitudinally  
129 between 500 and 1750-1800 m (Fig. 1b).

130

131 The main arboreal element of the forest is *Quercus* (*Quercetum aegilopidis*,  
132 *Quercetum aegilopidis-infectoriae* and *Quercetum infectoriae-libani*), while in some  
133 small areas near Mosul *Pinus halepensis* var. *brutia* is predominant. In undisturbed  
134 areas the tree cover is high, resulting in a closed forest that becomes an open forest  
135 in more densely populated places, since near villages, trees are slashed (their side  
136 branches are removed) to provide winter fodder for goats. Steppe vegetation can  
137 completely replace forest in those areas where the trees have been over-exploited  
138 and in dry places (Guest and Al-Rawi, 1966). In the study area, close to Shanidar  
139 Village, oak forests are rather open and quite heavily grazed, with grass-rich swards  
140 between the trees, characterised by abundant wild cereals and a rich herb flora  
141 (Fiacconi & Hunt, 2015).

142

143 [Insert Figure 1]

144

145 The studied caves differ in morphology, aspect, location and human and animal  
146 presence (Table 1).

<b>Cave</b>	<b>Characteristics</b>
Shanidar Cave	<p>GPS 36° 50' 0.1" N, 44° 13' 11.8" E, 747 m asl.</p> <p>Cave of phreatic origin; it shows well-developed half-domes and other phreatic features. There are some vadose features, particularly in the network of narrow vadose canyons which open off the right side of the main chamber. There is also a small second chamber to the rear right of the main chamber that is largely infilled with sediment and appears to have no archaeological significance. Until recently the cave was inhabited, during winters, by tribal Kurds with their animals; more recently it has become a popular local tourist destination and it is visited by up to several thousand people per day in the spring and summer. The cave floor is covered by silty organic sands, mostly derived from granular disintegration of the cave roof, with an admixture of aeolian dust and animal dung.</p>
SLS203	<p>GPS 36° 42' 22.3" N, 44° 12' 29.6" E, 581 m asl.</p> <p>Shows a sub-tubular morphology with half-domes characteristic of formation in a phreatic system. An adjacent cave shows vadose features but there are none in SLS203. The cave is single-chambered, but has two entrances and is 36 m long and up to 12 m wide, with the accessible mouth to the south. To the north, the back of the cave opens on to a cliff face and is partially blocked by a drystone wall. During the work in the cave (a period</p>

	<p>of some 10 days) a strong draft came through the northern entrance to the cave. The cave floor is covered by silty highly-organic sands with very abundant dung of sheep and cattle. The cave is still used on occasion by local shepherds to keep their animals safe from wild creatures overnight.</p>
SLS207	<p>GPS 36° 49' 12.8" N, 44° 14' 22.1" E, 559 m asl.</p> <p>This cave is developed along a gull, where cambering is dragging the bedrock to the west of the cave outward and downward into the valley which runs parallel to and to the west of the chamber. There are no phreatic or vadose features. The cave is single-chambered, single-entranced, 13 m long, 7 m wide at the front and 2 m at the back, facing north. The cave floor deposits are predominantly inorganic sandy silts, most probably primarily of aeolian origin with some material derived from granular disintegration of the cave walls and roof.</p>
SLS210	<p>GPS 36° 49' 10.1" N, 44° 14' 15.6" E, 623 m asl.</p> <p>This is a complex phreatic remnant, single-chambered, single-entranced, 6 m long, 8 m wide. The floor deposits are organic silts with occasional animal dung.</p>
SLS215	<p>GPS 36° 49' 8.7" N, 44° 14' 15.3" E, 681 m asl.</p> <p>This is another complex phreatic remnant. It is single-chambered, single-entranced, 6 m long, 8 m wide. The cave floor is composed of slightly gravelly sand and there are seeps on joints to the rear and right side of the cave</p>
SLS218	<p>GPS 36° 49' 37.2" N, 44° 14' 35.3" E, 771 m asl.</p>



The cave is a phreatic tube remnant, terminated now by highly-cemented rockfall. It is single-chambered, single-entranced, 10 m long, 9 m wide. The cave floor deposits are slightly organic slightly sandy silts, disturbed in places by small-scale shallow irregular digging. The sampling transect was placed to avoid disturbed areas of the cave floor.

148

149

#### 150 4. Material and methods

151 Caves were located by ground survey and through conversations with local  
152 informants. The caves were selected on the basis of their morphological  
153 characteristics and human and animal presence in order to understand the influence  
154 of those factors on the pollen composition and in particular: single vs double  
155 entrances, narrow vs wide shapes and human and/or animal presence or absence.  
156 Their locations were noted using handheld GPS units and on a Google Earth image.  
157 These GPS locations proved to be unreliable in the narrow, precipitously-sided  
158 valleys in the survey area. Locations obtained using GPS, when compared with the  
159 Google Earth locations, showed considerable discrepancies.

160

161 Surface samples were collected in each cave along a linear transect going from the  
162 back to the front of the caves in order to study the influence of sample location in the  
163 pollen composition and, in particular, the distribution of anemophilous and  
164 entomophilous taxa at different distances from the cave entrance (Fig. 2). At least  
165 one sample was collected outside each cave entrance to analyse the different pollen  
166 transport and deposition inside and outside the caves and to provide a 'baseline' of

167 the local pollen rain close to the cave. A total of 48 surface samples were analysed  
168 (12 from Shanidar Cave, 9 from SLS203, 7 from SLS207, 7 from SLS210, 6 from  
169 SLS215 and 7 from SLS218). Additionally, six moss samples from polsters growing  
170 on seeps in the east wall of SLS203 were analysed. SLS203 was the only cave  
171 where moss polsters were present and they offered an opportunity to compare  
172 polster material with the pollen recorded in the surface soil samples, considering the  
173 inconsistencies usually noticed between these sampling methods (Cundill, 1991).  
174 Finally, four samples of bird droppings, two of droppings of sheep/goats, eight  
175 dripwater samples and two pollen trap samples from the period March-August 2016  
176 from Shanidar Cave were analysed for comparative purposes.

177

178 Samples were prepared by boiling in potassium hydroxide (KOH) solution to  
179 disaggregate the matrix and dissolve the humic material. Carbonate-rich sediments  
180 were treated with dilute hydrochloric acid (HCl). Boiling in sodium pyrophosphate  
181 ( $\text{Na}_4\text{O}_7\text{P}_2$ ) solution was used for clay-rich sediments (following Bates et al., 1978).  
182 Only for samples from Shanidar Cave was it necessary for KOH and HCl treatments  
183 to be followed by density separation using a solution of sodium polytungstate (SPT)  
184 in water adjusted to a specific gravity of 1.9 in order to separate mineral fragments  
185 from organic according to their relative density (Munsterman and Kerstholt, 1996).  
186 Samples were stained with aqueous safranin and mounted using glycerine. Pollen  
187 grains were identified (with reference to Reille, 1995; Moore et al., 1991 and Faegri  
188 and Iversen, 1975) and then counted using an optical microscope (Meiji MT4000  
189 Series with magnification of  $\times 400$  and  $\times 1000$ ). Relative pollen percentage  
190 frequencies have been calculated on the basis of a pollen sum including all terrestrial  
191 pollen and spores including unidentifiable grains to produce the relative pollen

192 diagrams. Unidentified pollen grains reflect the fraction of deteriorated grains and  
193 their number was used as an indication of the preservation of the pollen and,  
194 therefore, of the environmental conditions where the pollen has been found (Moore  
195 et al., 1991).

196

197 [Insert figure 2]

198

## 199 2. Results

200

### 201 4.1 Shanidar Cave

202 Results from Shanidar Cave have already been published in a previous preliminary  
203 work (Fiacconi & Hunt, 2015). Here we report the relative pollen diagram (Fig. 3)  
204 annotated to show the anemophilous and entomophilous pollen types, while the  
205 significance of the results is examined in relation to the findings from the other caves  
206 in the discussion. The samples from the transect in Shanidar Cave all show good  
207 concentration (187-508 grains per sample) and preservation (87.2-97.7% identifiable  
208 grains ). Herbs are the more abundant (62.6-93.9-%) followed by trees (0.6-22.6%)  
209 and shrubs (1.0-93.9%).

210 The comparative animal dropping, dripwater and pollen trap data for the cave are  
211 shown in Table 2. Very few pollen grains were recovered from these experiments.

212

213 [Insert Figure 3]

214

215

216 Table 2. Water samples, pollen traps, goat/sheep dung and bird dropping pollen count from Shanidar Cave..

Sample	Water samples								Pollen traps		Goat/sheep dung		Bird dropping			
	1	2	3	4	5	6	7	8	1	2	1	2	1	2	3	4
Poaceae	1	0	0	0	0	0	0	0	1	1	5	3	0	1	0	0
<i>Quercus</i>	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0
Brassicaceae	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Fabaceae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Cyperaceae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Chenopodiaceae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Senecio</i> -type	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Fern spores	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
VAM	0	0	0	0	0	0	0	0	0	0	10	2	0	0	0	0
Indeterminate	0	0	0	0	0	0	1	0	1	1	5	2	0	0	0	0

217

218 4.2 Cave SLS203 (Caf Sidar)

219 Samples from cave SLS203 all show good concentration (241-492 grains per sample)  
 220 and preservation (92.5-100% identifiable grains) with the exceptions of the two  
 221 outside samples where a higher percentage of grains (2.2-7.5%) were poorly  
 222 preserved. Herbs are the more abundant (75.2-97.0%) followed by trees (2.7-10.8%)  
 223 and shrubs (0.3-5.5%); ferns are also present with a peak in one of the samples  
 224 (SLS203/S1, 39.4%) from outside the cave probably reflecting the fern-rich flora on  
 225 the rocky ground outside the cave. The main taxa identified are Poaceae,  
 226 Asteraceae, Lactuceae, Cyperaceae, Caryophyllaceae and *Quercus*. Anemophilous  
 227 taxa show higher percentages at the back of the cave, decreasing towards the  
 228 entrance then increasing again outside, while entomophilous taxa increase from the  
 229 back to the front of the cave (Fig. 4).

230

231 [Insert Figure 4]

232 The moss polster samples show a very different pattern (Fig. 5). Preservation is  
233 good (97.8-99.4% identifiable grains) with herbs showing the highest values (57.3-  
234 96.6%) followed by trees (1.7-15.3%) and shrubs (0.0-16.1%). The two samples  
235 most distant from the humanly-accessible entrance are characterised by fairly  
236 uniform assemblages with very high Lactuceae, high monolete and trilete spores,  
237 some cereal sized Poaceae, Chenopodiaceae, *Bidens* type, a little *Quercus* and  
238 Poaceae. The next sample is very different, being marked by very high *Centaurea*  
239 and *Artemisia*. The three samples near the accessible southern entrance to the cave  
240 have very high Chenopodiaceae, some *Quercus* and Rosaceae.

241

242 [Insert Figure 5]

243

#### 244 4.3 Cave SLS207

245 The samples show good preservation (100-94.3% identifiable grains) but generally a  
246 lower concentration (107-344 grains per sample) compared to the previous cave,  
247 especially for the samples from the middle of the transect (SLS207/3, 70 grains).  
248 Herbs are the more abundant (12.9-96.7%) followed by trees (1.2-18.35%) and  
249 shrubs (0.0-2.4%). Ferns reach high values (71.8% and 50.2%) in the two samples  
250 near the cave entrance. The main taxa identified are Lactuceae, Asteraceae,  
251 Poaceae, *Quercus*, Caryophyllaceae and Brassicaceae. Cupressaceae and *Pistacia*  
252 are almost absent inside the cave but their abundance increases dramatically  
253 outside. Anemophilous taxa increase strongly from the back to the front of the cave  
254 and zoophilous taxa show the opposite trend (Fig. 6).

255

256 [Insert Figure 6]

257

#### 258 4.4 Cave SLS210

259

260 The concentration and preservation of the pollen are good (313-674 grains per  
261 sample and 96.7-99.2% identifiable grains) with the exception of samples SLS210/6  
262 and SLS210/7 (located just inside the cave entrance and outside it, respectively).

263 Herbs are the more abundant (50.2-84.4%) followed by trees (11.1-33.7%) and  
264 shrubs (2.0-10.0%). The main taxa identified are Lactuceae, *Quercus*, Asteraceae,  
265 Poaceae, *Pistacia* and Brassicaceae. The increase of anemophilous taxa and  
266 decrease of entomophilous taxa towards the cave entrance is gradual (Fig. 7).

267

268 [Insert Figure 7]

269

270

#### 271 4.5 Cave SLS215

272 Concentration and preservation of the samples are both good (220-312 grains per  
273 sample and 96.8-98.9% identifiable grains). Herbs are the more abundant (30.0-  
274 89.1%), followed by trees (4.2-34.5%) and shrubs (0.0-10%) with trees percentage  
275 higher compared to the other caves. The main taxa identified are Lactuceae,  
276 *Quercus*, *Pinus*, Poaceae, Asteraceae and Chenopodiaceae. Ferns are present and  
277 their percentage increases from the back to the front of the cave. Anemophilous taxa  
278 show again the rear to front increasing trend seen before (Fig. 8).

279 [Insert Figure 8]

280

281

#### 282 4.6 Cave SLS218

283 The samples from the cave and outside show a good preservation (97.9-99.0%  
284 identifiable grains) and a general good concentration (178-300 grains per sample)

285 Herbs are the more abundant followed by trees and shrubs. The main taxa identified  
286 are Lactuceae, *Quercus*, Asteraceae, Poaceae and *Pistacia*. Anemophilous taxa  
287 increase towards the entrance of the cave where they reach their maximum to then  
288 decrease again outside (Fig. 9).

289

290 [Insert Figure 9]

291

### 292 5. Discussion

293 The palynological results obtained from the six caves studied provide interesting  
294 insights for understanding the influence of different factors in the formation of cave  
295 pollen assemblages and for evaluating the stratigraphic results from Shanidar Cave.

296

#### 297 *Cave morphology*

298 The morphology of the cave seems to be one of the main element influencing the  
299 pollen distribution. In four of the five sac-like caves with a single entrance there is a  
300 clear and consistent pattern, with anemophilous pollen showing the highest  
301 percentages near the mouths of the caves and declining towards their backs. The  
302 distribution of entomophilous pollen is the inverse of this pattern, with higher  
303 percentages at the backs of the caves and a decline towards the fronts (Fig. 10).

304 This finding is similar to that noted by van Campo & Leroi-Gourhan (1956), Coles &

305 Gilbertson (1994), Camacho et al. (2000), Navarro et al. (2001) and de Porras et al.  
306 (2011) and it can therefore be regarded as a general pattern.

307

308 [Insert Figure 10]

309

310 This pattern is most marked in relatively narrow caves, such as SLS207, and less  
311 noticeable in broad caves, such as SLS210. This may well be because relatively  
312 wider caves are prone to more lateral circulation of air than narrow caves are, thus  
313 carrying anemophilous pollen into the rear of the cave. The relationship seems not to  
314 be scale-dependant, however, since it is as marked in SLS215, which is a little over  
315 4 m deep, as it is in SLS207 and SLS208, which are both over twice as long. The  
316 pattern is considerably less clear at Shanidar Cave probably because its geometry,  
317 relatively broad in comparison to its depth, that also influences the air circulation. In  
318 fact, on some days during the recent excavations in the cave (Reynolds et al., 2016)  
319 there was a noticeable lateral air circulation in the cave, with air entering on the west  
320 side of the cave mouth, passing up the west wall, around the rear of the cave, then  
321 down the east side and finally exiting from the east side of the cave mouth. The  
322 limited results from pollen trapping (Table 2) suggest, however, that the influx of  
323 anemophilous pollen to the cave is low (4-6 grains per cm<sup>2</sup> per year) and thus that  
324 the anemophilous pollen in the surface sediments of the cave has accreted over a  
325 considerable number of years. It is also possible that the pattern at Shanidar Cave  
326 has been influenced by other factors (below).

327 Only at SLS203 there is a different pattern from the sac-like caves that reflects its  
328 greater geomorphological complexity. When the cave was surveyed, a few days later



329 when the sample transect was made and later when further work in the cave  
330 occurred, there was a strong draft from the narrow north entrance on the cliff-face  
331 towards the wider south entrance through which the survey team entered the cave.  
332 If this circulation is consistent through the main periods of pollen shedding, it is  
333 possible that this might influence the pattern of pollen dispersal within the cave, with  
334 the anemophilous pollen deposited preferentially proximal to the point of ingress into  
335 the cave.

336

### 337 *Human presence*

338 The only cave with a constant and significant human presence is Shanidar. The less  
339 clear anemophilous/entomophilous pattern recorded in here might be related to the  
340 disturbance and mixing of the superficial cave sediments caused by the thousands of  
341 people who visit the cave every year. It is also possible that there may have been  
342 contributions to the cave-floor pollen from the numerous bunches of flowers  
343 (particularly wild *Anemone* and *Ranunculus* spp., but also commercially-grown roses,  
344 lilies and orchids) deposited by them. At Creswell Crags, Coles & Gilbertson (1994)  
345 noted that the flow of visitors to Robin Hood's Cave seems to have enhanced pollen  
346 deposition in the cave, thus corroborating the similar observation of van Campo &  
347 Leroi-Gourhan (1956). At Shanidar, however, the pollen concentration in the surface  
348 sediments of this highly-visited cave was sufficiently low that a heavy liquid step was  
349 required to obtain countable slides. This might suggest that the visitors did not  
350 import very much pollen into the cave on their feet. The rather irregular decline of  
351 anemophilous and rise of entomophilous pollen towards the rear of the cave is likely,

352 however, to be at least in part the result of trampling and stirring of the surface  
353 sediments in the cave by the feet of visitors.

354

#### 355 *Animal vectors*

356 We analysed droppings from birds at Shanidar Cave but these contained only very  
357 few pollen grains (Table 2), which are unlikely to have impacted on the surface  
358 assemblages there. An alternative hypothesis to explain the distribution of pollen on  
359 the cave floor in SLS203 might be pollen brought into the cave by the sheep and  
360 cattle sometimes kept there overnight, and deposited with the abundant dung on the  
361 floor of the cave. The limited analyses of animal dung (Table 2) shows that import of  
362 pollen by sheep and cattle is likely to have occurred. The animals were stalled at the  
363 rear of the cave and the differences between assemblages at the front and rear of  
364 the cave may reflect this patterning. Previous studies underline the great impact  
365 that animals can have on pollen influx and distribution, such as the work of Hunt &  
366 Rushworth (2005) at the Great Cave of Niah in Malaysian Borneo where birds and  
367 bats had a strong influence on the taxonomic pollen composition, especially below  
368 their roosting areas where very high numbers of pollen with entomophilous and  
369 zoophilous pollination biology had accumulated.

370

#### 371 *Cave entrance flora*

372 The presence of plants within the Kurdish caves is worthy of note as influencing the  
373 pattern of pollen distribution. This is particularly marked in temperate-zone caves in  
374 England and France, which can have their mouths largely blocked by ferns (e.g.  
375 Hunt & Gale, 1986; Coles et al., 1989). In Kurdish Iraq, ferns were present in few

376 caves. *Adiantum* spp. were noted growing on the walls of SLS207 close to the  
377 entrance, but these are small plants which would not have appreciably disrupted air  
378 circulation in the cave. These seem to be well-represented by monoete spores in  
379 the pollen diagram (Fig. 6). Similarly a few *Adiantum* spp. were noted on the walls  
380 of Shanidar Cave, mostly within 5 m of the entrance. These small ferns were,  
381 however, several metres from the sampled transect and do not seem to have  
382 influenced the pollen diagram appreciably (Fig. 3).

383 During the spring 2016 season, the very wet weather led to a considerable number  
384 of drips appearing within Shanidar Cave. Grasses, *Cardamine* sp., *Ranunculus* spp.,  
385 *Malva* sp. and seedlings of *Fraxinus* sp. all appeared on the cave floor in response to  
386 the drips. Conversation with the custodians of the cave indicated that the  
387 appearance of plants in any quantity within Shanidar Cave was a rare occurrence.  
388 Nevertheless, it is possible that plants growing there during previous wet years did  
389 contribute to the pollen in the cave-floor sediments

390

#### 391 *Drip water*

392 Pollen may also have been carried by the ingress of water in the drips at Shanidar –  
393 although here the quantities of water entering the cave were very small and the  
394 quantities of pollen in dripwater samples were minimal (3 pollen grains in eight  
395 dripwater samples: Table 2).

396 Other factors also seem to be operating at Caf Sidar. It can be hypothesised that the  
397 three quite different assemblages in the moss polster transect might come from  
398 water that was entering the cave through three separate small conduits. The  
399 polsters therefore would mostly contain pollen and spores generated by plants

400 growing close to the entrance to the respective conduits, with only a minor part of the  
401 pollen load arriving by airfall in the cave. Pollen has previously been shown to enter  
402 caves through meteoric waters by Genty et al. (2001). At present these remain  
403 untestable hypotheses, awaiting further work.

404

405

## 406 8. Archaeological and palaeoecological implications

407

408 These observations are important for cave-palynological studies in the following  
409 ways. First, the fact that there are regular and relatively predictable distribution  
410 patterns for pollen in sac-like caves means that sampling location is important in  
411 caves of this type. A sampling point near the mouth of a cave will be in a location  
412 where anemophilous pollen is well-represented, whereas one near the rear of the  
413 cave will have relatively better representation of entomophilous or zoophilous taxa.  
414 This patterning will be most marked in relatively narrow caves and less so in broad  
415 caves and rock-shelters. Outside the tropics, this phenomenon in turn is likely to  
416 influence palaeoecological deductions drawn from the pollen assemblages,  
417 particularly at the crude 'arboreal/non-arboreal' level, since the anemophilous taxa  
418 include many trees whereas the majority of entomophilous taxa are herbaceous or  
419 shrubby. A sampling strategy based on a single sample column will reduce 'noise'  
420 which might otherwise be introduced by moving the sampling point. If multiple  
421 localities in a cave are sampled for pollen, it would be advisable to ensure  
422 stratigraphic overlap between localities so that such effects could be quantified. In  
423 the case of Shanidar Cave, the trench sampled by Leroi-Gourhan (Solecki and Leroi-  
424 Gourhan, 1961; Leroi-Gourhan, 1968, 1975, 1998, 2000) lies close to the entrance to

425 the cave and thus her pollen assemblages should reflect a predominance of  
426 anemophilous taxa. Some of these assemblages are, however, dominated by  
427 entomophilous Asteraceae, raising the possibility either that insect transport was  
428 more prominent in the past, or that other taphonomic factors, most probably  
429 oxidative and/or microbial degradation of pollen may have influenced their  
430 composition.

431 Second, taphonomic patterns are less predictable in geomorphologically complex  
432 caves with multiple entrances. There is no substitute for a preliminary taphonomic  
433 study in such caves.

434 Third, other sources of complexity include inputs from ingressing meteoric waters,  
435 human activity, bats and birds, livestock and so on. In some cases it is possible to  
436 establish whether these processes have operated in the past. Thus, ingressing  
437 meteoric waters may leave characteristic fluvial bedforms in the sediments (e.g. Hunt  
438 et al., 2010) or may have led to induration. Vertebrate activity may result in  
439 characteristic *fumier* deposits in the case of intensive livestock keeping, or a  
440 proportion of guano in the deposits which is often recognisable micromorphologically  
441 or chemically (e.g. Shahack-Gross, 2011; Canti & Huisman, 2015 and references  
442 therein).

443

## 444 9. Final remarks

445

446 This paper presents palynological results from surface sediment transects of six  
447 caves in the Zagros Mountains of Kurdish Iraq, exploring primarily the influence of  
448 cave morphology and animal vectors in the composition of pollen assemblages. The

449 four simple sac-like caves show a clear and consistent pattern in pollen distribution  
450 with anemophilous taxa recording the highest percentages near the mouth of the  
451 cave and entomophilous taxa showing the opposite trend.. The same pattern occurs,  
452 but less clearly at Shanidar Cave, most probably because of the disturbance and  
453 mixing of the superficial sediments by people visiting the cave and because of the  
454 geometry of the cave, relatively broad in comparison to its depth. Only Caf Sidar  
455 shows an opposite pattern that likely reflects the geomorphological complexity of the  
456 cave and, consequently, its air circulation, although other factors, particularly pollen  
457 import by animal vectors are also likely to have been involved. These results  
458 suggests that the main factors acting in caves in Iraq are the cave morphology and  
459 the presence of biotic vectors such as animals, insects and humans. Further  
460 research on air circulation and its relation to morphology would lead to a better  
461 understanding of pollen taphonomy in caves. Other factors that played an important  
462 role in the pollen assemblages of caves elsewhere, such as the presence of  
463 entrance flora, seem to be of little importance here, the same can be said for the  
464 impact of drip water, even if some kind of influence can be presumed at least in  
465 Shanidar Cave and Cave SLS203.

466

#### 467 Acknowledgments

468

469 We thank the members of the Shanidar Project, led by Graeme Barker, for support in  
470 the field and discussion. We thank the Leverhulme Trust for funding under RPG-  
471 2013-105. We thank the Kurdistan Department of Antiquities for permissions and

472 support in the field. We also thank the editor and the reviewer for the constructive  
473 comments which helped us to improve the manuscript.

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690

691 List of figures

692

693 Fig. 1 a and b. Phytogeographic division and vegetation zones of Iraq with the study  
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696

697 Fig 2. Caves plans with sampling transect.

698

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700 from the cave back to outside the cave (after Fiacconi & Hunt 2015).

701

702 Fig. 4. Pollen diagram of selected taxa from cave SLS203 on a transect running from  
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704

705 Fig. 5. Moss polster samples from Caf Sidar (SLS203).

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709

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711 from the back of the cave to outside the cave.

712

713 Figure 8. Pollen diagram of selected taxa from cave SLS215 on a transect running  
714 from the back of the cave to outside the cave.



715

716 Figure 9. Pollen diagram of selected taxa from cave SLS218 on a transect running  
717 from the back of the cave to outside the cave.

718

719 Figure 10. Distribution of anemophilous and entomophilous taxa in the sampled  
720 caves.

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