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Short-term mid-Holocene climatic deterioration in the West Mediterranean region: climatic impact on Neolithic settlement pattern?

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with 6 figures and 2 tables

Summary. Recent Holocene palaeoclimatic and palaeoecologial archives indicate a climatic deterioration between ~6.0 and 6.5 ka in the western Mediterranean region. High to moderate resolution records from marine, limnic and fluvial archives in central Italy and northern Tunisia especially show a decrease in humidity at that time. Additionally, archaeological surveys of early to late Neolithic sites in semiarid Northeast Morocco reveal a mid-Neolithic gap during this short-term climatic drop. Similar to the results from northeastern Morocco, there is also no evidence of middle Neolithic populations in other dry environments in today's Morocco.

However, middle Neolithic sites at coastal northwestern Morocco indicate an enduring human presence between 6.0 and 6.5 ka. In contrast to the early and late Neolithic hunter-gatherer economies from the steppe of northeastern Morocco, the coastal societies of subhumid Northwest Morocco show more sedentary land use systems like the exploitation of marine resources and pastoralism. Consequently, the coastal societies were either more adaptable against climatic shifts or the subhumid landscape of Northwest Morocco was less sensitive against drops in humidity. Nevertheless, regarding Moroccan drylands, the impact of a mid-Holocene short-term climatic deterioration on Neolithic societies should not be ignored or considered unimportant.

Zusammenfassung. Aktuelle Ergebnisse aus holozänen paläoklimatischen und paläoökologischen Archiven geben Hinweise auf eine klimatische Verschlechterung im westlichen Mediterranraum zwischen 6000 und 6500 Jahren vor heute. Daten hoher Auflösung aus marinen, limnischen und fluvialen Archiven Mittelitaliens und Nordtunesiens weisen insbesondere auf einen Rückgang der Feuchtigkeit in jener Zeit hin. Darüber hinaus zeigen Befunde aus archäologischen Grabungen an spät- bis frühneolithischen Fundplätzen im semiariden Nordosten Marokkos eine chronologische Lücke während dieser mittelholozänen Trockenphase. Vergleichbar mit der Situation in Nordostmarokko, lässt sich für die Zeit zwischen 6000 und 6500 Jahren vor heute auch im hyperariden Südwesten Marokkos bisher keine Besiedlung mit Hilfe numerischer Datierungen nachweisen.

Andererseits zeigen mittelneolithische Siedlungsplätze an der Küste Nordwestmarokkos eine durchgehende Besiedlung zwischen 6000 und 6500 Jahren vor heute. Im Gegensatz zu den früh- und spätneolithischen Jäger- und Sammlerkulturen aus der nordostmarokkanischen Steppe zeigen die nordwestmarokkanischen Küstenbewohner entwickeltere Wirtschaftsweisen wie Viehwirtschaft und die Nutzung mariner Ressourcen. Möglicherweise waren die Küstenbewohner dadurch anpassungsfähiger gegenüber klimatischen Trockenphasen, oder der subhumide Landschaftsraum Nordwestmarokkos reagiert weniger sensitiv auf trockenere Klimaverhältnisse.

1 *Introduction*

Since a couple of years some high to moderate resolution records of late Quaternary archives are available for the western Mediterranean region. Especially off-shore records indicate a teleconnection between the North Atlantic and the West Mediterranean climatic history during the

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late Pleistocene (CACHO et al. 1999, 2000, BUCCHERI et al. 2002, COMBOURIEU-NEBOUT et al. 2002, SÁNCHEZ-GONI et al. 2002, DE ABREU et al. 2003, MORENO et al. 2005). D'ERRICO & SÁNCHEZ GONI (2003) compared the Alboran Sea record of CACHO et al. (1999, 2000) with Southwest European Palaeolithic findings. They assume that Middle to Upper Palaeolithic transitions, especially the Neanderthal extinction and major shifts in settlement pattern of Modern human populations were linked to Pleistocene Dansgaard-Oeschger climatic variability and Heinrich events.

Regarding the Holocene, SHENNAN (2003) remarks that some archaeological researchers have implied relatively constant climatic conditions, and consequently, changes in human societies and behaviour have been explained by internal factors like the evolution of a new tool. However, recent archaeological studies reveal correlations between changes in prehistoric settlement pattern and Holocene climatic shifts (SHENNAN 2003). According to NEHREN (1992), PETIT-MAIRE et al. (1997) and LINSTÄDTER & KRÖPELIN (2004), oscillations in humidity must be regarded as a major factor for Neolithic settlement behaviour in North African deserts and drylands. Additionally, abrupt shifts in Holocene landscape dynamics in North African drylands are also well-known from geomorphological and palaeoecological studies (CHEDDADI et al. 1998, SWEZEY 2001, FAUST et al. 2004). According to these authors, shifts in landscape dynamics have been predominantly humidity-driven.

During the mid-Holocene a short-term period of drier conditions is observed in northern Tunisia (ZIELHOFER et al. 2004), when the Medjerda river system reveals a sharp shift in fluvial dynamics from 6.0 to 6.6 ka. The authors conclude drier conditions in northern Tunisia at that time. In this paper we discuss this short-term climatic desiccation documented also in other environmental archives in the western Mediterranean region and its impact on Neolithic societies.

For a couple of years, a Morocco-German research group has been surveying archaeological sites in northeastern Morocco (Fig. 1). Preliminary results evidence Ibéromaurusian, Epipalaeolithic and Neolithic remains from caves and rock shelters (MIKDAD et al. 2000, MOSER 2003, LINSTÄDTER 2003, 2004). In this paper we present a collection of early to late Neolithic ^{14}C data from caves and open air sites in semiarid northeastern Morocco (Fig. 2), and compare this data with those of other Neolithic sites from Morocco (Fig. 3) and with palaeoclimatic records from the western Mediterranean region.

2 *Radiocarbon calibration and comparability of numerical ages*

Table 1 documents a compilation of published numerical ages from Neolithic sites in Morocco. Different dating and calibration methods complicate the comparability of numerical ages. Therefore, all ^{14}C raw data are newly calibrated according to the CALIB 5.0.1 radiocarbon calibration program. The program is used in conjunction with STUIVER & REIMER (1993) and the intcal04.14c calibration data set of REIMER et al. (2004). Table 1 shows dating material, radiocarbon ages, 2σ calibrated ages and median probabilities deduced from CALIB cumulative probability curves. Intercepts with the calibration curve are not documented because they do not provide a robust indicator of sample calendar age, whereas the median of the probability distribution is a more stable estimate (TELFORD et al. 2003).

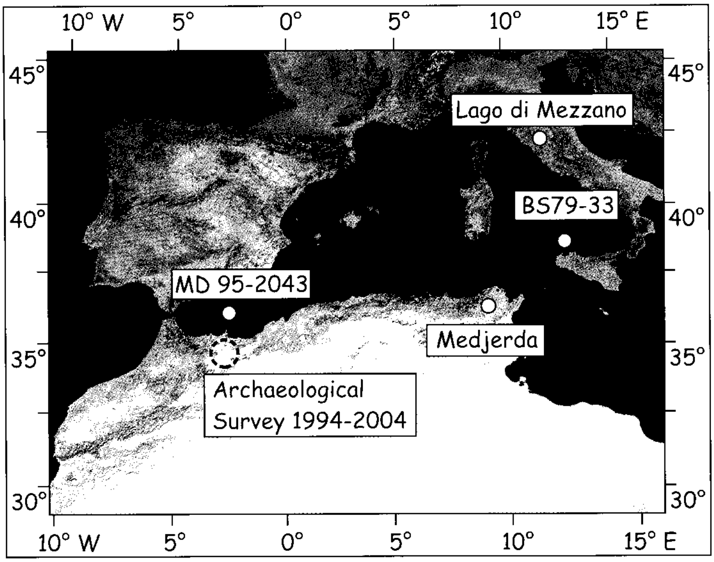


Fig. 1. Western Mediterranean region and main study sites mentioned in this paper.

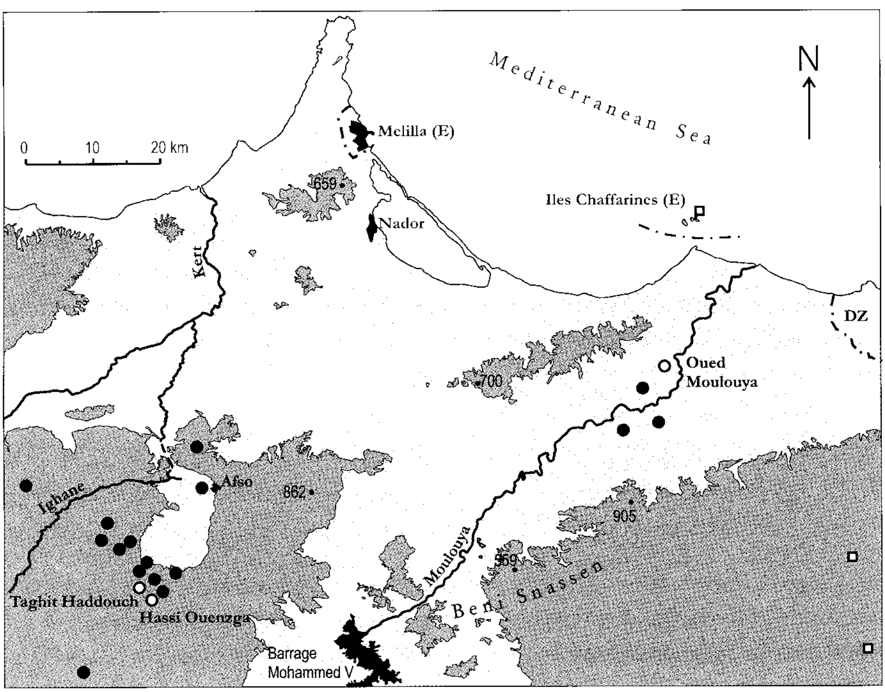


Fig. 2. Distribution of currently known Neolithic sites in northeastern Morocco: dots document sites of the 1994–2004 survey at Afso and the 2002 survey at the lower Moulouya river. Squares document secondary Neolithic sites (Wengler & Vernet 1992, Bellver Garrido & Bravo Nieto 2003). White dots and squares provide ^{14}C data.

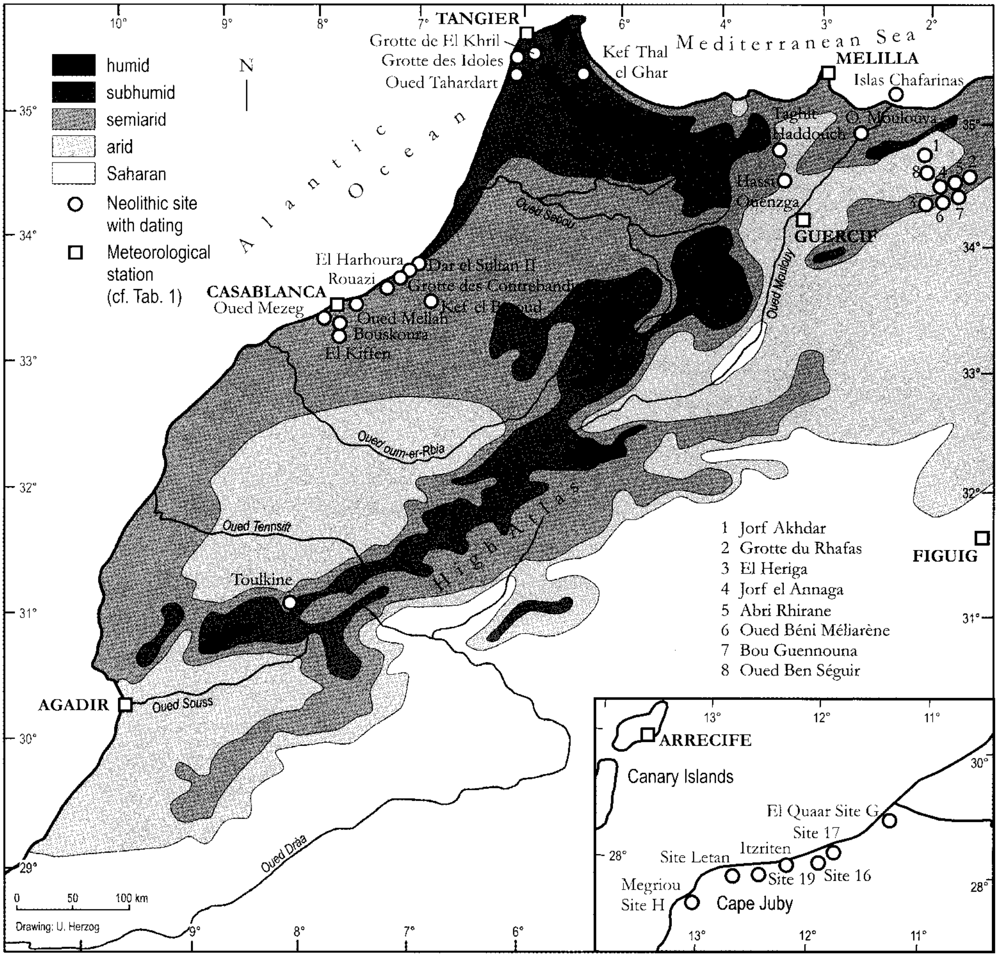


Fig. 3. Recent bioclimatical classification (EMBERGER 1939, SAUVAGE 1963) and the distribution of major Neolithic sites in Morocco.

TL and OSL ages are documented in years before 1980 (Table 1). In Fig. 4 all TL, OSL and calibrated ^{14}C ages are shown in a compiling view. Histograms in Fig. 4 document the number of 2σ confidence interval overlapping. It has to be taken into account that only the OSL and TL ages reveal a Gaussian distribution but not the calibrated radiocarbon ages.

3 *Mid-Holocene climatic data from the western Mediterranean region*

The onset of the Neolithic period can be observed in the western Mediterranean region around 7.5 ka (NEHREN 1992, LINSTÄDTER 2003). Generally, this new cultural epoch concurs with a climatic optimum in the Mediterranean and vicinal Saharan region. Orbital forcing led to more humid conditions than today (cf. BERGER 1978, GASSE & VAN CAMPO 1994, DE MENOCAL et al.

2000, RAMRATH et al. 2000, CARRIÓN et al. 2003, ZIELHOFER et al. 2004). However, recent palaeoecological studies indicate that this climatic optimum during the Neolithic period might have been interrupted by a short-term decrease in humidity: FAUST & ZIELHOFER (2002) and ZIELHOFER et al. (2002) surveyed the Medjerda floodplain in semi-arid to sub-humid northern Tunisia. They document well-stratified alluvial sequences, which represent Holocene changes between calm fluvial dynamics with soil formation on the one hand and enhanced flooding of coarser overbank deposits on the other (FAUST & ZIELHOFER 2002, ZIELHOFER et al. 2002). Coarser overbank sediments are interpreted as signals of enhanced fluvial activity. According to ROHDENBURG's (1983) approach, fluvial activity in subtropical river systems corresponds with more arid phases, resulting from sparse vegetation cover, high rainfall intensities and, therefore, high surface runoff with related erosion in the headwaters. Consequently, rivers tend to aggrade their floodplains. In contrast, calm fluvial dynamics is related to a more humid climate. A dense vegetation cover permits low surface runoff, low load ratio and thus river incision in the floodplain. One of the most noticeable periods of increased fluvial dynamics in the Medjerda system is between 6.0 and 6.6 ka (Fig. 5). This period does not match well with the cyclicity of the North Atlantic Bond events (cf. BOND et al. 2001), why ZIELHOFER et al. (2004) consider climatic impacts of more local scale.

The earlier palaeolimnological study carried out at Lago di Mezzano in central Italy (Fig. 5; RAMRATH et al. 2000) also clearly documents a period of drier conditions around 6.6 ka. However, other palaeolimnological studies from southern and central Italy do not indicate a climatic depression at that time. CACHO et al. (2001) document benthic $\delta^{18}O$ and $\delta^{13}C$ values as well as sea surface temperatures (SST) from two off-shore sites in the Alboran and Tyrhennian Sea. Whereas the MD 95-2043 Alboran record does not show a clear mid-Holocene climatic deterioration, the B579-33 Tyhennian core reveals a clear drop in temperature around 6.0 ka (Fig. 5; CACHO et al. 2001). Approximately 500 years earlier, the oxygen isotope curve of planktic foraminifera *Globigerina bulloides* from a marine core in the Adriatic Sea documents a mid-Holocene decrease in temperature (COMBOURIEU-NEBOUT et al. 1998). Although there is some evidence of a mid-Holocene climatic depression in the West Mediterranean between ~6.0 and 6.5 ka (see also LAMB et al. 1995), the previous palaeoenvironmental data sets remain somewhat inconsistent. Do western Mediterranean archaeological data reveal new arguments for a short-term mid-Holocene climatic deterioration? In this paper, we present the temporal and spatial distribution of known Neolithic sites in the western Maghreb region, especially in present-day's Morocco.

4 *Sites and archaeological data from Morocco*

The modern climate in Morocco is driven by winterly westerlies and subtropical anticyclones during the summer (Cs climate: Mediterranean type). The strong impact of wet westerlies is ubiquitous at the sub-humid to humid Atlantic coast of northwestern Morocco and at the northwest-facing slopes of the Rif and High Atlas mountains (Fig. 3). These ranges cause a sharp climatic divide: unlike the northwestern part of Morocco, the southeast-facing slopes and forelands of the High Atlas Mountains are characterized by dry fall winds and Saharan aridity (Fig. 3 and Table 2). Similarly, northeastern Morocco and the Mediterranean coast, situated in the lee of the Rif Mountains, are characterized by mean annual precipitation between 200 and 400 mm.

Table 1. Compilation of major Neolithic sites in Morocco and related ^{14}C and TL ages (Ref. A: Wengler & Vernet 1992, B: Gärsdorf & Eiwanger 1999, C: own results, D: Daugas et al. 1989, E: Daugas et al. 1998, F: De Wailly 1976, G: Bailloud & Mieg De Boofzheim 1964, H: Bellver Garrido & Bravo Nieto 2003, I: Ousmoi 1989, J: Smith et al. 1990, K: Delibrias et al. 1976, L: Grébénart 1975.

NE Moroccan hinterland (semi-arid) Site	type	lab no.	material	^{14}C [BP]	^{14}C [cal BP] (2 sigma)	median probability [ka cal BP]	TL [before 1980]	OSL [yr]	latitude	longitude	Ref
Jorf Akhdar	hearth	Gif 6493	charcoal	5080±70	5656-5984	5.8			N 34° 46’	W 1° 56’	A
Jorf Akhdar	hearth	Gif 6494	charcoal	5930±80	6550-6959	6.8			N 34° 46’	W 1° 56’	A
Jorf Akhdar	hearth	Gif 6879	charcoal	5700±70	6319-6657	6.5			N 34° 46’	W 1° 56’	A
Jorf Akhdar	hearth	Gif 6923	charcoal	5870±100	6448-6933	6.7			N 34° 46’	W 1° 56’	A
Jorf Akhdar	hearth	Gif 7684	charcoal	5760±80	6355-6743	6.6			N 34° 46’	W 1° 56’	A
Oued Ben Séguir	hearth	Gif 7685	charcoal	4410±70	4853-5286	5.0			N 34° 31’	W 1° 58’	A
Oued Ben Séguir	hearth	Gif 7552	charcoal	4610±70	5048-5577	5.3			N 34° 31’	W 1° 58’	A
Oued Ben Séguir	hearth	Gif 7686	charcoal	5760±80	6355-6743	6.6			N 34° 31’	W 1° 58’	A
Oued Bni Mliařne	hearth	Gif 7002	charcoal	4190±270	3984-5465	4.7			N 34° 18’	W 1° 53’	A
Grotte du Rhafas	cave	Gif 6185	charcoal	5190±100	5719-6263	6.0			N 34° 30’	W 1° 33’	A
El Hériga	cave	Gif 6186	charcoal	4600±60	5050-5569	5.3			N 34° 18’	W 1° 53’	A
Jorf el Annaga	cave	Gif 6492	charcoal	4110±90	4423-4838	4.6			N 34° 24’	W 1° 46’	A
Abri Rhirane	shelter	Gif 6490	charcoal	3900±90	4006-4572	4.3			N 34° 26’	W 1° 43’	A
Bou Guennouna	cave	Gif 6491	charcoal	3820±90	3932-4506	4.2			N 34° 18’	W 1° 43’	A
Bou Guennouna	cave	Gif 6880	charcoal	3400±80	3454-3844	3.7			N 34° 18’	W 1° 43’	A
Taghit Haddouch	shelter	Hd 19868	charcoal	6139±30	6950-7157	7.1			N 34° 47’	W 3° 20’	B
Hassi Ouenzga	cave	UtC 6184	charcoal	5029±47	5660-5897	5.8			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	Bln 4956	charcoal	6035±47	6748-7001	6.9			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	UtC 6185	charcoal	6230±70	6948-7289	7.1			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	KIA 437	charcoal	6240±40	7015-7259	7.2			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	KIA 436	charcoal	6270±40	7026-7273	7.2			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	UtC 6186	charcoal	6378±44	7181-7422	7.3			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	UtC 6187	charcoal	6540±50	7328-7564	7.5			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	Bln 4957	charcoal	6611±40	7437-7567	7.5			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	Bln 4913	charcoal	6683±48	7464-7653	7.6			N 34° 42’	W 3° 17’	B
Hassi Ouenzga	cave	KIA 434	charcoal	6710±50	7492-7664	7.8			N 34° 42’	W 3° 17’	B
Oued Moulouya	open air	Erl 5888	charcoal	6402±40	7268-7420	7.3			N 34° 56’	W 2° 33’	C
NW Morocco (sub-humid) Site	**type**	**lab no.**	**material**	**^{14}C [BP]**	**^{14}C [cal BP] (2 sigma)**	**median probability [cal BP]**	**TL [before 1980]**	**OSL [yr]**	**latitude**	**longitude**	**Ref**
Kaf That el Ghar	cave	Ly 7288	charcoal	5400±290	5490-6856	6.2			N 35° 30’	W 5° 15’	E
Kaf That el Ghar	cave	Ly 3821	charcoal	5800±150	6294-6955	6.6			N 35° 30’	W 5° 15’	D
Kaf That el Ghar	cave	Cle 128	ceramics				5800±750		N 35° 30’	W 5° 15’	I
Kaf That el Ghar	cave	Cle 127	ceramics				6350±600		N 35° 30’	W 5° 15’	I
Kaf That el Ghar	cave	Cle 126	ceramics				6780±550		N 35° 30’	W 5° 15’	I
Kaf That el Ghar	cave	Cle 129	ceramics				7200±750		N 35° 30’	W 5° 15’	I
Grotte des Idoles	cave	Gif A 92332	charcoal	5630±80	6288-6630	6.4			N 35° 40’	W 6° 00’	E
Grotte des Idoles	cave	Cle 120	ceramics				6900±800		N 35° 40’	W 6° 00’	I
Grotte de Él Khril C	cave	Cle 119	ceramics				5950±350		N 35° 40’	W 5° 50’	I
Grotte de Él Khril C	cave	Cle 118	ceramics				6400±500		N 35° 40’	W 5° 50’	I
Oued Tahadart	open air	UQ 1556	shells	5600±200	5933-6848	6.4			N 35° 30’	W 6° 00’	D
Oued Tahadart	open air	Cle 122	ceramics				6490±560		N 35° 30’	W 6° 00’	I
Oued Tahadart	open air	Cle 124	ceramics				6710±510		N 35° 30’	W 6° 00’	I
Oued Tahadart	open air	Cle 125	ceramics				6850±520		N 35° 30’	W 6° 00’	I
Oued Tahadart	open air	Cle 123	ceramics				5047±580		N 35° 30’	W 6° 00’	I
Oued Tahadart	open air	Ox 726all	dune					6200±800	N 35° 30’	W 6° 00’	J
Oued Tahadart	open air	Ox 726 bll	dune					5900±800	N 35° 30’	W 6° 00’	J

Table 1. (continued)

W Morocco (semi-arid to sub-humid) Site	type	lab no.	material	^{14}C [BP]	^{14}C [cal BP] (2 sigma)	median probability [cal BP]	TL [before 1980]	OSL [yr]	latitude	longitude	Ref
El Harhoura I	cave	Gif 5519	bone	5400±290	5490-6856	6.2			N 33° 55'	W 6° 55'	D
El Harhoura II	cave	UQ 1601	shells	5800±150	6294-6955	6.6			N 33° 55'	W 6° 55'	D
El Harhoura II	cave	Ly 2149	bone	5980±210	6323-7307	6.8			N 33° 55'	W 6° 55'	D
Rouazi	necropol	Cle 139	ceramics				4400±650		N 33° 50'	W 7° 05'	I
Rouazi	necropol	Ly 3087	bone	4480±190	4588-5590	5.1			N 33° 50'	W 7° 05'	D
Rouazi	necropol	Ly 4096	charcoal	4560±150	4862-5583	5.2			N 33° 50'	W 7° 05'	D
Rouazi	necropol	Cle 137	ceramics				5260±350		N 33° 50'	W 7° 05'	I
Rouazi	necropol	Cle 140	ceramics				5400±450		N 33° 50'	W 7° 05'	I
Rouazi	necropol	Cle 138	ceramics				5500±1500		N 33° 50'	W 7° 05'	I
Rouazi	necropol	UQ 1557	shells	4950±150	5320-5996	5.7			N 33° 50'	W 7° 05'	D
Rouazi	necropol	UQ 1868	bone	5350±150	5751-5828	6.1			N 33° 50'	W 7° 05'	E
Kaf el Baroud	cave	Gif 2889	bones	5160±110	5657-6189	5.9			N 33° 40'	W 7° 00'	F
Kaf el Baroud	cave	Gif 2888	bones	4750±110	5070-5731	5.5			N 33° 40'	W 7° 00'	F
El Kiffen	necropol	Auck. W 1518	bone	4300±80	4582-5270	4.9			N 33° 20'	W 7° 35'	G
Dar es Soltan II	cave	Cle 132	ceramics				5000±350		N 34° 00'	W 7° 00'	I
G. d. Contrebandiers	cave	Cle 135	ceramics				4200±350		N 33° 55'	W 7° 58'	I
G. d. Contrebandiers	cave	Cle 136	ceramics				6600±600		N 33° 55'	W 7° 58'	I
Toulkine	cave	Cle 142	ceramics				4000±450		N 31° 30'	W 8° 20'	I
Toulkine	cave	Cle 143	ceramics				4300±400		N 31° 30'	W 8° 20'	I
Toulkine	cave	Cle 141	ceramics				4400±350		N 31° 30'	W 8° 20'	I
NE Moroccan shore line (semi-arid) Site	**type**	**lab no.**	**material**	^{14}C [BP]	^{14}C [cal BP] (2 sigma)	median probability [cal BP]	TL [before 1980]	OSL [yr]	latitude	longitude	Ref
Islas Chafarinas	open air	KIA 17373	charcoal	5600±30	6309-6438	6.4			N 35° 11'	W 2° 26'	H
SW Morocco (Saharan) Site	**type**	**lab no.**	**material**	^{14}C [BP]	^{14}C [cal BP] (2 sigma)	median probability [cal BP]	TL [before 1980]	OSL [yr]	latitude	longitude	Ref
Site 11/1b Itzriten	open air	Gif 2910	charcoal	6100±120	6678-7257	7.0			N 28° 02'	W 12° 20'	K
Site H Megriou	open air	Gif 2911	charcoal	4450±110	4833-5446	5.1			N 27° 45'	W 13° 43'	K
Tarfaya village	open air	Gif 2821	charcoal	3300±100	3343-3826	3.5			N 27° 45'	W 12° 45'	K
Oued el Quar Site G	open air	Gif 3013	shells	3550±120	3487-4221	3.9			N 28° 10'	W 11° 52'	K
Oued el Quar Site G	open air	MC 710	mollusks	4950±100	5475-5915	5.7			N 28° 10'	W 11° 52'	L
Site Letan	open air	MC 669	mollusks	4400±90	4841-5294	5.0			N 27° 55'	W 12° 40'	L
Site Letan	open air	MC 670	charcoal	3290±70	3379-3687	3.5			N 27° 55'	W 12° 40'	L
Site 16	open air	MC 707	mollusks	3540±100	3573-4138	3.8			N 27° 55'	W 11° 55'	L
Site 16	open air	MC 708	mollusks	3830±100	3929-4517	4.2			N 27° 55'	W 11° 55'	L
Site 17	open air	MC 709	mollusks	4320±100	4585-5287	4.9			N 27° 55'	W 12° 30'	L
Site 19	open air	MC 555	ostrich egg	6350±120	6969-7482	7.3			N 28° 00'	W 11° 50'	L
Site 19	open air	MC 556	ostrich egg	6150±120	6741-7307	7.0			N 27° 55'	W 12° 30'	L

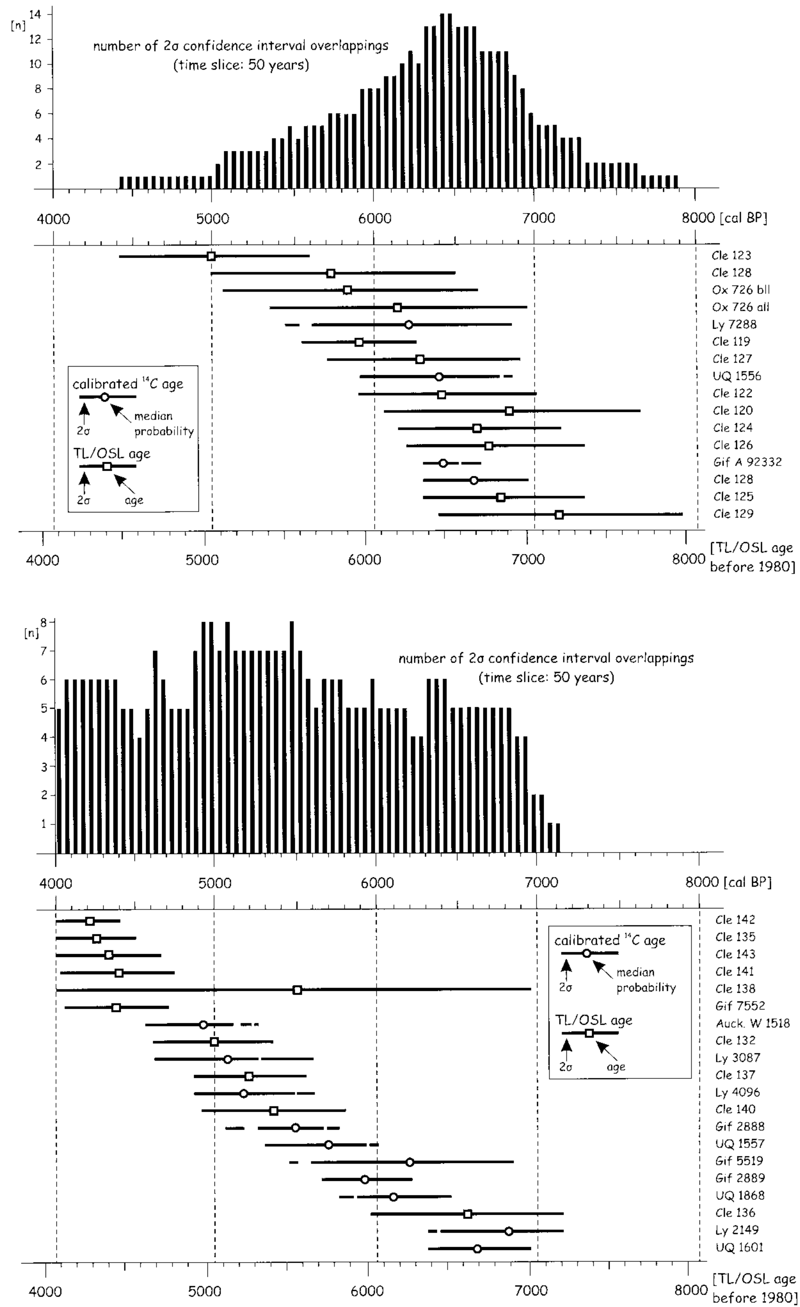


Fig. 4a. TL and calibrated ^{14}C ages of Neolithic sites from northwestern (above) and western (below) Morocco: white squares document mean TL ages, white dots reveal median probabilities of calibrated radiocarbon ages, and black lines show 2σ confidence intervals. Histograms (time slice: 50 years) document the number of 2σ confidence interval overlapping.

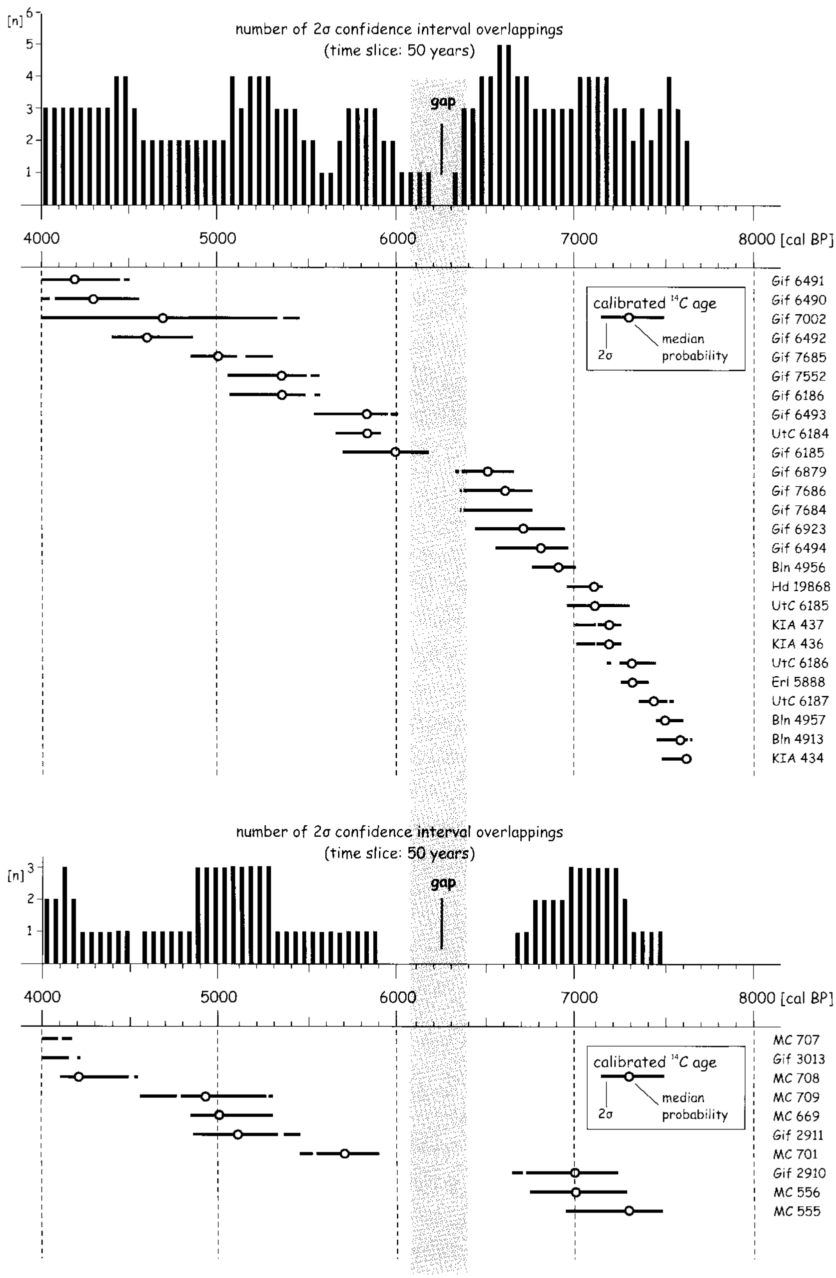


Fig. 4b. Calibrated ^{14}C ages of Neolithic sites from northeastern (above) and southwestern (below) Morocco: white dots show median probabilities of calibrated radiocarbon ages, and black lines show 2σ confidence intervals. Histograms (time slice: 50 years) document the number of 2σ confidence interval overlapping. The chronological gap around 6.0 and 6.5 ka might document the abandonment of Neolithic settlements in Moroccan drylands during a period of climatic deterioration.

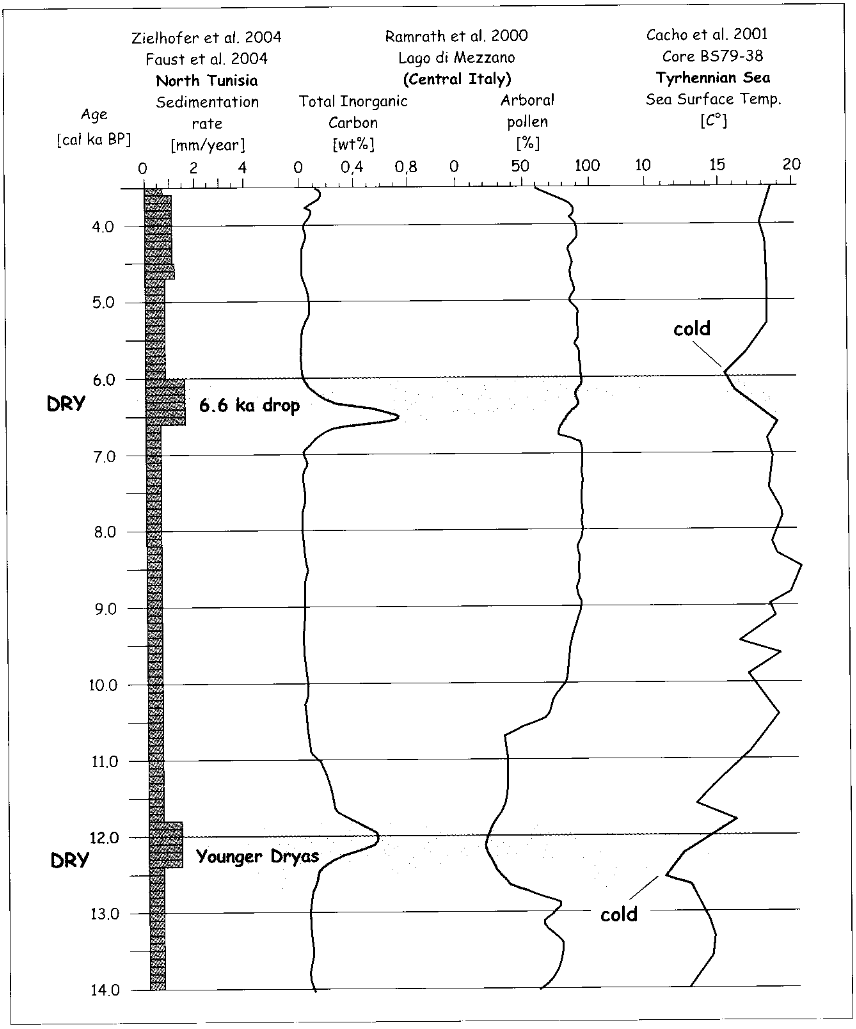


Fig. 5. Climatic deterioration between ~6.0 and 6.5 ka in the western Mediterranean.

With regard to the geographical setting and the Moroccan climate, the distribution of Neolithic sites can be classified into four major regions: a) The semi-arid hinterland of the Mediterranean coast (northeastern Morocco), b) the sub-humid to humid Atlantic littoral zone of northwestern Morocco, c) the semi-arid to sub-humid Atlantic Ocean littoral zone and its hinterland (western Morocco) and d) the Saharan type littoral zone at Cape Juby in the southwestern Morocco.

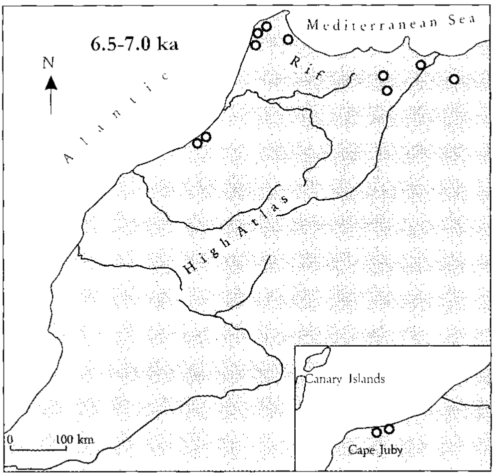
Considering the ^{14}C data set in Table 1, first early Neolithic populations can be observed around 7.5 ka. In northeastern Morocco at the Hassi Ouenzga cave (Figs. 2 and 3) the onset of the early Neolithic culture is dated 7,492–7,664 cal BP. The first early Neolithic site known in northwestern Morocco is the Kaf That el Ghar cave (DAUGAS et al. 1989, OUSMOI 1989), where

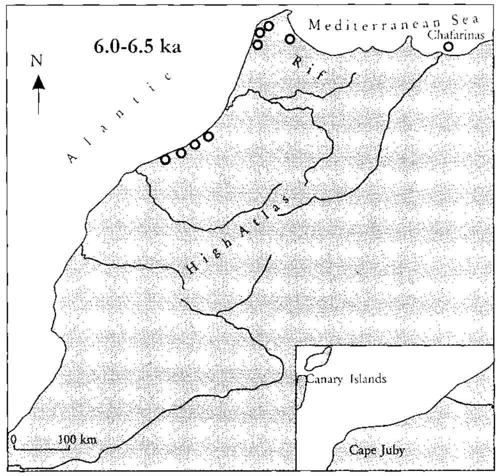
Table 2. Mean annual temperature und precipitation at selected stations in Morocco.

Meteorological station	annual precipation [mm]	average temperature [°C]	bioclimatical classification	Köppen climate type
Tanger	887	17,4	sub-humid	Csa
Melilla	389	18,3	semi-arid	Csa
Guercif	192	18,3	semi-arid	BSh
Oran (Algeria)	366	17,3	semi-arid	Csa
Rabat-Sale	578	17,3	sub-humid	Csa
Casablanca	430	17,1	semi-arid	Csa
Agadir	224	18,9	arid	BSh
Figuig	107	21,1	Saharan	BWh
Arrecife (Canary Is.)	139	20,2	Saharan	BWh

Cardial ceramics provided a TL age of 7,200 ± 750 years. Neolithic occupations in western Morocco and Cape Juby occurred somewhat later. In western Morocco the oldest early Neolithic age known derives from the El Harhoura cave (DAUGAS et al. 1989) at the Atlantic coast near Rabat (6,325–7,307 cal BP). At Cape Juby, ostrich eggs of an early Neolithic open air site attain an age of 6,969–7,482 cal BP (GRÉBÉNART 1975). The spreading of Neolithic sites attained a first peak between 6.5 and 7.0 ka. This is documented by many TL and ^{14}C ages derived from all major Neolithic regions of Morocco (Figs. 4 and 6). At that time the western Mediterranean climate was at its Holocene optimum (warm and wet): ROBERTS et al. (1994) document water level peaks at Tigalmamine (High Atlas). However, between 6.0 and 6.5 ka a sharp decrease in the number of Neolithic sites in the drylands is observed (Figs. 4b and 6). Neither the open air sites at Saharan Cape Juby nor the Neolithic stations within the Northeast Moroccan hinterland exhibit calibrated ^{14}C ages between 6.0 and 6.5 ka. The only exception is a charcoal date of 6,309–6,438 cal BP from an open air site in the Spanish Islas Chafarinas, a few hundred meters off-shore the northeastern Moroccan coast (BELLVER GARRIDO & BRAVO NIETO 2003).

BELLVER GARRIDO & BRAVO NIETO (2003)'s open air station shows abundant marine molluscs and fish remnants giving evidence of a copious exploitation of marine resources. These remains and bone remnants from domesticated ovicaprines show that the Neolithic population on Islas Chafarinas was probably more or less independent from climatic fluctuations. Archaeological investigations at the Hassi Ouenzga cave (Fig. 3) within the adjacent semi-arid northeastern Moroccan hinterland indicate a gap of occupation between 5.9 and 6.7 ka (Table 1). Unlike the population on Islas Chafarinas, the Hassi Ouenzga people were hunter-gatherer. Mammal fossils representing the whole spectrum of wildlife animals give no clear evidence of domestic animals during the early Neolithic (LINSTÄDTER 2004). The hunter-gatherers' way of living at Hassi Ouenzga was dependent on the wildlife populations of the surrounding drylands. Decreases in annual precipitation probably led to the abandonment of the cave. The well-stratified layers at Hassi Ouenzga and the closely sampled ^{14}C data clearly show that this station was unused at ~6.5 ka





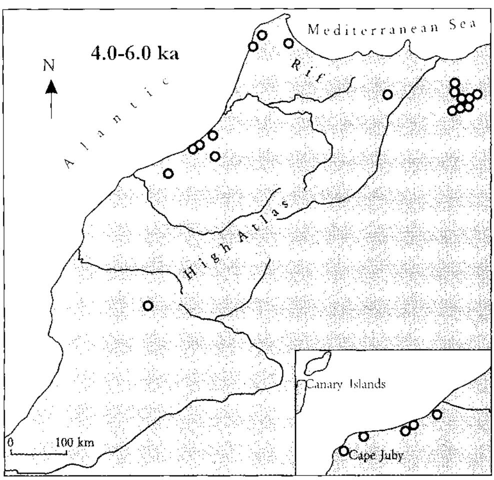


Fig. 6. Distribution of Neolithic sites between 6.5 and 7.0 ka, 6.0–6.5, and between 4.0 and 6.0 ka.

(middle Neolithic period). According to the palaeoclimatic and paleoecological records presented in Fig. 5, a decrease in rainfall can be deduced between 6.0 and 6.5 ka in the western Mediterranean region. A mid-Holocene climatic impact on Neolithic settlement pattern might be taken into account. Additionally, the missing proof of Neolithic populations at arid Cape Juby during this period must be considered (Figs. 4b and 6).

Archaeological investigations from Neolithic sites at the Atlantic coast of northwestern and western Morocco give no evidence for a decrease in early to middle Neolithic settlement pattern (Fig. 4a). In contrast, several northwestern Moroccan Cardial ceramics point to a TL age between 6.0 and 6.5 ka (Table 1 and Fig. 6). Similarly to the open air site on Islas Chafarinas, the Neolithic populations at the Northwest Moroccan shore line benefited from the rich marine resources (Gilman 1975). In contrast to the Hassi Ouenzga cave located in a semi-arid region, the Mugharet el'Aliya site near Tangier contains bone fragments of domestic animals with a mortality peak of pig bones between 2 and 2 ½ years that points to herd management (GILMAN 1975). Exploitation of marine resources and domestic animals might be a good strategy to survive climatic crises of longer duration, and northwestern Morocco offers more annual precipitation than the semi-arid region of northeastern Morocco (Fig. 3 and Table 2). The sub-humid landscape of the Tangier region may therefore be less sensitive to climatic depressions similar to those we discussed for the period between ~6.0 and 6.5 ka. After the mid-Holocene (middle Neolithic) dry period, at ~5.9 ka, the late Neolithic culture returned to the semi-arid regions of northeastern Morocco and the Saharan littoral zone again (Figs. 4b and 6).

5 *Conclusions*

Modern archaeological or geomorphological studies emphasize palaeoclimatic or palaeoenvironmental history as a triggering (or a very important) cause of human development (WEISS et al. 1993, VERSCHUREN et al. 2000, DE MENOCAL 2001, D'ERRICO & SÁNCHEZ GONI 2003, LAMB et al. 2003). Nevertheless, a correlation of archaeological data with Holocene palaeoenvironmental findings often remains unsatisfying due to lack of well-dated and continuous sequences or due to missing stratigraphic linkages between archaeological sites and palaeoenvironmental archives. Interlocked archaeological and palaeoenvironmental archives (layers) are not presented in our compilation of North African settlement behaviour in the course of the mid-Holocene, but continuous palaeoclimatic and palaeoenvironmental sequences (RAMRATH et al. 2000, CACHO et al 2001, ZIELHOFER et al. 2004), and a lot of well documented Neolithic sites with many TL and ^{14}C datings (Table 1) are available.

There is evidence from the western Mediterranean for a climatic depression between ~6.0 and 6.5 ka (Fig. 5) with decreasing temperatures (e.g. CACHO et al. 2001) and – much more important – decreasing humidity (e.g. ZIELHOFER et al. 2004). The fact that all Neolithic sites currently known in Saharan and semi-arid Morocco were abandoned between 6.0 and 6.5 ka (Fig. 4b) leads to a correlation of settlement pattern and climate, especially decreasing humidity. Mediterranean drylands and corresponding human populations may react very sensitive to Holocene climatic shifts. Existing archaeological and mid-Holocene proxies cannot clearly prove our hypothesis of an interaction between human behaviour and climate change. Well-stratified terrestrial archives with interlocked archaeological sites have not yet been investigated in Morocco, although geomorphological and archaeological surveys have a long tradition there. In this sense, future geoarchaeological studies should be supported by adjacent palaeoenvironmental surveys of high to moderate resolution.

For the western Mediterranean, the palaeoclimatical interpretation of the climatic drop at ~6.0 ka remains difficult. Are we dealing with a local phenomenon or do we have to discuss this climatic deterioration on a more regional scale? According to GUO et al. (2000) and GASSE & VAN CAMPO (1994), drier conditions were also present in the adjacent Saharan-Sahelian region at that time. However, if we compare palaeoclimatic records from the western Mediterranean region itself, the 6.0 ka climatic depression is not ubiquitous (cf. PANTALÉON-CANO et al. 2003). Due to the different temporal resolution of continuous palaeoclimatic records, many questions remain open so far. Additionally, the sensitivity of palaeoenvironmental archives to climatic changes differs extremely.

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