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The Mesolithic–Neolithic transition in southern Iberia

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ABSTRACT

New data and a review of historiographic information from Neolithic sites of the Malaga and Algarve coasts (southern Iberian Peninsula) and from the Maghreb (North Africa) reveal the existence of a Neolithic settlement at least from 7.5 cal ka BP. The agricultural and pastoralist food producing economy of that population rapidly replaced the coastal economies of the Mesolithic populations. The timing of this population and economic turnover coincided with major changes in the continental and marine ecosystems, including upwelling intensity, sea-level changes and increased aridity in the Sahara and along the Iberian coast. These changes likely impacted the subsistence strategies of the Mesolithic populations along the Iberian seascapes and resulted in abandonments manifested as sedimentary hiatuses in some areas during the Mesolithic–Neolithic transition. The rapid expansion and area of dispersal of the early Neolithic traits suggest the use of marine technology. Different evidences for a Maghrebian origin for the first colonists have been summarized. The recognition of an early North-African Neolithic influence in Southern Iberia and the Maghreb is vital for understanding the appearance and development of the Neolithic in Western Europe. Our review suggests links between climate change, resource allocation, and population turnover.

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Introduction

The transition from the Mesolithic to the Neolithic and the Neolithic expansion across Europe are among the most fascinating research topics of human prehistory (e.g., Fernández López de Pablo and Jochim, 2009; Haak et al., 2010). The Mesolithic–Neolithic transition in Iberia has been traditionally associated with the presence of cardial (impressed) pottery. The "cardial model" expansion (e.g. Bernabeu et al., 2009 and references therein), has been taken as the paradigm to explain the onset and expansion of the Neolithic cultures in the Western Mediterranean.

Recently, the occurrence of well dated non-cardial Neolithic sites has called into question such paradigm (Fig. 1). Examples include a number of Italian settlements, with *impressa* pottery, the French Languedoc (Pont de Roque-Haute, Peiro Signado, Guilaine et al., 2007) and the Spanish Levant (El Barranquet and Mas d'Is/"lower hut" Bernabeu et al., 2009). All of these sites provide evidence for neolithisation in the western Mediterranean prior to the Cardial expansion. Within such context, the neolithization of the Iberian peninsula (Fig. 1) is of particular interest (e.g. Manen et al., 2007; Ramos et al., 2008; Carvalho, 2010) due to its strategic location on the confluence of Atlantic, African and Mediterranean Neolithic traditions. The study of this region may additionally provide data to test models of Neolithic migration paths and migration rates through the different continents. Interestingly, this southern Iberian early Neolithic population was established in enclaves located in areas previously occupied by Mesolithic populations that depended on a broad range of coastal resources, and appear to decline for unknown reasons at this time. What seems clear at this point is that the vestiges of this Mesolithic settlement vanished soon after the arrival of the Neolithic populations.

Our main goal in this paper is to integrate archeological and climatic records, in particular paleoceanographical data, in order to characterize the context of the Mesolithic–Neolithic transition in southern Iberia. As the earliest evidences of neolithization in this area were found in coastal environments, the coasts of Málaga (Spain) and of the Algarve (Portugal) are the focus of our study.

Physical setting

The Southern Iberian Mediterranean coastal region (i.e., Malaga, Andalusia) (Fig. 1) is a coastal strip bordered by the mountains of the Betic system. Rivers and deltaic systems are poorly developed due to the proximity of these mountains that promote an abundance of rocky coastal environments. Despite its narrow shelf, marine productivity in the area is high when compared to other regions of the Mediterranean, thanks to the presence of the Fuengirola upwelling system (Bárcena and Abrantes, 1998).

The Algarve coast (Fig. 1) of Southern Portugal also features a comparatively high marine productivity thanks to local upwelling and to waters that flow from the northernmost section of the NW African/Canary/Iberian upwelling system (Fiúza, 1984; Sousa and Bricaud, 1992; Voelker et al., 2009). Local topography, including submarine canyons and coastal features (e.g. Cape St. Vincent), result in plumes of cold productive water that also impact circulation.

Regional climate in both regions is under the influence of the southern Azores anticyclone during the summer, and the interannual variability mode that defines the North Atlantic Oscillation (NAO), during the winter (Walter et al., 1975). Aridity reaches its maximum along the southern Spanish coast and peaks of precipitation occur in the Spanish hinterlands during the spring and autumn and in northern Africa, rainfall concentrates near the coast from autumn to spring, decreasing sharply southwards (Combourieu Nebout et al., 2009).

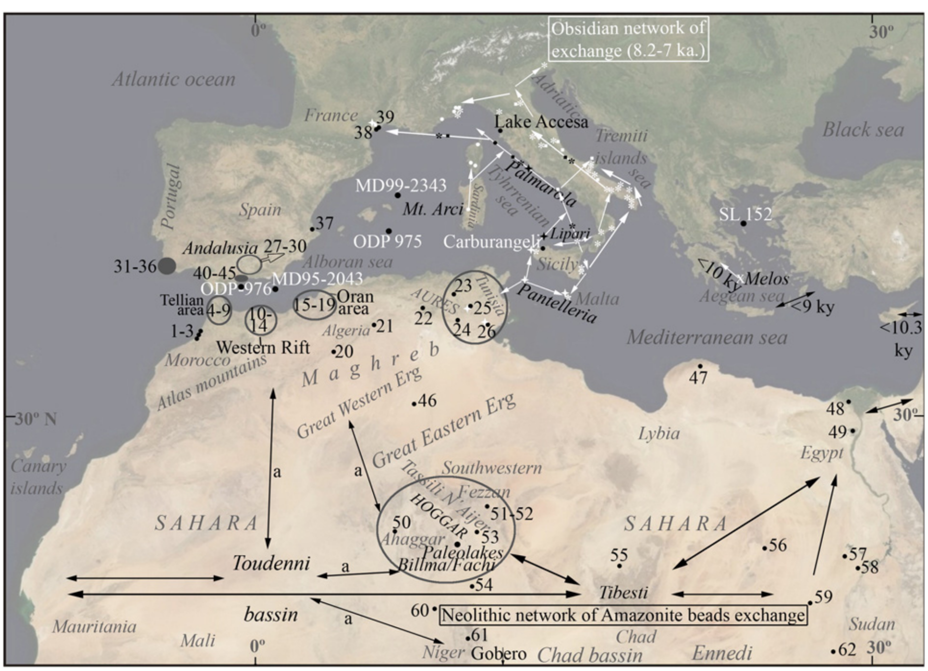

Figure 1. Reviewed archeological sites during the 8th millennium (BP) and paleoenvironmental record locations mentioned in the text. Archeological sites: 1. El M´nasara, 2. Contrebandiers, 3. El Harhoura, 4. Achakar les Idoles, 5. El Khril, 6. Ghar Kahal, 7. Berzú, 8. Kaf Thaht el Ghar, 9. Boussaria, 10. Ifri Armas, 11. Ifri Oudadane, 12. Ifri Ouzabour, 13. Hassi Ouenzga, 14. Zafrín, 15. Oued Guettara, 16. C. de la Fôret, 17. Bou Aichen, 18. Baterie Espagnole, 19. Cimitière des Escargots, 20. Columnata, 21. Ain Naga, 22. Capéletti, 23. Medjez II, Bou Zabaouine, 24. Redeyef, 25. Damous el Ahmar, 26. Doukanet el Khoutifa, 27. Carigüela, 28. Castillejos, 29. Toro, 30. Murciélagos, 31. Castelo Belinho, 32. Vale Boi, 33. Padrão, 34. Rocha das Gaivotas, 35. Cabramosa, 36. Castelejo, 37. El Barranquet, 38. Peiro Signado, 39. Pont de Roque-Haute, 40. Roca Chica, 41. Hostal Guadalupe, 42. Bajondillo, 43. Hoyo de la Mina, 44. Abrigo 6/Humo, 45. Nerja, 46. M. Sebka, 47. Maua Fteah, 48. Merimde, 49. El Fayum, 50.Amekni, 51. Ti-N-Thora, 52. Uan Muhuggiag, 53. Ti-N-Hanakkatan, 54. Adrar Bous 10, 55. E. Bardagué, 56. Wadi el Alchadar, 57. Bir Kuseiba, 58. Nabta, 59. Selima Oasis, 60. Launey, 61. Tagalagal, and 62. Oyo. Networks of exchanges of raw materials (manufactured or not) and movement of people mentioned in the text. White arrows, obsidian (8.2–7 ka) and amazonite exchange networks (Clark et al., 1973; Tykot, 1995; Vaquer, 2007; Mulazzani et al., 2010;). Black arrows: inferred population movements (Daugas et al., 2008). Grey circles: Most important Neolithic areas of Maghreb and South Iberia. Location of obsidian Neolithic tools and origins: Pantelleria (+), Lipari (*), Palmarola (white squares), Mt. Arci (white dots) and Melos (x).

Brief account of the settlements

Five Epipaleolithic–Mesolithic sites and more than fifty Neolithic archeological sites dot the Malaga coast (Cortés et al., 2010). Except for Nerja, most of these are caves or rock shelters located 100–250 m from the coast. Only five sites (e.g. Nerja, Bajondillo, Abrigo/6, H. Guadalupe and Roca Chica, Fig. 1A) incorporated early Neolithic evidence.

The western portion of the Algarve coast features a large number of Mesolithic and Neolithic sites (Fig. 1). The Late Mesolithic is recorded exclusively in the westernmost tip of the region, the St. Vincent Cape Coast, where three sites have been excavated (Castelejo, Rocha das Gaivotas and Monte de Azureque). Two of these are shell middens ("concheiros") with several levels of occupation and domestic structures, such as hearths (e.g. Silva and Soares, 1987; Soares, 1996; Bicho et al., 2003; Soares and Silva, 2004). The Mesolithic/Neolithic transition was stratigraphically documented only in the shell middens of Castelejo and Rocha das Gaivotas, although it may have also been present on the site of Vale Boi. The transition at all these sites is well preserved and short-lived elements were selected for enhanced chronological control (see below). During the Early Neolithic the number of sites and their functional diversity increased.

Material culture and subsistence strategies in Mesolithic and early Neolithic

Coast of Malaga

An erosional phase was documented during the Mesolithic/Neolithic transition on the sites of Nerja and Bajondillo (Pellicer and Acosta, 1997; Aura et al., 2005; Cortés, 2007). The Neolithic material culture included ceramic assemblages which were homogenous in form and decoration. The main decorative technique used was impression using different types of utensils, although many examples had no cardial impressions. "Cardialoid" forms were rare in the earliest phase of the early Neolithic, and increased during the later period although they were found only in Nerja and Abrigo/6 where they constituted a small fraction of the ceramic assemblages (Pellicer and Acosta, 1997). "Almagra" slip covering decorative elements, were also documented in low frequencies. The lithic industry was dominated by blades and bladelets. Sickle sheen was present, including on a few marginally retouched blades like those found at Nerja and Bajondillo. Bone tools included fish hooks (Nerja) and punches made on bones (i.e., ovicaprids) (Pellicer and Acosta, 1997; Aura et al., 2005). Adornments were common in the Neolithic sites and included marble and schist bracelets, and perforated shells. Bracelets are decorative elements unknown in the previous Epipaleolithic–Mesolithic substrate, but mollusc pendants were used before the Neolithic. Another singular kind of artifact from Nerja (Aura et al., 2005) and Hostal Guadalupe was the facetted form mimicking red deer canines. To summarize, the material culture of the southern Spanish early Neolithic was characterized by the presence of techniques and stylistic elements undocumented in the previous Mesolithic tradition.

Subsistence strategies around the Malaga Bay show that the Epipaleolithic and Mesolithic populations practiced a broad spectrum coastal economy (Table 1, Fig. 2). The records from Nerja indicate that marine resources constituted the basis of this subsistence, with rocky shore intra-tidal molluscs, in particular mussels, playing the dominant role. Epipaleolithic/Mesolithic fishing included a large diversity of groups, with demersal gadids (e.g. codfish) and sparids (e.g. sea bream) as main items (Fig. 3), although retrieval biases probably underestimated the role played by some very productive smaller-sized taxa (e.g. clupeids). These assemblages are remarkable in their combination of strictly temperate (Mediterranean) species with some boreal gadids, whose presence reveals a biogeographic realm that does not correspond to that of the present-day Sea of Alboran (Gil-De-Sola, 1999). Such mixture of fish faunas suggests that fish productivities must have been greater in the area previous to the onset of the Neolithic. From that moment on, the fish assemblages from Nerja exhibited their typical Mediterranean character (Fig. 3). Signals of farming and pastoralism followed the marine dominated layers. The former included remains of sheep, goat, pig, cow, and dog at the Malaga sites (e.g. Morales and Martín, 1995; Aura et al., 2005), which were eaten by people (Table 2), with sheep being the most frequent species. This pattern is consistent with data recorded at inland sites in southeastern Spain during the early Neolithic (e.g. Peña Chocarro, 1999; Zapata et al., 2004), although here wild species such as the ibex and the rabbit, were often common. Agricultural activities were confirmed through the presence of cultivated plants on four sites (Table 2). Barley and naked wheat were the most common species in four sites although hulled wheats and some legumes were also present.

Table 1
Comparative mammals, birds, fish and molluscs data between Epipaleolithic/Mesolithic (Cortés et al., 2008) and Early Neolithic (this study) periods from Nerja.

Period	Mammal	Bird	Fish	Mollusc	Total
Early Neolithic	1198	3	53	5145	6399
Epipaleolithic/Mesolithic	2079	157	3672	11515	17425

Roca Chica, a deposit dated to the second half of the 8th millennium, incorporated more than 12 kg of charred cereals suggesting the existence cereal surpluses. Cultivation was of such importance that it may have already had an impact on the local ecosystems, as testified by the Bajondillo pollen record. The later revealed a marked reduction in the arboreal cover after the Mesolithic (see Cortés et al., 2008). Cereal pollen frequencies above 3% were taken to indicate the practice of agriculture in the vicinity of Bajondillo. In addition, the presence of both anthropophytes, probably weed, and of coprophilous fungal spores (*Sordaria*, *Cercophora*) was suggestive of the presence of domesticated animals in the vicinity of that site. Finally, use wear analyses of lithic tools from Nerja and Bajondillo documented the presence of chert sickles inserted into handles in a diagonal position, a feature consistent with agricultural practices. Archaeobotanical data thus supports the existence of a fully developed agriculture and the exploitation of a wide range of domestic species in the region, in contrast to the pattern observed in other European regions (e.g. central Europe) where hulled wheats constituted the dominant species during the early Neolithic.

Coast of Algarve

The transition from the Mesolithic to the Neolithic in western Iberia was characterized by a regional mosaic of disparate trajectories. In the Algarve, Mesolithic settlements were centered along riverine and estuarine areas (Carvalho, 2008, 2009, 2010) and the archeological record

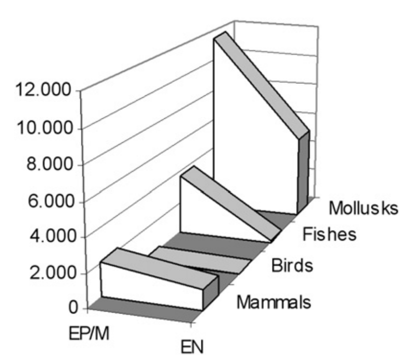

Figure 2. Comparative number of mammals, birds, fish and molluscs remains between Epipaleolithic/Mesolithic (EP/M) (Cortés et al., 2008) and Early Neolithic (EN) (this study) periods from Nerja. Detailed information in Table 1.

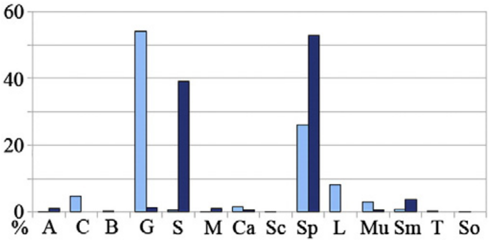

Figure 3. Comparative number of identified fish remains between Epipaleolithic/Mesolithic (light blue) and Neolithic (dark blue) from Cueva de Nerja: Acipenseridae (A), Clupeidae (C), Belonidae (B), Gadidae (G), Serranidae (S), Moronidae (M), Carangidae (Ca), Sciaenidae (Sc), Sparidae (Sp), Labridae (L), Mugilidae (M), Scombridae (S), Trigidae (T), Scorpaenidae (So).

evidenced a notable concentration of sites along the coastal strip around Cape St. Vincent, on the western tip of the region (Bicho, 2009) (Fig. 1). Although evidences for fishing are lacking, shell middens (e.g. Rocha das Gaivotas and Castelejo) are indicative of a reliance on marine resources (for detailed analyses, see; Morales and Martín, 1995; Stiner et al., 2003; Soares and Silva, 2004; Dean and Carvalho, 2011; Valente et al., in press). The lack of complex stratigraphic sequences, mammal remains, burials or large lithic assemblages suggests that these sites were seasonal camps possibly linked with the exploitation of the locally available flint. Base camps are unknown in the region, but could lie buried under the thick alluvial sediments at the mouths of major rivers, such as the Arade, located a few kilometers to the east (Lubell et al., 2007).

With the appearance of the Early Neolithic, the diversity of sites increased and shell middens, base camps, burial caves, residential camps, and knapping sites, are found throughout the region. In addition, a more extended territory, comprising the limestone hills of the hinterland, was systematically occupied (Cardoso et al., 2001; Soares and Silva, 2004; Gomes, 2008; Carvalho et al., 2008; Carvalho, 2008, 2009). The transition is only recorded in two shell middens although their chronology was suggestive of hiatuses (see below). The elements of the earliest Neolithic in the Algarve came marked by the Cardial tradition, as seen in the stylistic characteristics of its pottery and adornments. However, there are some specifics of the lithic and ceramic productions suggestive of a partial cultural reformulation (Carvalho, 2010). These characteristics were also observed in the Andalusian hinterland, where cardial decoration was restricted to the upper parts of pots and the occurrence of bag-like pots and "bottles" with pottery shapes unknown elsewhere in the Mediterranean are found. Likewise, the Almagra slip finishing procedure of pottery making, so typical of Andalusia, was also present in Portugal. Segments were the most common geometric types, whereas flint was systematically heat treated.

Evidence of Neolithic agriculture is only indirect in the Algarve (Fletcher et al., 2007). Domestic animal species have been found. As is evident from Table 2, cattle and ovicaprids are prevalent wherever mammal remains are preserved. Hunted species (i.e., rabbit, hare, red deer and wild boar) represent minor items of the economy when one considers the amount of meat provided. Birds and fish seem to be present marginally.

The Neolithic period in the western Algarve implies a clear shift in economic practices. In this way, mollusc collecting and processing, although present (complete inventories are in Stiner et al., 2003; Carvalho, 2008; Carvalho et al., 2010; Dean and Carvalho, 2011; Valente et al., in press) was no longer central to subsistence and, as a result, shell middens were no longer the most abundant kind of site. Although this could be taken to reflect a decrease of the marine resources, what it reveals is a change in behavior linked to the establishment of a new socio-economic system based on animal husbandry and agriculture. Such a shift implied lower mobility across the land during the Neolithic, and, indeed, the Early Neolithic discoveries of Castelo Belinho (e.g. burials, storage pits, and large rectangular wooden houses) testify to a more permanent settlement in the hinterland. Unpublished faunal data suggest that a broad spectrum of resources was exploited at the time (Gomes, 2008), and also that some of the Early Neolithic coastal sites such as Vale Boi (Fletcher et al., 2007; Carvalho, 2008, 2009) represented short-term occupations for the harvesting of very specific resources. But mobility and use of coastal resources do not exclude a focus on agriculture. In fact, as seasonal activities, planting, tending, and the harvesting of domestic grains could be coordinated with seasonal mobility of a part of the group. Also, the coexistence of sites like Vale Boi (seasonal) and Castelo Belinho (permanent) implies a degree of logistic occupation associated with a large population. Both kinds of occupations should thus be interpreted in a larger, regional, context representing partial views of the undoubtedly far more complex Neolithic subsistence model.

Maghreb

The Mesolithic to Neolithic transition on the north-African coast of the Strait of Gibraltar (Fig. 1) is not well documented although work along the Atlantic and Mediterranean sectors is starting to produce interesting results (e.g. Mikdad and Eiwanger, 1999; Daugas et al., 2008; López Sáez and López Merino, 2008; Rojo et al., 2010; on-going projects from the authors of this paper). At Hassi Ouenzga (Eastern Morocco), the existence of an Epipaleolithic occupation featuring ceramics of the Oran typology along with an economy based on hunting has been already suggested (e.g. Linstädter, 2003, 2010). As in Nerja, Cardial ceramics in the region appear later on in the sequence, (i.e., around the mid-8th millennium at Ifri Oudadane and Kaf Taht el Ghar), becoming frequent from the Eastern Rif to the Atlantic between 6.1 and 5.6 cal ka BP (Linstädter, 2008). Their conic bag-shaped bottoms and the heavy and extensive decoration, occasionally associated with the "Almagra" slip, exhibit parallels with forms found in the Algarve, and suggest contacts between both regions (Manen, 2000). Lithic assemblages, scarce for the most part, were characterized by the production of blades, although no evidences of sickles for cereal harvesting have been documented. These data suggest that the emergence of agriculture in the Western Maghreb was a mosaic process, apparently different from that of the Eastern Magreb (i.e., the Oran region). The earliest Neolithic of Oran featured impressed, incised and grooved ceramics. The decoration was light, often restricted to the upper portions of pots without necks and conic bases. Sometimes there

Table 2
Remains of domestic plants and animals retrieved from Early Neolithic sites in Malaga and Algarve. RC (Roca Chica), HG (Hostal Guadalupe), Bj (Bajondillo), N (Nerja), C (Carigüela), P (Parralejo), Ca (Castillejo), Cb (Cabranosa), P (Padrão), VB (Vale Boi). a) see Aura et al., 2005. b) Riquelme, 1998. c) Cortés et al., 2008, Morales and Martín 1995, Aura et al., 2005. d) Jordá 1986. e) Silva and Soares, 1987; Cardoso et al., 2001. f) Carvalho, 2008. * This study, new data.

Site Taxa	RC	HG	Bj	N	N	C	P	Ca	Cb	P	VB
Cultivated plants	*	*	*	*	(a)	(b)	(b)	(b)	(e)	(f)	(f)
Triticum aestivum/durum	X		X	X	X						
Triticum diccoccum	X										
Triticum sp.					X						
Hordeum vulgare var *nudum*	X	X		X	X						
Lathyrus sativus/cicera				X							
Pisum sativum				X							
Vicia faba				X							
Fauna	*	*	*	*	(c)	(d)	(d)	(d)	*	*	*
Ovis aries	X	X	X	X	X	X	X	X			
Capra hircus				X	X	X	X	X			
Ovis/Capra	X	X		X	X	X	X	X	X	X	X
Sus domesticus		X			X	X	X	X			
Canis familiaris	X					X	X	X			
Bos taurus?					X			X		X	

Table 3
Distribution of calibrated (CalPal2007_HULU) (Weninger et al., 2007) AMS dates on short lived and diagnostic elements of early Neolithic from western Mediterranean (Aura et al., 2005; Carvalho, 2008; Bernabeu 2002, Bernabeu and Molina, 2009; Bernabeu et al. 2001, 2002, 2003; *, this study).

Site/Level		^{14}C yr BP	cal yr BP	Sample	Lab. Id.
Vale Boi		6036 ± 39	6882 ± 56	*Ovis/capra*	OxA-13445
		6042 ± 34	6891 ± 49	*Ovis/capra*	Wk-17030
Caldeirão		6330 ± 80	7270 ± 90	*Ovis aries*	OxA-1035
		6230 ± 80	7132 ± 104	*Ovis aries*	OxA-1034
		5970 ± 120	6828 ± 147	*Bos taurus*	OxA-1037
		5870 ± 80	6685 ± 100	*Bos taurus*	OxA-1036
Kaf That el Ghar		6350 ± 60	7286 ± 85	*Hordeum*	Ly(OxA)-971
Nerja		6590 ± 40	7500 ± 43	*Ovis aries*	BETA-13157
Roca Chica*		6265 ± 60	7167 ± 85	*Hordeum vulgare*	Ua-34135
		6185 ± 30	7087 ± 54	*Hordeum vulgare*	Wk-25172
		6234 ± 30	7156 ± 76	*Ovis aries*	Wk-27462
Hostal Guadalupe*		6298 ± 30	7224 ± 35	*Homo sapiens*	Wk-25169
		6249 ± 30	7205 ± 34	*Ovis aries*	Wk-25167
		6197 ± 35	7098 ± 61	*Hordeum vulgare*	Wk-25168
		6190 ± 50	7094 ± 71	*Hordeum vulgare*	Ua-34136
Murciélagos/IV		6190 ± 130	7078 ± 156	Wheat + acorn	CSIC-54
		6190 ± 130	7078 ± 156	Wheat + acorn	CSIC-55
		6170 ± 130	7058 ± 159	Cereal indet.	CSIC-58
		6150 ± 45	7035 ± 161	Cereal + acorn	Gr.N-6169
Mas d'Is		5550 ± 40	6352 ± 38	*Hordeum*	Beta-171908
		5590 ± 40	6370 ± 39	*Triticum*	Beta-171907
		6600 ± 50	7505 ± 46	*Hordeum*	Beta-166727
		6600 ± 50	7505 ± 46	*Hordeum v.*	Beta-16672
Falguera		6510 ± 70	7416 ± 69	Cereal	Beta-142289
Or	/14	6275 ± 70	7175 ± 94	*Triticum ae.*	OxA10191
	/17	6310 ± 70	7244 ± 73	*Triticum*	OxA10192
	/Cardial/top	6265 ± 75	7162 ± 100	*Triticum ae.*	H1754/1208
	/Cardial/low	6510 ± 160	7406 ± 139	Cereal	KN-51
Cendres	/H19	6510 ± 40	7415 ± 47	*Ovis aries*	Beta-23977
	/VII	6340 ± 70	7282 ± 75	*Hordeum v.*	Beta-142228
	/H16	6490 ± 90	7401 ± 80	*Triticum dic.*	Gif-10136
	/VIIa	6280 ± 80	7171 ± 106	*Ovis aries*	Beta-107405
	/H15	5980 ± 100	6834 ± 123	*Triticum ae.*	GifA-101358
La Draga		6060 ± 40	6861 ± 87	Cereal indeterminate	UBAR-313
		6010 ± 70	6917 ± 54	Indeterminate	Hd-15451
Can Sadurní		6405 ± 50	7347 ± 54	Indeterminate	UBA-760
Baume d'Oullins		6210 ± 69	7118 ± 96	*Capra hircus*	AA-53292
		6168 ± 63	7071 ± 84	*Capra hircus*	AA-53293
		6233 ± 64	7138 ± 94	*Capra hircus*	AA-53291
		6233 ± 64	7138 ± 94	*Capra hircus*	AA-53294
		6191 ± 63	7096 ± 84	*Capra hircus*	AA-53296
		6361 ± 66	7305 ± 79	*Sus cf. domesticus*	?
Arene Candide		6830 ± 40	7661 ± 32	*Hordeum*	Beta-110542
San Marco		6120 ± 90	7014 ± 124	*Hordeum*	OxA-1854
		6270 ± 70	7169 ± 94	*Triticum*	OxA-1851
		6430 ± 80	7352 ± 67	*Triticum*	OxA-1853
Coppa Nevigatta		6880 ± 90	7735 ± 88	*Hordeum*	OxA-1475
		6850 ± 80	7706 ± 77	*Hordeum*	OxA-1474
Torre Sabea		6890 ± 130	7750 ± 118	Cereal indeterminate	Gif-88247
		6960 ± 130	7804 ± 116	Cereal indeterminate	Gif-88066
		6590 ± 140	7473 ± 117	Cereal indeterminate	Ly-4002

existed mammillated shaped pegs, often perforated. All of these features resemble materials found in Andalusia (e.g. Nerja, Murciélagos, Carigüela, etc.) more than those deriving from the Neolithic of the Sahara.

Assessing the chronology of the Neolithic emergence in the Southern Iberian Peninsula

Most of the Neolithic radiocarbon dates from Southern Iberia have been obtained on charcoal. The uncertainty of dates based on such long-lived materials precludes a precise timing for the appearance of the Neolithic in the region. In order to circumvent this problem, in this paper we have radiocarbon-dated only short-lived samples, unequivocally associated with farming and pastoralist practices. Seven new dates from four archeological sites have now been added to the existing database (Table 3).

In the Malaga coast, there exists an erosional hiatus at the Mesolithic–Neolithic boundary. At Nerja, this hiatus represents 500 yr (8.0–7.5 cal ka BP) (Aura et al., 2009), whereas at Bajondillo the hiatus is of minor importance (Cortés, 2007). Erosion of the last of the Mesolithic levels seems to be a general feature around the Mediterranean (Aura et al., 2009) that also affected Neolithic/Early Calcolithic sites in the Eastern Mediterranean (Clare et al., 2008). The new dates from Hostal Guadalupe and Roca Chica place the earliest Neolithic at around 7.3 cal ka BP (Table 3, Fig. 4). These dates are slightly younger than those obtained on a short-lived sample from Nerja (i.e., 7.5 ± 0.09 cal ka BP/2σ) (The sample was a sheep bone recovered from the bottom of a pit that reached to the underlying Mesolithic levels: Aura et al., 2005).

The chrono-stratigraphical framework of the Mesolithic–Neolithic transition in the Algarve is based on the sedimentary sequences from Castelejo and Rocha das Gaivotas. In both cases, the transition was associated with significant time lags (i.e., almost one millennium at Rocha das Gaivotas and around three centuries at Castelejo) (Table 3). These hiatuses suggest a period of depopulation or of a marginal exploitation of the region at the time of arrival of the Neolithic. According to the available radiocarbon dates, the arrival of the

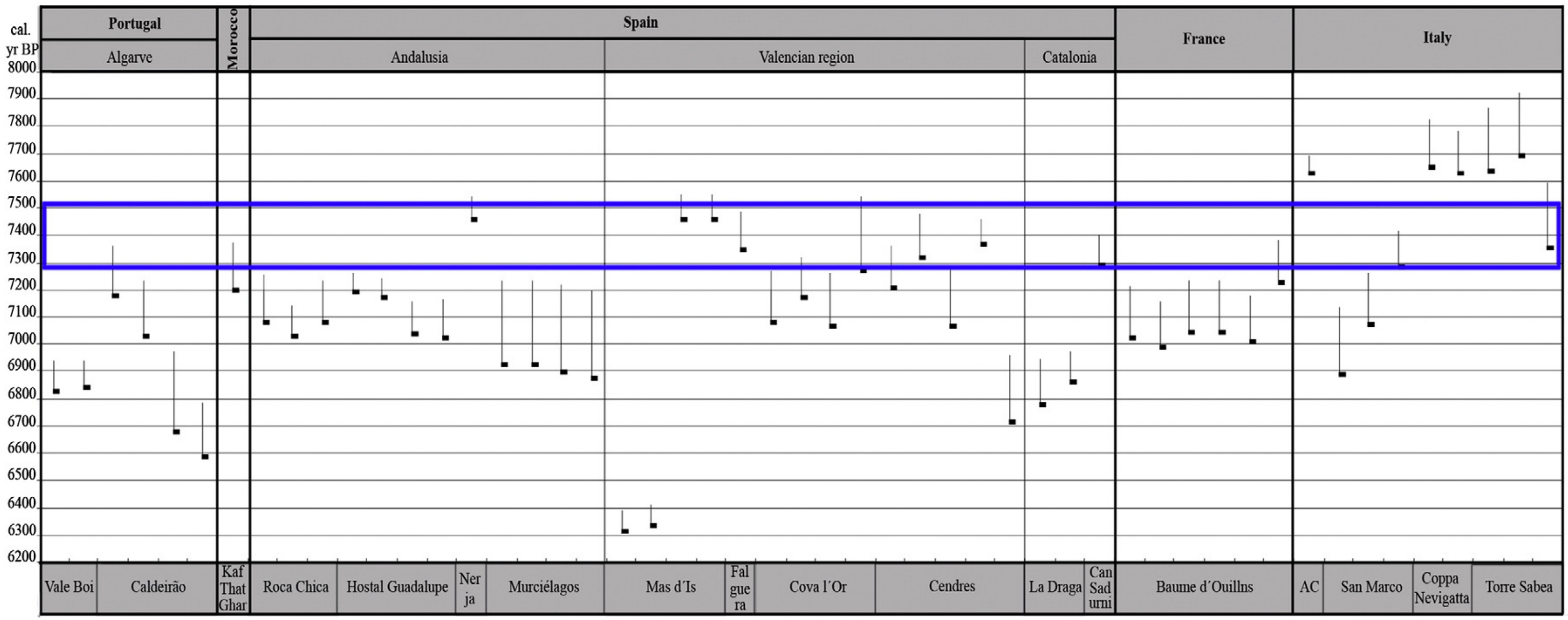

Figure 4. Distribution of obtained and reviewed calibrated (CalPal2007_HULU) (Weninger et al., 2007) AMS dates on short-lived and diagnostic elements of early Neolithic archeological sites from western Mediterranean. Detailed information in Table 3. Blue bar 7.4 ± 0.1 cal ka BP event.

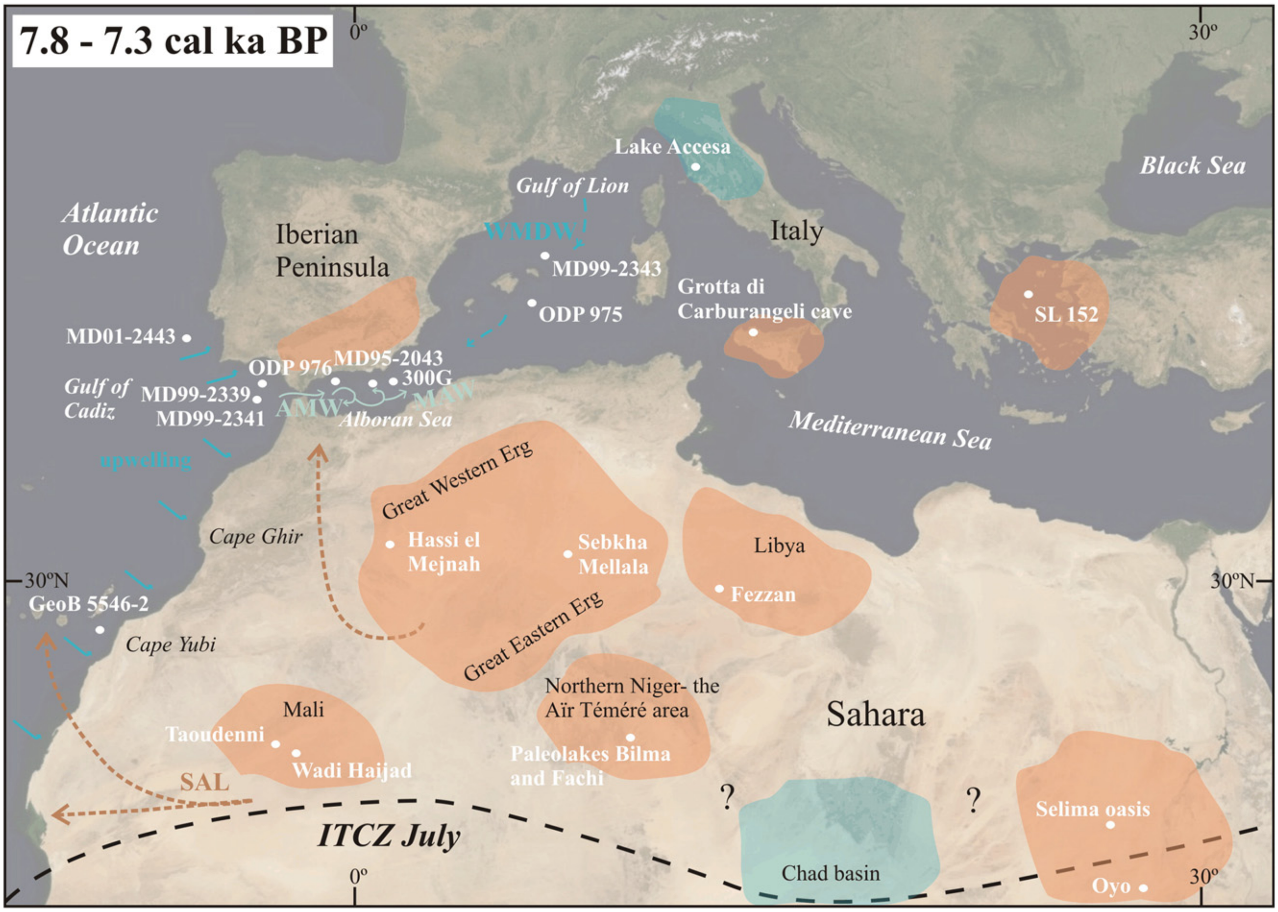

Figure 5. Map with the different paleoenvironmental records mentioned in the text. Light blue/orange areas show wet/dry conditions respectively obtained in each paleorecord at this time interval (7.8–7.3 ka). Dark blue arrows indicate the upwelling system and Western Mediterranean Deep Water (WMDW). Light blue arrows indicate the theoretical superficial water circulation in the Alboran Sea, Atlantic Surface Water (ASW) and Modified Atlantic Water (MAW). Dashed brown arrows represent the wind system Saharan Air Layer (SAL).

Neolithic in the Algarve may have taken place at around 7.4 ± 0.1 cal ka BP (Table 3, Fig. 4). On other southern Iberian regions (e.g., Huelva, Cadiz, Almería and the coast of Murcia) neither radiocarbon dates on short-lived Neolithic elements nor the bibliography detect settlements prior to 7.0 cal ka BP.

For the western Maghreb, Neolithic radiometric dates are fairly abundant, although only one of these was obtained on a clear item of the Neolithic economy: this is the wheat sample from Kaf Taht el Ghar (7.2 ± 0.1 cal ka BP) (Ballouche and Marinval, 2003). Its age fits well with those recorded on the coast of Malaga (Table 3, Fig. 4).

Paleoclimatic changes between 8.2 and 7.0 cal ka BP

Paleoenvironmental records from a broad range of sites including ODP-975, OPD-976, MD95-2043, MD99-2339, MD99-2343, MD99-2341, GeoB 5546-2, SL 152, TTR-300G among others (e.g. Martínez et al., 2003; Martrat et al., 2004, 2007; Frigola et al., 2007; Jiménez Espejo et al., 2007, 2008; Combourieu Nebout et al., 2009) (Figs. 5–7) are considered in order to obtain a comprehensive picture of the climatic and environmental changes that took place in the region between 8.2 and 7.2 cal ka BP. These records reveal an arid and cold episode at 8.2 cal ka BP related to a meltwater pulse that affected the whole of the Northern Hemisphere (e.g. Alley and Ágústsdóttir, 2005). Nevertheless, this event had a small impact in the Central and Western Mediterranean amounting to a temperature drop of <1°C (Wiersma and Renssen, 2006; Zanchetta et al., 2007). Faunal shifts associated with the 8.2 cal ka BP event in the SE Atlantic Iberian coast and the Alboran Sea were relatively restricted (Eynaud et al., 2009), although site 300G bio-indicators such as *Braarudosphaera bigelowi*, a foram species of low-salinity surface waters (Smayada, 1966) evidenced a peak which was interpreted as a freshwater pulse in the Alboran Sea at that time (Figs. 6, 7). Climatic changes that affected southern Iberia more profoundly were likely not related to the 8.2 cal ka BP event but instead to the more intense changes that took place between 7.8 and 7.3 cal ka BP (Figs. 5–7). Various paleo-records indicate that, during the latter time interval, the prevailing humid conditions that had been in place since the beginning of the Holocene changed rapidly towards an increased aridity (e.g. Frisia et al., 2006; Dormoy et al., 2009; Fletcher et al., 2010; Peyron et al., 2011). In the Alboran Sea's borderlands, the drop in temperature (~3°C) and precipitation (~50 mm) started around 7.8 cal ka BP (Dormoy et al., 2009). Different sea-surface temperature proxies indicate a cooling of up to 2°C (Combourieu Nebout et al., 2009) (Fig. 6), and a concomitant decrease in the abundance of coccolithophorid (i.e., warm) species (this paper) (Fig. 7). These cold and arid conditions expanded eastwards progressively, reaching the Eastern Mediterranean around 6.5 cal ka BP (Geraga et al., 2000; Fletcher et al., 2010).

In southeastern Iberia, arid conditions were revealed by low terrigenous input on the Alboran Sea (Moreno et al., 2002) as indicated by low Si/(Si + K) values at this time (Fig. 7). Simultaneously, a major episode of aridity was recorded in Sicily (Dormoy et al., 2009) and the eastern Mediterranean (Geraga et al., 2000) but the 7.4 cal ka BP climatic event had a different impact in other parts of Europe (Dormoy et al., 2009) (e.g. increased precipitation in the central and northern areas of the Italian peninsula) (Magny et al., 2007; Zanchetta et al., 2007; Zhornyak et al., 2011). Around 7.2 ± 0.1 cal ka BP (Figs. 5–7), more

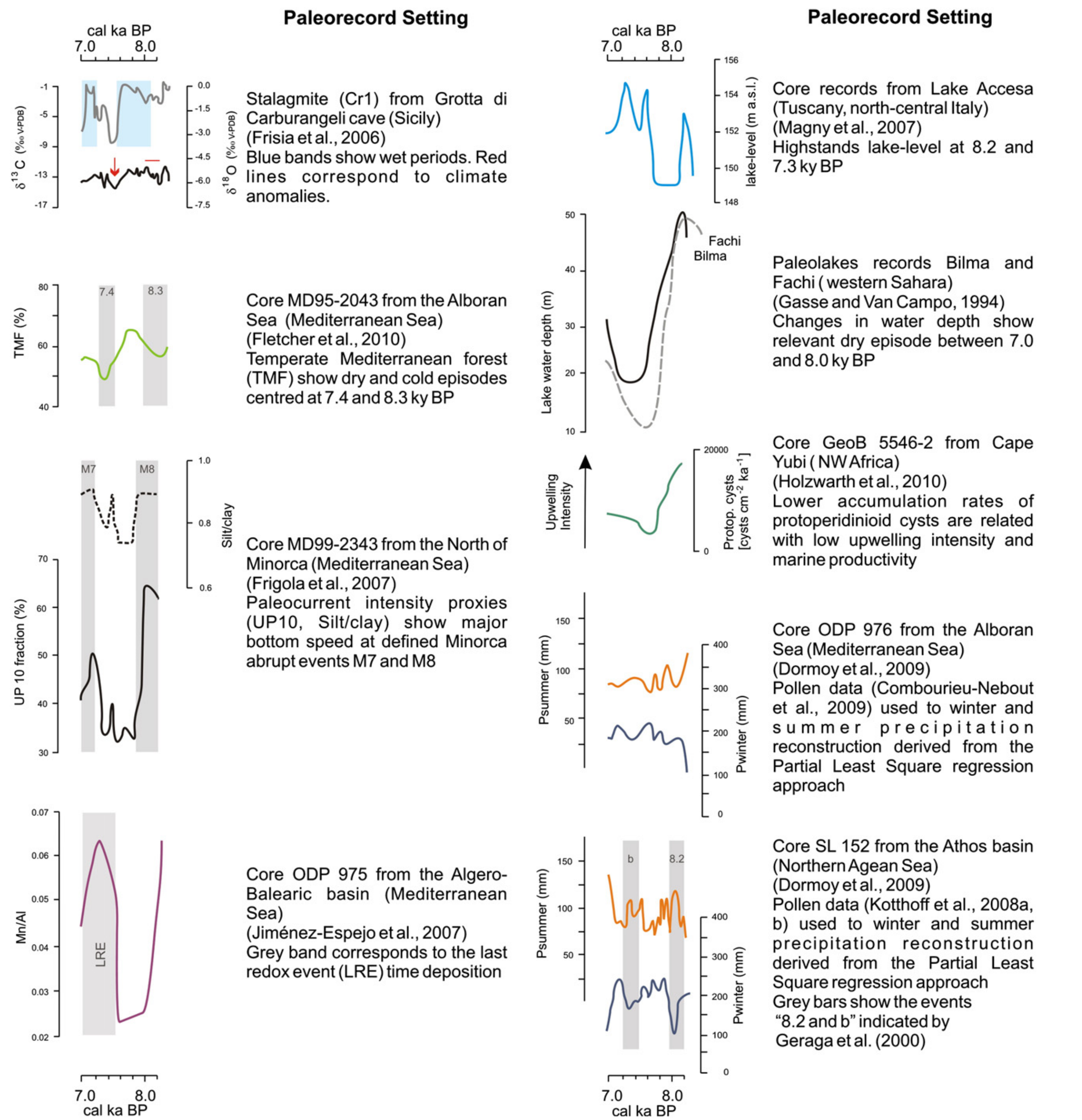

Figure 6. Environmental proxies used in diverse paleorecords for the time interval 8.2–7.0 ka: Grotta di Carburangeli cave; Cores MD95-2043, MD99-2343, ODP 975, ODP 976 and SL 152; Lake Accesa; Bilma and Fachi paleolakes (References in text) (Gasse and Van Campo, 1994).

humid conditions resumed in various areas of southwestern Europe (e.g. Colonese et al., 2010).

Major changes in the thermohaline circulation also occurred in the western Mediterranean at 8.2 cal ka BP and during the period between 7.8 and 7.3 cal ka BP. The thermohaline circulation in the western Mediterranean Sea (WMS) is controlled by sea level, Gibraltar Strait's section and climatic conditions over the Gulf of Lyon where deep Mediterranean waters are generated. As a result, changes in the intensity of the overturning cell can provide good diagnoses for the climatic conditions in the region (Cacho et al., 2006). In the Alboran region, a decrease in the U/Th ratio (Fig. 7), resulting from an increase of the ventilation associated with cold and arid conditions in the Gulf of Lyon, were recorded at this time (Mangini et al., 2001; Jiménez Espejo et al., 2007). Not surprisingly, marine productivity as evidenced by biogenic Barium content started to decrease around 8.2 cal ka BP and reached a minimum between 7.8 and 7.3 cal ka BP (Fig. 7).

The aridity between 7.8 and 7.3 cal ka BP was particularly intense in the Sahara, as suggested by an increase in the Saharan aeolian dust inputs on the Atlantic coast of the Western Sahara (e.g. Cole et al., 2009; Holzwarth et al., 2010), and a progressive decrease of terrigenous inputs in the Alboran Sea (Rodrigo Gámiz et al., 2011). Variations in the African/Canary/Iberian upwelling system and diminishing marine productivities were also recorded at this time. For the so-called "green" Sahara, an arid episode that lasted from 8.0 to 7.0 cal ka BP (Fontes and Gasse, 1989; Gasse, 2000) was recorded, with moister conditions resuming after 7.0 cal ka BP. A complex precipitation regime

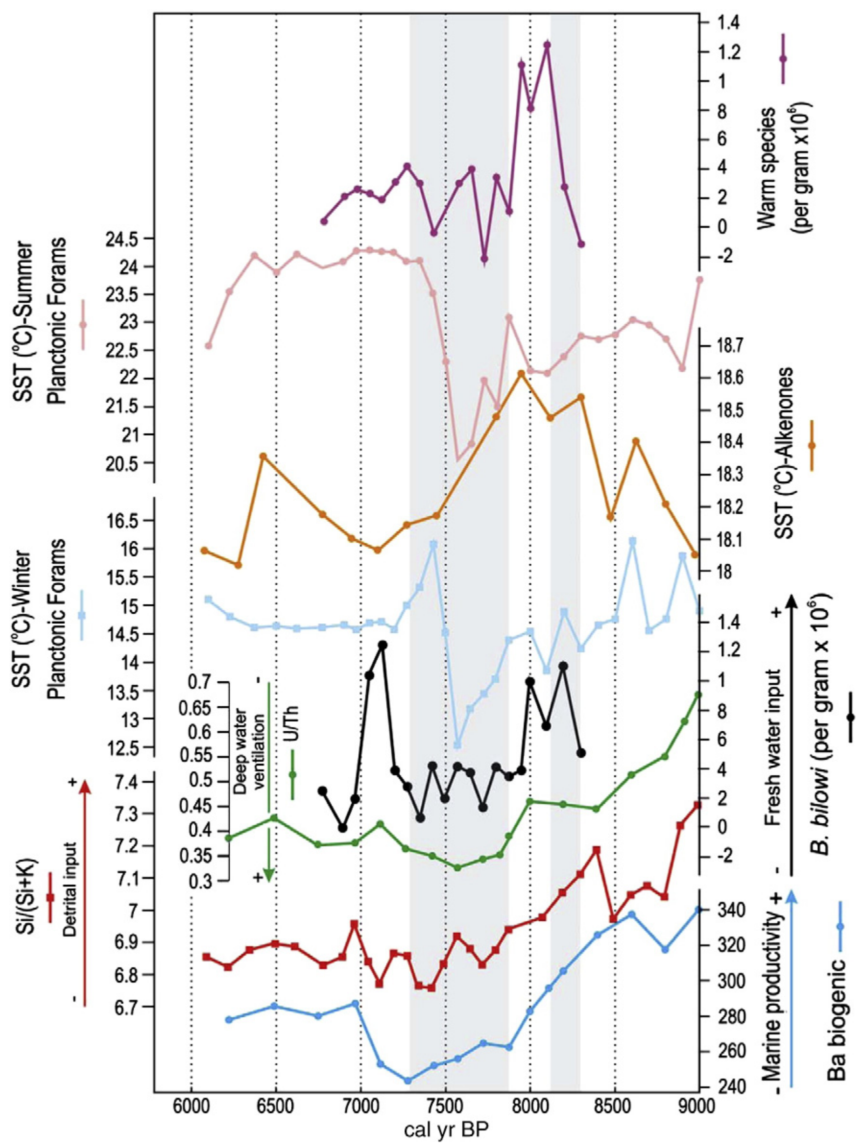

Figure 7. Environmental indicators and interpretation recorded in site 300G for the time period 9.0–6.0 cal ka BP. Alkenone record correspond to the site MD01-2443 (Martrat et al., 2007).

also has been recorded for North Africa and the Sahara during that interval of time. In areas such as Melhalla Sebka on the North Sahara, the western inter-dunal lake on the Grand Erg (Fontes and Gasse, 1989), southwestern Fezzan in Libya (Cremaschi, 1998, 2002; Di Lernia, 2002), the Selima oasis and Oyo (Richtkie et al., 1989), the dry spell took place at approximately 7.9–7.0 cal ka BP. In contrast, for the Chad basin at the central Sahara, an increased precipitation regime is recorded between 7.9 and 7.4 cal ka BP (Maley, 1977).

In southern Iberia increasing aridity has been mainly documented in the coastal zones (Cortés et al., 2010; Carvalho et al., 2010) and at the highest altitudes (Anderson et al., 2011). In the Guadiana estuary (Eastern Algarve), peaks in xerophytes and Ericaceae abundances between 7.8 and 7.4 cal ka BP coincided with a decline in the arboreal component, including *Pinus* and *Quercus*, and, to a lesser extent, thermophytes such as *Fraxinus* and *Olea* (Fletcher et al., 2007). Certain pollen sequences from the south-eastern hinterland such as Villaverde lake, revealed dry forests of *Pinus* with *Juniperus* and *Artemisia*, as well as a higher frequency of fires, between 9.7 and 7.5 cal ka BP (Carrión et al., 2001).

On the other hand, many pollen records of mid-altitude locations from SE Spain documented mesophytic maxima involving forest development of angiosperms such as *Quercus, Corylus, Alnus, Betula, Fraxinus, Pistacia, Olea*, etc., during the aridity period which impacted sites across North Africa (Carrión, 2002; Carrión et al., 2009). Locally mid-elevation forests in southern Iberia expanded from 7.5 cal ka BP until 4.5 cal ka BP, a time when some of the coastal and continental territories were too arid for sustaining deciduous forests. The shift in distribution and abundance of the pollen taxa at the onset of the mid-Holocene suggests significant spatial and temporal climatic variability in all of the sites studied. These differences in regional pollen records were recently well explained in Anderson et al. (2011) and related to greater differences in seasonal insolation between early and middle Holocene, translated into different conditions of humidity on sites at higher or lower elevations. Additionally, these differences reflect the importance of biotic factors such as competition, population, and community resilience that have been historically contingent in order to establish the trends of vegetational developments across the region during the early Holocene (see Carrión et al., 2010, for review).

The dry episodes recorded in the Indian and African moonsonal regions between 8.0 and 7.0 cal ka BP are synchronous with the dry phases described in the Mediterranean (Jalut et al., 2008). The main cause for the climatic changes that took place between 7.8 and 7.3 cal ka BP is likely related to the low Northern Hemisphere summer solar insolation, and the corresponding weakening of the monsoonal system that triggered a displacement of the Intertropical Convergence Zone (ITCZ) (Wang et al., 2005; Brooks, 2006). Other important events that occurred during this period include meltwater outbursts from the Ungava and Labrador Lakes (Canada) (Jansson and Kleman, 2004). Additional new, high-quality, well-dated, and high-resolution multi-proxy records are essential to resolve the expressions of these rapid climate changes between 8.0 and 7.0 cal ka BP within the Mediterranean region.

Paleoenviromental changes and early neolithization

The role of environmental factors in the Mesolithic–Neolithic transition transition in the Iberia has already been discussed (Fernández López de Pablo and Jochim, 2009; González Sampériz et al., 2009). According to González-Sampériz and colleagues, there exists for the lower Aragon region of northeastern Spain an "*archeological silence*" between 8.0 and 7.3 cal ka BP, when all of the Mesolitthic settlements were abandoned, presumably due to migrations in search of more humid territories. In the Saharan sites of Nabta and Bir Kiseiba, such a displacement of human populations has been documented between 8.2 and 7.0 cal ka BP (Schild and Wendorf, 2001; Wendorf et al., 2007; Sereno et al., 2008) (Fig. 1). Also, the so-called Post-Ru'at El Ghanam period that ranges between 7.7 and 7.5 cal ka BP, records a discernible absence of humans between the Middle to Late Neolithic.

On the southern Iberian coast, erosional hiatuses (Aura et al., 2009) hinder a precise dating of the Mesolithic–Neolithic transition but the sharp reduction in the use of marine resources, associated with sea-level rise and enhanced upwelling variability, along with certain changes in the terrestrial ecosystems have been documented and will be discussed briefly.

Between 8.0 and 7.0 cal ka BP the main estuaries in southern Iberia (Fig. 1), such as those of the Guadalete and Guadalquivir rivers (Goy et al., 1996; Pozo et al., 2010), were inundated as a result of sea-level rise (Boski et al., 2008). For the Mesolithic populations that had settled on the coast and based their sustenance on coastal resources, sea-level changes and the progressive drowning of the shore must have turned harvesting uncertain. Coinciding with these events, changes in the thermohaline circulation on the western Mediterranean, must have had a direct impact in the regional plankton species (Jiménez Espejo et al., 2008) altering food webs in yet undocumented ways. These changes probably provoked the disappearance of gadids and other northern Atlantic fishes from the Mesolithic archeological record of Nerja between 8.0 and 7.3 cal ka BP (Morales, A. and Roselló, E., pers. comm. 2011), and also the decline of certain marine mammals (e.g. *Phocoena phocoena*) in the WMS (Fontaine et al., 2010). Such faunal impoverishments must have heavily impacted the Mesolithic coastal economies of the western Mediterranean.

Previous studies indicated that marine productivity in the coast of the Algarve had a direct impact on human adaptations (Bicho and Haws, 2008). The upwelling system of the southern Portuguese coast (Fig. 5) has been well studied during the last glacial cycle (Voelker et al., 2009; Salgueiro et al., 2010), but high-resolution Holocene records are still scarce. This area belongs to the NW African/Canary/Iberian upwelling system (Voelker et al., 2009) and allows for a comparison with other sites affected by the same climatic events. Holocene up-welling intensity lows, coupled with low marine productivity and low fluvial input, are documented in the NW African Atlantic margin around 7.4 cal ka BP (Kotthoff et al., 2008). The decrease of the NW Africa upwelling was linked to less intense northerly winds that generated declines in the west Iberian coastal upwelling systems during the summer (Fiúza, 1984). In addition, changes in the Mediterranean Outflow, the ITCZ location, and atmospheric pressure systems (see discussion in Section 6) would have also promoted changes in the intensity of the upwelling (Fiúza, 1984). All these variations, along with an increasing aridity must have affected the sensitive coastal and estuarine ecosystems upon which Mesolithic populations based they economy, changing the predictability, availability, and the composition of the marine resources. Eventually, these changes triggered the abandonment of the shell middens (Blanton et al., 1987; Fa, 2008; Dean et al., 2011).

Summarizing both data, reviewed and new-acquired, suggest the existence of a long-term climatic and environmental crisis that impacted the Mesolithic populations of southern Iberia and the early Neolithic people of northern Africa. The response to this crisis in the interior of Iberia was evident in the change of settlement patterns and the abandonment of a large number of sites, with a subsequent archeological silence (González-Samperiz et al., 2009). In the southern Iberian coastal areas, the reduction of the marine resources resulted in the abandonment of at least a few sites. All these changes may have been instrumental in provoking the adoption of the Neolithic innovations by the Mesolithic populations.

Southern Iberian Neolithic pioneers — a Maghrebian origin?

The arrival of the Neolithic innovations to the western Mediterranean can be interpreted in terms of demic diffusion, although not necessarily of the kind predicted by the wave of advance model (Ammermann and Cavalli-Sforza, 1984). According to available data, a maritime pioneer colonization model, analogous to that proposed by Zilhão (1993, 2001), seems to be the most viable explanation. Available data indicate the initial establishment of an Early Neolithic in southernmost Iberia with a likely Northern African origin. The evidences for such hypothesis are multifarious:

a) Ceramics—Formal and ornamental parallelisms among Neolithic sites in the Oran region, the eastern Rif and Andalusia (e.g. Manen et al., 2007; Linstädter, 2008; Ramos et al., 2008).
b) Lithic industries—Presence of segments and absence of Valencian trapezes (Manen et al., 2007) as well as heat treatment of flint in the Early Neolithic levels from sites in Portugal, Andalusia, and North Africa (Manen et al., 2007; Carvalho, 2008), in the Spanish Levant there is no evidence for this technique (García, 2006).
c) Presence of straighteners made on human bone in both the early non-Cardial Neolithic from Nerja (Adam, 1995) and in sites from Andalusia and the Maghreb (Algeria, Libya and Tunisia).
d) Use of a large variety of plant species (Table 2) and many domesticated animals (Pereira et al., 2006), unlike the more restricted and specialized cereal use of other European regions during the Early Neolithic.
e) The unique features of sickles in the Malaga sites (i.e., flint implements inserted in a slightly diagonal position in the handle during the Early Neolithic. This pattern contrasts with the style found in Northern Iberia, where whole flint blades are inserted parallel to the handle (Ibáñez et al., 2008; Gibaja et al., 2010).
f) Preliminary paleogenetic data from an individual from the Middle Neolithic levels of Nerja (Simón et al., 2005) evidence a close genetic relationship with individuals of haplogroup L1b, commonly found in the West African tribes of Fulbe, Mandenka, and Yoruba (Watson et al., 1996) and, less frequently, in Central and North Africa (Salas et al., 2002). The presence of an African mitochondrial haplogroup at Nerja does not necessarily indicate a recent African origin for that individual. It may be consistent with the fact that African ancestry was present in the region during earlier periods but obviously more data will be required to confirm a Neolithic African ancestry through genetic tracers.

Limits and implications of the Maghreb Neolithization wave

The new dates on short lived samples, together with other relevant evidence presented here indicate an essentially synchronous development of the Neolithic for Andalusia, the Algarve and North Africa (Fig. 4). This would suggest that the process of Neolithic expansion in the region could have been faster than that predicted by Ammermann and Cavalli-Sforza (1984) wave of advance model. The same pre-Cardial French-Iberian Neolithic was found in the Spanish Levant and in the Gulf of Liguria and is similar to that seen in Malaga and eastern Morocco, making it possible to postulate a new territory as the origin of the Neolithic from southern Iberia, namely the Maghreb coast (Bernabeu et al., 2002, 2009).

The rapid expansion of the Neolithic in the western Mediterranean was likely facilitated by the use of maritime technology and raw-material networks based on long established central and eastern Mediterranean centers (Broodbank, 2006). One such network is that of obsidian (Fig. 1), that originated in Mediterranean islands such as Panteleria, and was transported to Tunisia, Sicily, the French Provence and Catalonia since at least 9 cal ka BP (Guilaine, 1994; Lugliè, 2010). Within such context, a crucial question is why the African coastal populations moved to the western Mediterranean and Atlantic coast and why was this move so fast? A prime reason could have been the aridification of the Sahara that caused a rapid depletion of resources forcing people on a fast migration northwards to the western Mediterranean. The coastal regions are very sensitive to aridification (Combourieu Nebout et al., 2009) and major rivers in the Algerian coastal region are scarce. In connection with this matter, it is meaningful to highlight the areas selected by these pioneers in Southern Iberia. The early locations appear to be linked with Malaga coastal locations close to stable water masses as rivers and major karstic sources (e.g., Guadalhorce river and springs of Torremolinos for Bajondillo, Hostal Guadalupe or Roca Chica; Totalán river and springs of La Araña for Complejo del Humo and the Spring of Maro close to Nerja Cave: e.g. Andreo et al., 1994) (Fig. 1). In arid areas such as south-easternmost Iberia (Almería region) and other arid zones this very early Neolithic appears to be absent. Additionally, sea-level rise negatively impacted the cultivation-based economies of the Neolithic coastal people (e.g. Turney and Brown, 2007).

This first Neolithic wave, of plausibly Maghrebian origin, overlapped and was gradually replaced by Neolithic groups using Cardial ceramics or, perhaps, such kind of ceramic was simply adopted later. On the other hand, heat-treated flint technology was widely spread in the rest of Europe after a few centuries. The role played by the pre-Neolithic indigenous populations in this process remains unknown and needs to be clarified. The available data indicate that the earliest Neolithic with such distinct traits occupied an area ranging from the easternmost limit of central Andalusia to the Tagus–Mondego estuaries in Portugal. That the contact with North Africa was maintained through time is evident in the retrieval of exotic items, such as ostrich eggshell and ivory elements, documented in megalithic funerary contexts (e.g. Los Millares: Arribas and Molina, 1991).

Conclusions

Paleoenvironmental and archeological data suggest that a climatic and environmental crisis between 8.0 and 7.3 cal ka BP may have impacted negatively populations on both sides of the Strait of Gibraltar. In southern Iberia this crisis was recognized by an increase in climatic instability, hydrological changes, and a decrease in temperatures and marine productivity. As such, it affected the composition of the terrestrial and marine faunas that were available to the Mesolithic hunter gatherers. At the same time, in different areas of the Sahara, an increase in the aridity, forcing migrations and the abandonment of various Neolithic settlements, has been documented.

New AMS dates on unequivocally Neolithic short-lived samples (i.e., cereals and sheep bones) and the associated elements of the material culture from sites located along the Malaga and Algarve coasts, document the earliest presence of Neolithic symbolism and the production economy (i.e., body ornaments, burials, agriculture and animal husbandry) by at least 7.5 cal ka BP. Despite the detailed sampling that has been undertaken, at this point one cannot exclude slightly older dates for the origin of this regional phenomenon. In fact, based on the timing of the paleoenvironmental changes reported, we postulate that this first arrival could have occurred anywhere in the time period ranging between 8.0 and 7.3 cal ka BP.

The 7.4 cal ka BP crisis also affected the central and eastern Mediterranean area and could have been an important factor in determining the influences that appear to radiate from these areas during the earliest stages of the Neolithic. Still, the original Neolithic features of the Malaga region (i.e., mostly ceramics) differ from those of the Cardial style to the extent of suggesting a distinct origin and arrival route on the western Mediterranean, most likely from the Maghreb. The speed and timing of this southern route of neolithization suggest that it not only involved maritime technologies but also previously existing networks.

Therefore, the emergence of the Neolithic in southern Iberia around 7.3 ± 0.2 cal ka BP seems to be connected to four main factors: (a) the crisis of the Mesolithic subsistence system, (b) the Neolithic migrations in the Sahara, (c) the existence of navigational technologies and (d) a series of environmental changes associated to the 7.4 cal ka BP climatic event. This set of conditions drove the fast development and expansion of the Neolithic into southern Iberia, a process that was likely based on cultural fusion resulting in a new Neolithic cultural entity quite distinct from the French-Iberian cardial.

The data presented here are consistent with an African origin model, proposed originally in the first half of the 20th century (Manen et al., 2007; Ramos et al., 2008). The present scenario, however, seems to be far more complex than a simple migration process; we should thus look for transfers, integration and reinterpretation of cultural traits among the cultural mosaic of coeval groups settled along the Western Mediterranean during the 8th millennium BP, from the Andalusian and Algarvian coasts to the northern African territories of Morocco and Algeria, in order to solve this issue. In this sense, more in-depth studies should be carried out before definitively accepting the described African origin for the Neolithic in South Iberia.

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