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A stationary Mediterranean forest in southeastern Iberia during OIS 3? A reply to the comments by J.S. Carrión[☆]

Carrión challenges our interpretation of the pollen record from marine sequences located off South Iberia by arguing that our palaeoenvironmental reconstruction is in contradiction with that proposed, mostly by him, on the basis of pollen data “from lakes, peat bogs and cave deposits” from southern Spain, indicating that the Mediterranean forest persisted almost unchanged in the coastal areas during OIS 3 and was apparently not affected by the D-O millennial scale climatic variability. He suggests that in order to sort out these contradictions we should consider alternative interpretations for our marine pollen spectra, and in particular the possibility that these spectra do not reflect the vegetation colonising the nearby continent during OIS 3. We are going to show that the four statements he presents in the introduction of his comment as firmly established palaeoecological facts must be seen as no more than

working hypotheses unsupported by the evidence he cites and contradicted by a growing body of multiproxy palaeoenvironmental data. In the second part of this reply we will show that his criticism of our work applies in fact to his own conclusions.

Mediterranean forest and the cold events of OIS 3

Carrión misleadingly inflates the range of sites that would have produced palynological evidence contradicting our hypotheses. No lake sequences and only two peat bogs, Padul and Navarrés, the latter only marginally covering OIS 3, are available for study in South Iberia. This is surprising considering that this author has repeatedly used (Carrión et al., 1999, 2003, p. 1071, 124) the lack of such sequences to justify his interest in cave deposits in spite of the well known serious drawbacks of these deposits for palaeoecological reconstruction.

The studies cited by Carrión (Carrión et al., 1995, 2003) to shore up the stationary character of the Mediterranean forest and Ibero-Maghrebian

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thermophilus scrub in southern Iberian coastal environments during OIS 3 (his first point) cannot be reasonably used to suggest vegetational stability. The Perneras cave sequence (Carrión et al., 1995, 1999) is not dated and the chronology of the pollen spectra is based on the cultural attribution of the archaeological layers, most of which have yielded Mousterian assemblages. These are overlaid by a 20 cm thick final Aurignacian level (III), followed by a hiatus and a 10 cm thick Magdalenian/Epipalaeolithic level. Considering that the Mousterian levels cannot be securely attributed to OIS 3, and may well be older, the only palaeoenvironmental record concerning this isotopic stage consists of four pollen spectra from the Aurignacian level. These spectra (Carrión et al., 1995, p. 362), heavily dominated by herbaceous taxa (Compositae, Chenopodiaceae, Brassicaceae and *Artemisia*, accounting for between 50% and 80%) record low values of evergreen *Quercus* pollen (less than 10%) and a sporadic presence of Mediterranean taxa. A single spectrum from Perneras level III records the presence of *Withania*-type pollen, the only taxon that might suggest the survival in southern Iberia of Ibero-NW African flora during OIS 3. In addition, the high amplitude variation between close samples in the percentages of the main recorded taxa make these spectra unsuitable for palaeoenvironmental reconstruction, as the authors themselves are forced to admit in their conclusion (Carrión et al., 1995, p. 366): “While the Mousterian pollen record suggests conditions for chemical and stratigraphical stabilisation and, therefore, could be reliable, the Upper Palaeolithic pollen record shows features that indicate pollen deterioration, differential preservation, contamination, downward movement and reworking”. In sum the Perneras evidence cannot be used to suggest that Mediterranean forest played a continuous major role in southern Iberian coastal environments during OIS 3.

The other study mentioned by Carrión (Carrión et al., 2003), unpublished when our paper in QSR came out, reports pollen data from three other cave deposits: Siles, Cueva Negra del Estrecho del Río Quípar and Sima de las Palomas del Cabezo Gordo. The first site is not relevant here as it only covers part of OIS 2 and OIS 1. Pollen spectra from Cueva Negra do reflect a typical Mediterranean forest (abundance of deciduous and evergreen *Quercus* associated with *Pistacia*, *Phillyrea* and *Olea*, together with a conspicuous presence of steppic plants and absence of NW African taxa). However, Carrión et al. state in their study that the archaeological assemblages found therein are not dated and can only be tentatively attributed to the “last glacial age, most likely early to mid Upper Pleistocene” (Carrión et al., 2003, p. 121). It is therefore difficult to understand how this author can use such evidence to sustain the hypothesis of the stationary nature of the Mediterranean forest during OIS 3. Also, Carrión

surprisingly seems to ignore that the researchers working at Cueva Negra, affiliated to his own university, now firmly attribute this sequence to the Middle Pleistocene, based on the discovery of Acheulean handaxes and the identification of associations of rodents dated to this period (Walker, pers. com.). This conclusively rules out Carrión’s attribution of these spectra to OIS 3.

The 13 pollen spectra from Sima de las Palomas reflect a Mediterranean forest integrating NW African thermophytes. However, the chronological attribution of these spectra gives rise to the same criticisms levelled at the Cueva Negra sequence. Carrión et al. (2003, p. 122) state that “Thorium–Uranium and AMS radiocarbon dating assign these deposits to about 60,000–40,000 years ago” but neither provide the ^{14}C and U/Th determinations supporting this age, nor indicate a stratigraphic provenance for the dated samples. In fact the single U/Th date (56 ± 13–10 ka) available (Sánchez-Cabeza et al., 1999) for the levels submitted to palynological analysis may represent, considering its large standard error, an age falling well outside the limit of OIS 3. This date was obtained from an aragonite crystal collected before the start of the excavation and its original stratigraphic position cannot be securely traced (Walker, 2001 and pers. com.). First attempts to date the sequence submitted to pollen analysis (Units 1–2) failed as the charcoal samples contained insufficient carbon for radiocarbon dating (Walker, 2001) and the single unpublished AMS date (34,500 ^{14}C yr BP OxA) now available for Unit 2, obtained from burnt bone, is considered as a minimum age by the dating laboratory (Walker pers. com.). Since little is known about the site formation process and its sedimentation rate we do not know how long the two lithostratigraphic units submitted to pollen analysis took to accumulate. In other words there is no evidence that this sequence covers OIS 3 or a time span long enough to record stadial conditions within this or another isotopic stage. An older age for Sima de las Palomas Units 1–2 is a likely hypothesis considering that well-dated spectra similar to those from this sequence (relatively high percentages of deciduous and evergreen *Quercus*) characterise warm episodes in southern Iberia (Saint-Germain Ia, Ic and II) within OIS 5 (Sánchez Goñi et al., 1999, 2000b).

Carrión’s second statement, that grasses and pine were constantly more abundant than *Artemisia* during OIS 3 in continental areas, is surprising since it is clearly contradicted by his own data. The Carihuela pollen diagram for example (Carrión et al., 1998, p. 334), that he cites to support this view, records three periods dominated by *Artemisia* pollen (percentages between 40% and 80%), interpreted by him as arid stages within OIS 3. Ironically, these spectra are very similar to those from marine cores recording stadial periods (Heinrich events and the other D–O stadials) that Carrión considers, showing a remarkable double standard of

interpretation, biased by the dominance of a particular pollen transport agent.

The study that Carrión cites to support his third statement, that modern humans colonised Mediterranean Spain during “phases of xerophytization”, has little to do with population dynamics and does not provide data to support this hypothesis. In this study (Carrión et al., 1999, p. 1062) he simply observes that at Cueva Beneito, Upper Palaeolithic layers attributed to the Aurignacian, Gravettian, Solutreo-Gravettian and the Solutrean are associated with spectra dominated by steppic plants. Since no evidence exists that the Upper Palaeolithic layers of this site, dated by only two AMS dates, contain a continuous record of the human population and vegetation dynamics during the end of OIS 3 and OIS 2 that would include the phases of colonisation envisaged by Carrión, we do not see how this observation, made on a single site, could “demonstrate” a link between human colonisation and steppe development in the Mediterranean Iberia. The other problem with this interpretation is that it sees each of the cultural phases of the Upper Palaeolithic as the result of distinct population waves. This obsolete historico-culturalistic view is contradicted by patterns of continuity observed in anthropological features, subsistence strategies, technology and symbolic traditions, indicating that in many instances cultural changes are better explained as developments occurring within regional populations.

The claim that cold events of OIS 3 would coincide with the expansion of Mediterranean forest—Carrión’s fourth point—is internally flawed and contradicted by his own data. In order to make such an assertion this author would need sequences with good chronological control and palaeoclimatic indicators independent of pollen, conditions not fulfilled in any of the sequences he has analysed.

To sustain this hypothesis Carrión exclusively relies on his analysis of Navarrés 3 peat bog covering, at the bottom of the sequence, the closing phases of OIS 3 (31,000–24,000 ¹⁴C yr BP). The spectra between 31,000 and 27,000 ¹⁴C yr BP are interpreted by Carrión and Van Geel (1999) as indicating the development of a Mediterranean forest (Carrión and Van Geel, 1999, p. 225). However, a close examination of this high resolution diagram reveals alternating steppe and open Mediterranean forest curiously undetected by the authors of the analysis, which contrary to Carrión’s claim, closely matches the succession of stadials/interstadials that characterises the period between Heinrich Event (HE) 4 (ca 35.3–33.9 ¹⁴C kyr BP) and HE 3 (ca 28–26 ¹⁴C kyr BP). As evidenced in the synthetic diagram (Fig. 1) that we have elaborated upon using Carrión and Van Geel’s data, pollen spectra reflecting interstadials are characterised by the increase of *Quercus* and Ericaceae (*Erica arborea*) pollen

percentages and concentrations, as well as by the presence of *Olea* and *Pistacia* pollen grains. The rise of *Artemisia* and Chenopodiaceae percentages and concentrations marks the stadials. While more radiocarbon dates would ideally be necessary to construct a more detailed chronostratigraphical framework, the available ¹⁴C determinations are compatible with attributing the three identified interstadials to IS 7, IS 6 and IS 5 of the GISP record and their continental counterparts, well identified in the pollen diagrams from marine cores (Sánchez Goñi et al., 2000a, 2002). This is further supported by a striking similarity in taxonomic composition and representation that exist between the pollen spectra from the two sedimentary environments.

The stadial identified by the upper part of this diagram, dated between 27,000 and 25,000 ¹⁴C yr, records the first continuous presence of *Ephedra distachya-nebrodensis*, and the highest percentages and concentrations of *Artemisia* and percentages of Chenopodiaceae. The correlation of this climatic deterioration with the Heinrich 3 event is consistent with the dating of these spectra, and again their close resemblance to those characterising this event in marine cores (Sánchez Goñi et al., 2000a, 2002, p. 397, 98). In sum, analysis of the evidence not only shows that the Navarrés 3 diagram does not demonstrate, as Carrión proposes the link between cold episodes and the development of Mediterranean forest, it also identifies several previously unseen periods of forest retreat. These periods seem in phase with those detected by marine and continental proxies during OIS 3 for southern Iberia, thus contradicting Carrión’s anti-ecological view of an antiphase relation between climate and vegetation. Modern studies on sea surface temperature–vegetation relationship show that the full development of Mediterranean forests requires summer sea surface temperatures above 18°C (Van Campo, 1984). The average annual temperatures indicated by the analysis of the alkenones for the Alboran sea during the Heinrich events oscillates between 9°C and 10°C, those for the other stadials of the D-O climatic variability are between 10°C and 12°C (Cacho et al., 1999). Planktonic foraminifera assemblages indicate summer sea surface temperatures between 11°C and 13°C during the Heinrich events (Pérez-Folgado, 2003; Pérez-Folgado et al., submitted for publication) which is the present day limit for the development of temperate forests. Influence of sea temperatures on vegetation during these cold events was certainly more marked in coastal areas, which are precisely those considered by Carrión (see his point 1) as enclaves of unchanged Mediterranean forest with Ibero-Maghrebian flora. In this context and considering our reassessment of the Navarrés 3 pollen diagram, Carrión’s hypothesis that Mediterranean forests spread during the cold events of OIS 3 can only be seen as a romantic anti-uniformitarian attempt to transform his

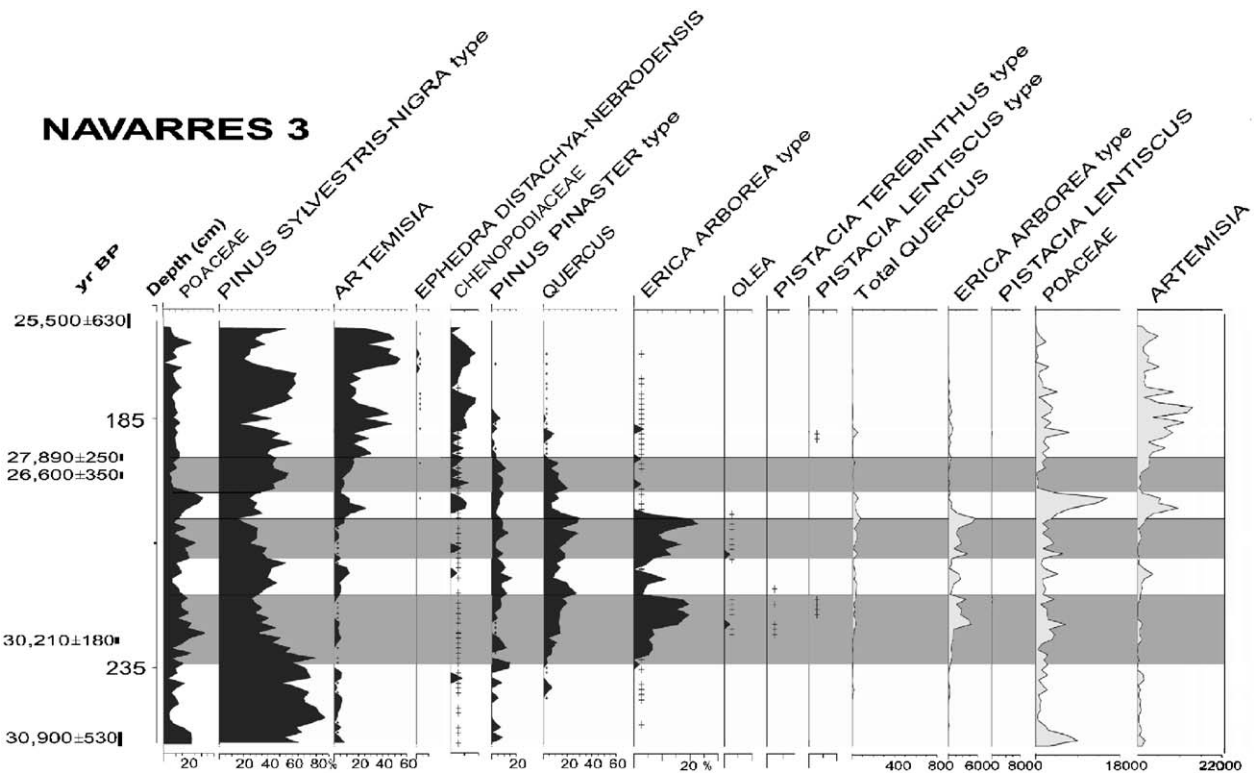


Fig. 1. Synthetic pollen diagram of the Navarrés 3 peat bog sequence (modified after Carrion and Van Geel, 1999, Figs. 4, 5, 9 and 11). Black and grey curves represent percentages and concentrations, respectively. Shaded intervals indicate spectra interpreted as interstadial periods by the authors of this reply. The upper part of the diagram characterised by the highest percentages of *Artemisia* and *Chenopodiaceae*, and the continuous presence of *Ephedra distachya-nebrodensis* is tentatively attributed to the Heinrich 3 event.

homeland into a Garden of Eden during the last Ice Age.

Marine sequences and refugia

We address below the five criticisms levelled at our interpretation by Carrión.

- (1) Doubts cast by Carrión on the palaeoecological representativeness of marine pollen spectra are unfounded (see our reply to Finlayson et al., in this issue) and the reference to Horowitz's work (1992) is misleading. While extensively discussing in his monograph pollen transport agents in arid environments (Horowitz's work, 1992, pp. 310–315), this author has never conducted experiments indicating that oscillations of *Artemisia* and chenopod pollen values depend, in marine sequences, on changes in pollen transport agents, nor mentions studies that would have demonstrated this phenomenon. Instead, he interprets variations in the proportion of these and other pollen taxa from marine spectra as reflecting palaeoenvironmental changes and climatic shifts (Horowitz's work, 1992, pp. 347–389).

Carrión's scepticism is also contradicted by the fact that pollen diagrams from marine sequences indicate late glacial and last interglacial vegetation successions that closely match the numerous continental sequences covering these periods (Turon, 1984; Lézine and Denèfle, 1997; Sánchez Goñi et al., 1999; Combourieu-Nebout et al., 2002; Turon et al., 2003). Since there is no reason to think that a different mechanism was at work only during OIS 3, we must reject Carrión's idea that pollen variation in marine cores is simply the result of transport agents and does not reflect environmental changes on the continent.

High resolution analysis of the lithogenic components of core MD 95-2043 (Moreno et al., 2002) document fluctuations of fluvial and eolian inputs and show an increase of Saharan wind intensity during the D/O stadial periods and the Heinrich events. This is to be expected, considering the low temperatures and aridity that characterised these phases and climatically consistent with contemporaneous pollen spectra indicating steppic formations. Following the hypothesis of a stationary Mediterranean forest, unaffected by the D/O climatic variability, the airborne periods would be characterised not only by high percentages of *Artemisia*,

Chenopodiaceae and *Ephedra* as Carrion implies, but also of the anemophilous tree pollen composing this forest. And this association is not observed in our marine sequences.

- (2) Contrary to Carrión's claim, we have never said that zoophilous angiosperms were absent from Iberian coastal environments during OIS 3. This would have been difficult since a number of them (e.g. Lamiaceae, Cistaceae, Asteroideae) are recorded in our marine spectra and presented in previously published diagrams (Sánchez Goñi et al., 2000a, 2002).
- (3) Carrión misquotes what we wrote about the composition of plant formations in the different regions of Iberia during OIS 3. We mention in our discussion steppes dominated by Poaceae such as *Stipa* and *Festuca* (d'Errico and Sánchez Goñi, 2003, p. 781) and not, as he says, the inedible species *Stipa tenacissima* and *Lygeum spartum*. The name of these two species and of *Artemisia barrelieri* only appear in our Fig. 6, which reports data from modern studies on steppe carbon storage.
- (4) Carrión's statement, according to which the southern Iberian palaeontological record would indicate that a continuity in the mammal communities characterised the whole of OIS 3, is contradicted by our review of the ^{14}C evidence indicating that there are no archaeological or palaeontological sites dated to H4 in this area. This would make a discussion of the available palaeontological evidence very short. Contrary to Carrion's claims, our model does not imply extinction of mammal species, but rather consistent fluctuations in communities, with a general decrease in biomass and a relative increase in species, such as ibex, adapted to arid environments. We accept Carrión's invitation to make our future approach even more interdisciplinary, but find his criticism of one of the rare attempts to integrate archaeological and palaeoecological multiproxy data for OIS 3 misplaced.
- (5) Finally, we see no contradiction between our model and present biodiversity in southern Spain. Relatively rapid contraction/expansion of the distribution area of a number of plant and interacting animal species may occur without reaching situations of crisis leading to habitat disappearance and species extinction. Repeated fragmentation and coalescence of populations through Pleistocene climatic cycles may have provided opportunity for genetic drift and allopatric speciation that guaranteed the survival of a number of species and preserved biodiversity (Hewitt, 2000; Qian and Ricklefs, 2000; Harrison et al., 2001). Even in some of the best documented refugial areas, such as NW Greece (Tzedakis et al., 2002), significant oscillations in the abundance of refugial populations are recorded throughout the last glacial.

Carrión's remark reveals a static view of Iberian phytogeography, a casual survey of our results and a basic misunderstanding of our interpretation. He seems to believe that we are against the persistence of refugium zones in southern Iberia during the cold phases of OIS 3, when in fact our result may be seen as the first formal demonstration of the existence of such refugia. Spectra from cave sequences are difficult to correlate to specific events of the D-O climatic variability and no proof exists that these deposits have kept a sedimentary record of the climatic deteriorations of this period. In contrast our marine sequences indicate, as we clearly state in our paper (Carrion, 2003, p. 777), a continuous presence of Mediterranean taxa, and this even in spectra that can be reliably correlated to the Heinrich events, thus demonstrating the presence of refugia of Mediterranean taxa during the coldest periods of OIS 3.

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