Tagungen des
Landesmuseums für Vorgeschichte Halle
Band 12/I | 2015

2200 BC – Ein Klimasturz als Ursache für den Zerfall der Alten Welt?
2200 BC – A climatic breakdown as a cause for the collapse of the old world?

7. Mitteldeutscher Archäologentag
vom 23. bis 26. Oktober 2014 in Halle (Saale)
7th Archaeological Conference of Central Germany
October 23–26, 2014 in Halle (Saale)

Tagungen des
Landesmuseums für Vorgeschichte Halle

Band 12/I | 2015

2200 BC – Ein Klimasturz als Ursache für den Zerfall der Alten Welt?

2200 BC – A climatic breakdown as a cause for the collapse of the old world?

7. Mitteldeutscher Archäologentag
vom 23. bis 26. Oktober 2014 in Halle (Saale)
7th Archaeological Conference of Central Germany
October 23–26, 2014 in Halle (Saale)

Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt
LANDESMUSEUM FÜR VORGESCHICHTE

herausgegeben von
Harald Meller,
Helge Wolfgang Arz,
Reinhard Jung und
Roberto Risch

Halle (Saale)
2015

Dieser Tagungsband entstand mit freundlicher Unterstützung von:
The conference proceedings were supported by:

UAB
Universitat Autònoma de Barcelona

Die Beiträge dieses Bandes wurden einem Peer-Review-Verfahren unterzogen. Die Gutachtertätigkeit übernahmen folgende Fachkollegen: Prof. Dr. Helge Wolfgang Arz, Prof. Dr. Robert Chapman, Prof. Dr. Janusz Czebreszuk, Dr. Stefan Dreibrodt, Prof. José Sebastián Carrión García, Prof. Dr. Albert Hafner, Prof. Dr. Svend Hansen, Dr. Karl-Uwe Heußner, Dr. Barbara Horejs, PD Dr. Reinhard Jung, Dr. Flemming Kaul, Prof. Dr. Ourania Kouka, Dr. Alexander Land, Dr. José Lull García, Prof. Dr. Rafael Micó, Prof. Dr. Pierre de Miroschedji, Prof. Dr. Louis D. Nebelsick, Prof. Dr. Marco Pacciarelli, Prof. Dr. Ernst Pernicka, Prof. Dr. Lorenz Rahmstorf, Prof. Dr. Roberto Risch, Prof. Dr. Jeremy Rutter, Prof. Dr. Gerhard Schmiedl, Anja Stadelbacher, Dr. Ralf Schwarz, Prof. Dr. Gerhard Trnka, Prof. Dr. Jordi Voltas, Dr. Bernhard Weninger.

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://portal.dnb.de abrufbar.

ISBN	978-3-944507-29-3
ISSN	1867-4402
ISBN (UNIVERSITAT AUTÒNOMA DE BARCELONA)	978-84-490-5585-0

Redaktion	Markus C. Blaich, Konstanze Geppert, Kathrin Legler, Anne Reinholdt, Manuela Schwarz, Anna Swieder, David Tucker, Melina Wießler
Redaktion und Übersetzung der englischen Texte	Sandy Hämmerle • Galway (Irland), Isabel Aitken • Peebles (Schottland), David Tucker
Organisation und Korrespondenz	Konstanze Geppert, Anne Reinholdt
Technische Bearbeitung	Thomas Blankenburg, Anne Reinholdt, Nora Seeländer
Sektionstrenner	Gestaltung: Thomas Blankenburg, Nora Seeländer; S. 33 Photograph Brooklyn Museum, Charles Edwin Wilbour Fund, 39.1. Creative Commens-BY; S. 95 © Eberhard-Karls-Universität Tübingen; S. 333 © UAB ASOME; S. 481 © R. Kolev (National Museum of History, Sofia), © Dr. M. Hristov (National Museum of History, Sofia); S. 669 © J. Lipták, München; S. 803 © Aberdeen University Museum, © National Museums of Scotland, © Dr. A. Sheridan (National Museums of Scotland)
Umschlag	Malte Westphalen, Nora Seeländer

Papier	alterungsbeständig nach DIN/ISO 9706
Satzschrift	FF Celeste, News Gothic
Konzept und Gestaltung	Carolyn Steinbeck • Berlin
Layout, Satz und Produktion	Anne Reinholdt, Nora Seeländer
Druck und Bindung	LÖHNERT DRUCK

Inhalt/Contents

Band I

Sektion Orient und Ägypten/
Section Middle East and Egypt

Sektion Östlicher und Zentraler Mittelmeerraum/
Section Eastern and Central Mediterranean

Sektion Westlicher Mittelmeerraum/ Section Western Mediterranean

Band II

Sektion Mittel- und Osteuropa/ Section Central and Eastern Europe

Sektion Mitteldeutschland/
Section Central Germany

Sektion Nord- und Westeuropa/ Section Northern and Western Europe

Anhang/Appendix

Climate and societal change in the western Mediterranean area around 4.2 ka BP

Mara Weinelt, Christian Schwab, Jutta Kneisel, and Martin Hinz

Zusammenfassung

Klimawandel und soziale Umbrüche im westlichen Mittelmeerraum um 4.2 ka BP

Die Übereinstimmung kohärenter Muster und die Gleichzeitigkeit gewisser Ereignisse im östlichen Mittelmeerraum weisen auf einen offensichtlichen Zusammenhang zwischen kulturellen Umbrüchen in urbanen Gesellschaften und Klimaeffekten hin. Im Folgenden wird ein Dürreereignis um 4.2 ka BP mit einer Reihe von ausbleibenden Monsunregenfällen in Zusammenhang gebracht. Auslöser für tief greifende wirtschaftliche Veränderungen sowie sozialen Aufruhr. Auf die zentralen und westlichen Regionen des Mittelmeerraums an der Schnittstelle zwischen nordatlantischen (3. Bond-Ereignis) und Monsun-beeinflussten Klimata trifft dies jedoch nicht zu. Die potenzielle Ausbreitung einer überregionalen Dürreperiode um 4.2 ka BP in den westlichen Mittelmeerraum hinein und bis nach Südmitteleuropa bedarf noch weiterer Abklärungen. Trotzdem waren präurbane, durch zunehmende Komplexität geprägte Gemeinschaften zwischen dem späten Neolithikum und der frühen Bronzezeit in einem tief greifenden Umbruch begriffen. Eine Vielzahl von abrupten gesellschaftlichen und kulturellen Veränderungen, die genau in die Zeit um 4.2 ka BP datieren – z. B. weitverbreitete »Krisensituationen« in mediterranen Glockenbechergesellschaften, der Übergang von der Vorpalastzeit zur Palastzeit auf den griechischen Inseln und, vielleicht besonders bemerkenswert, der Übergang zwischen der chalkolithischen Los Millares Kultur und der frühbronzezeitlichen El Argar Kultur im Südosten der Iberischen Halbinsel – sind bisher nur selten vor dem Hintergrund möglicher Reaktionen und Widerstandsstrategien im Falle eines abrupten Klimawandels und wechselnder Umweltbedingungen betrachtet worden.

In unserem Beitrag werden Untersuchungen bereits existierender archäologischer und klimatischer Datenbestände aus dem westlichen Mittelmeergebiet vorgestellt. Ziel ist es, mittels entsprechender Proxydaten zur Landnutzung, zur Bevölkerungsdichte und zu den Subsistenz- und Siedlungsmustern Hinweise auf eine sozialökologische Krise im Mittelmeerraum auszumachen.

Summary

In the eastern Mediterranean area, coherent patterns and synchronous events around 4.2 ka BP suggest an obvious link between cultural upheaval in urban societies and climate forcing. Here, the 4.2 ka BP aridification event, attributed to a series of monsoon failures, is thought to have been the cause of severe economic consequences and social unrest. The picture for the central and western Mediterranean regions, at the interface of North Atlantic (Bond event 3) and monsoon-influenced climates, is different. It remains unclear whether supra-regional drought around 4.2 ka BP extended into the western Mediterranean and southern Central Europe. Yet at the same period, pre-urban societies, already marked by emerging complexity, were in profound upheaval during their transition from Late Neolithic to Early Bronze Age ideologies. An array of abrupt societal and cultural transitions, precisely dating to 4.2 ka BP, include widespread »crises« of Mediterranean Bell Beaker populations, the transitions from Prepalace to Palace cultures on the Greek Islands, and – perhaps particularly outstanding – the transition from the Chalcolithic Los Millares Culture to the Early Bronze Age El Argar Culture in the south-eastern Iberian Peninsula. The possibility that these transitions may have been responses/resilience strategies triggered by abrupt climate and environmental change has so far hardly been considered.

Here we present a survey of existing archaeological and climate archives for the western Mediterranean area, aiming to trace patterns of socio-environmental crisis in the Mediterranean using pertinent proxy records, including proxies of population density, subsistence, and settlement patterns.

Introduction

A particular threat from the currently projected global warming are the related socio-environmental challenges. These are predicted to exacerbate existing problems – poverty, conflict, dangers to health, escalating food, age and water shortages – into crises (IPCC 2013; IPCC 2014). The archaeological retrospective on past supra-regional socio-environmental crises, particularly the 4.2 ka BP event, and the approaches of contemporary societies to overcoming them, may improve our understanding of their complex patterns and help us to identify successful resilience strategies.

The 4.2 ka BP event, at the transition from the Middle to the Late Holocene, affected the climatic stability of the entire northern hemisphere. Perhaps most severely affected was the subtropical and tropical domain, making it a prime candidate for exploring the traits and patterns of a supra-regional socio-environmental crisis (e.g. Dalfes et al. 1997; Booth et al. 2005). By the late 3rd millennium BC, population and land use levels in the circum-Mediterranean area had reached a first maximum of almost full coverage, as projected by global model simulations (e.g. Lemmen/Wirtz 2012). Emerging complexity, enhanced mobility, and exchange had certainly accelerated societal developments, including ideological and economic change.

Mediterranean climates and landscapes are particularly prone to desertification, their environments and economies being highly dependent on the precipitation they receive, predominantly in winter. Generally, Middle and Late Holocene climates in the Mediterranean area show a trend of gradual warming, more pronounced in South-Western than in South-Eastern Europe (Davis et al. 2003), while an opposing trend prevails in the mid-latitude Atlantic region, including the Iberian Margin. Long-term Holocene trends were punctuated by brief episodes of drought (Finné et al. 2011). Over the course of the Holocene, these episodes changed in frequency and character (Fletcher et al. 2007). Arguably, the most severe of these episodes, among them the 4.2 ka BP event, are related to North Atlantic Bond cycles (e.g. Marino et al. 2009) and thus considered to be driven and/or modulated by large-scale oceanic and atmospheric circulation changes. The 4.2 ka BP event, in particular, is considered to have its strongest effect in the subtropical realm, dominated by monsoonal climate constraints, where broad areas suffered from resulting monsoon failures. This view may be skewed by the archaeological evidence itself, since the sources for societal responses are most accessible in the most densely occupied region of the northern hemisphere of this time. In the eastern Mediterranean and Near East, the 4.2 ka BP event manifests as a brief episode of barely 300 years' duration (22nd century BC to 19th century BC; e.g. Weiss 2012), following a general, long-term shift from humid to drier conditions (Rohling/Rijk 1999). Aegean records show environmental change related to altered Mediterranean circulation. In Anatolia, drought evidence is reported from lacustrine records; nevertheless Anatolian vegetation appears to have responded only moderately to climate forcing (cf. Dörfler in the present volume). Interestingly, no evidence for a climatic event matching the 4.2 ka BP event chronology has been reported so far from the Peloponnese, despite high-resolution humidity records obtained from lagoonal environments there (I. Unckel pers. comm. 2015). A compilation of central Mediterranean climate records (Magny et al. 2013), integrating lake level, pollen, and speleothem records from Italy to North Africa, and marine records from adjacent ocean basins, reveals a broader climate episode of general instability at the Middle to Late Holocene transition, lasting for 400 years from 4300 BP to 3900 BP. A steep latitudinal gradient, situated at approximately 40 N, was found, separating sites marked by drought to the south from northern sites which coevally received enhanced precipitation. This broader interval easily encloses a potentially narrower 4.2 ka BP event, supporting the idea of a widespread climate disturbance, although with inverted sign in Central Europe.

A comparable compilation is still lacking for the western Mediterranean, which is under the immediate influence of Atlantic climate constraints. Such a compilation would reveal potential east to west Mediterranean climate gradients (EW gradients), such as those which can be observed in modern and past Mediterranean climate patterns (e.g. Kageyama et al. 2001; Martrat et al. 2004; Lionello et al. 2006). This gap needs to be filled for a better understanding of the patterns of the 4.2 ka BP event. Only then will it be possible to assess the potential roles of abrupt climate change vs. social constraints in the 4.2 ka BP upheaval of western Mediterranean societies, from the perspective of a supra-regional crisis scenario. A few high-resolution archaeobotanical records from the Iberian Peninsula, providing a continuous record of the whole Middle Holocene, report a sharp shift towards an increased frequency of fire events from around 4.0–4.2 ka BP onward. This was accompanied by profound forest change and is tentatively attributed to the onset of drier and warmer conditions (and/or enhanced human land use activities) (Carrión et al. 2003; Pérez-Obiol et al. 2011). Marine climate records from the Alboran Sea suggest drier yet cooler conditions (Cacho et al. 1999; Cacho et al. 2001). In contrast, the western Iberian Peninsula appears to have been affected by drought to a lesser degree (Pérez-Obiol et al. 2011).

From the interval spanning the last two centuries of the 3rd millennium BC, abundant archaeological evidence of major cultural change is available from the western Mediterranean area, coinciding with the Copper/Bronze Age transition. Mapping of cultural entities per chronological phase (Buchvaldek et al. 2007), as well as numerous more detailed studies of individual sites, reveals a widespread discontinuity of settlement patterns, accompanied by a widespread abandonment of entire districts and the occupation of new terrains. These studies suggest a dramatic shrinkage of territories occupied by Late Chalcolithic cultural entities in Southern Spain and Portugal, including the large sites of long-term occupation at Los Millares and Zambujal, in Andalusia and the Peninsula of Lisbon in the central Portuguese region respectively, as well as sites in the Meseta Central. Indeed, only a few sites in Southern Spain display continuous occupation across the 4.2 ka BP event, among them the site of Úbeda, province of Jaén, with its rich and well-dated record of economic and ecological change (Nocete et al. 2010). Large changes in Copper Age settlement patterns are also evident in the coastal zone of Mediterranean France, and in the Balearic Islands and Corsica. Surprisingly little is known about the Copper to Bronze Age transition in Mediterranean France, predominantly characterised by the Bell Beaker phenomenon. Here the previously rich record of a rapidly evolving material culture, in the eastern sector revealing a close relationship with Italy, appears to fade out with the declining Copper Age (Lemercier et al. 2014). The rapid spread of Early Bronze Age cultures (El Argar, Motillas Cultures) in the south-eastern Iberian Peninsula appears to be accompanied by a demographic boost (Lull et al. 2011; cf. Lull et al. in the present volume) as projected from regional land use reconstructions (Lull et al. 2011) and supported by cereal production estimates (Delgado Raack/Risch forthcoming). Recent studies,

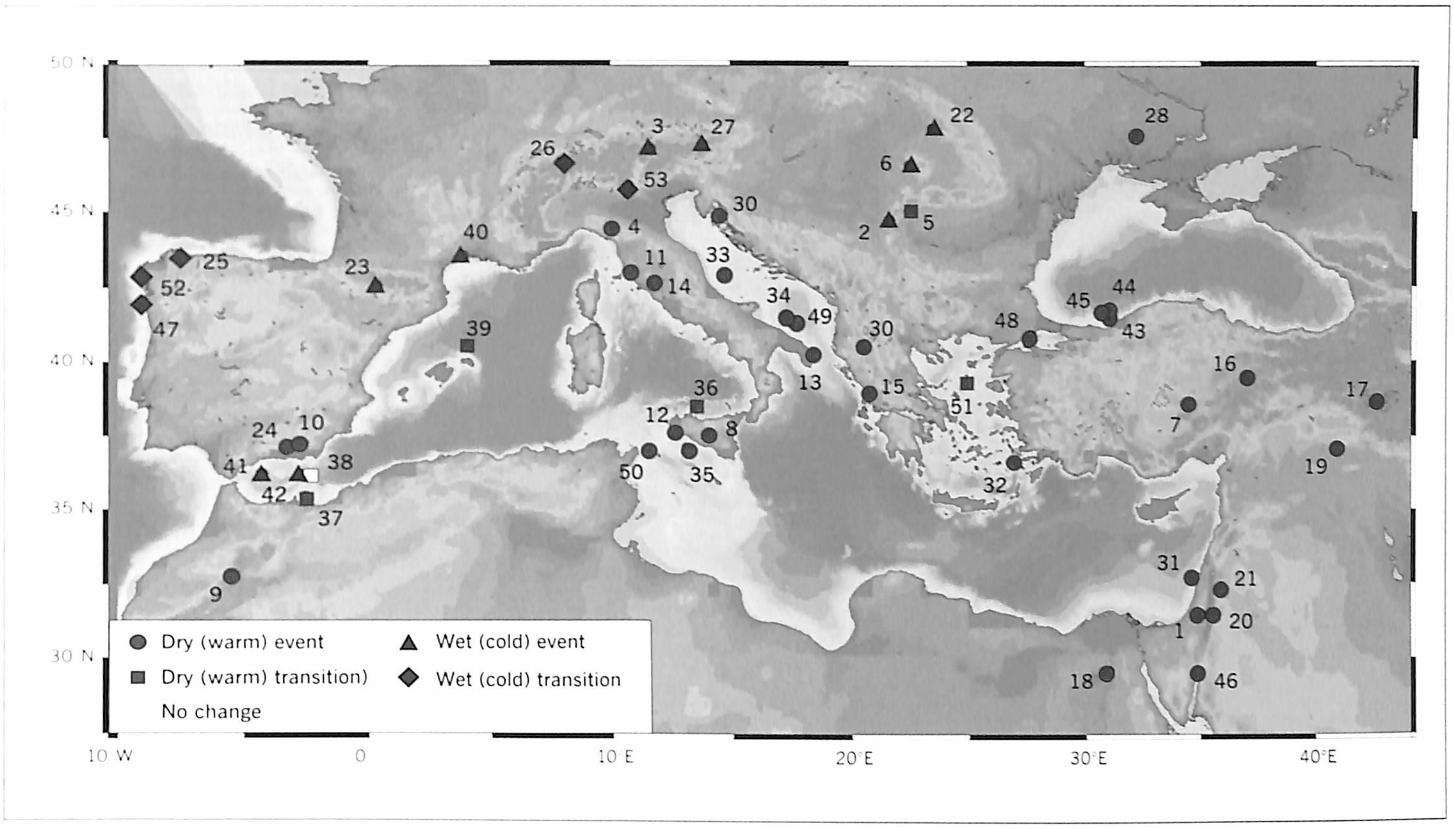


Fig. 1 Map showing finding places and climatic conditions in the circum-Mediterranean realm. Numbers correspond to those in table 1 and appendix.

Abb. 1 Karte mit Fundorten und Klimabedingungen im zirkummediterranen Raum. Die Nummerierung stimmt mit Tabelle 1 und Anhang überein.

based on improved and refined absolute chronologies, have further pin-pointed a marked Copper Age/Bronze Age discontinuity in the eastern Iberian Peninsula (e.g. Balsera et al. 2015). Based on a broad inter-regional study, tracing the differential trajectories of western Mediterranean societies by means of detailed chronologies of stone architecture and ditched enclosures, the latter have found converging, diverging, and disruptive patterns, and have pointed out that the diverging patterns of south-eastern and south-western Iberia, where those of the western region are less disruptive, also need to be explored from the perspective of a climate-driven environmental change.

Evidence for ecological and economic responses to increased climate-induced stress, related to the 4.2 ka BP event, still remain scarce. Substitutions of resources may indicate strategic responses to environmental constraints. However, these changes are rarely unambiguous, since they may be – and in archaeological literature mostly are – as well explained by resource shortages, resulting from overexploitation by a rapidly increasing population. At many sites, social upheaval and resource shortages appear to precede the climatic event, either slightly or considerably (if more subtle early indicators are considered). Thus climate change may be rejected as a trigger (cf. Müller in the present volume), but may still, nevertheless, have functioned as a modulator. An increasing trend of Early Bronze Age economies towards a barley monoculture, on the Iberian Peninsula and elsewhere, has been cautiously attributed to drought (Stika 2001). Archaeozoological evidence from the site of long-term occupation at Ubeda suggests changes in subsistence strategies (Nocete et al. 2010); the causes, however, remain unclear. Interestingly, in archaeobotanical records from Mediterranean France, the Early Bronze Age is poorly represented, or not represented at all, suggesting a gap in occupation here. In general, a coincidence of unfavourably evolving societal and environmental variables may well have caused aggregation effects in socio-environmental pressure.

To highlight the patterns and roles of these variables, in this study we compare climate and population patterns in the western Mediterranean area on an inter-regional scale.

Mediterranean climate variability across the 4.2 ka BP event

Modern Mediterranean climate and reconstruction of the 4.2 ka BP event climate patterns

Today, the regions bordering the Mediterranean Sea are characterised by an arid to semi-arid climate, with some regions receiving less than 200 mm of precipitation per year (Lionello et al. 2006). The borderlands of the Mediterranean Sea, including the southern Iberian Peninsula, are therefore prone to desertification and droughts, and climate exerts a strong influence on local societies and economies (Lionello et al. 2006). In general, the Mediterranean climate exhibits a strong seasonality, with dry and hot summers and mild and rainy winters. However, the general climate pattern is complex, due to the interrelation, strength, and extent of various climate processes such as the monsoon, El Niño system, the Siberian High, and the North Atlantic Oscillation (NAO). Imprints of these processes can be traced

Nr. in map	Name, Location	Latitude	Longitude	Variables	Resolution (years)	References
1	Soreq, Israel	31.45° N	35.03° E	$\delta^{18}O$, $\delta^{13}C$	19	Bar-Matthews et al. 2003
2	Poleva, Romania	44.71444° N	21.74119° E	$\delta^{18}O$, $\delta^{13}C$	60	Constantin et al. 2007
3	Spannagel, Austria	47.116667° N	11.66667° E	$\delta^{18}O$	1.6	Fohlmeister et al. 2013
4	Buca della Renella, Italy	44.4° N	10° E	$\delta^{18}O$, $\delta^{13}C$, Mg/Ca, Fluorescence	60	Drysdale et al. 2006
5	Ascunsa, Hungary	45° N	22.6° E	$\delta^{18}O$, $\delta^{13}C$	86	Dragusin et al. 2014
6	Ursilor, Romania	46.55388° N	22.569166° E	$\delta^{18}O$	150	Onac et al. 2002
7	Eski Acigöl, Turkey	38.55082° N	34.544722° E	$\delta^{18}O$	86	Roberts et al. 2011
8	Pergusa, Italy	37.5° N	14.1° E	$\delta^{18}O$, Pollen	150	Zanchetta et al. 2007; Sadori et al. 2011
9	Tigalmamine, Marocco	32.73763° N	5.45272° W	$\delta^{18}O$, Pollen	120	Cheddai et al. 1998; Roberts et al. 2008
10	Cañada del Gitano, Spain	37.2333° N	2.7° W	Pollen, Micro-charcoal	67	Carrión et al. 2007
11	Accesa, Italy	42.98333° N	10.88333° E	Pollen, Lithology	25	Magny et al. 2009; Peyron et al. 2011
12	Gorgo Basso, Italy (Sicily)	37.61666° N	12.65° E	Pollen	120	Tinner et al. 2009
13	Lago Alimini Piccolo, Italy	40.18333° N	18.4333° E	Pollen	120	Di Rita et al. 2009
14	Mezzano, Italy	42.61666° N	11.9333° E	Pollen	150	Sadori et al. 2011
15	Limni Voulkaria, Greece	38.86666° N	20.83333° E	Pollen	100	Sadori et al. 2011
16	Tecer, Turkey	39.43133° N	37.08355° E	Lithology	36	Kuzucuoğlu et al. 2011
17	Van, Turkey	38.6333° N	42.81666° E	Pollen, Lithology	120	Wick et al. 2003; Lemcke/ Sturm 1997
18	Faiyum, Egypt	29.6° N	31° E	Lithology	?	Hassan 1986
19	Mozan, Syria	37.056944° N	40.997222° E	$\delta^{13}C$ plant remains	150	Riehl et al. 2008
20	Dead Sea, Israel/ Palestine/Jordan	31.4833° N	35.48333° E	Isotopes tree, Lithology, Pollen	75	Frumkin et al. 2009; Migowski et al. 2006; Litt et al. 2012
21	Jableh, Syria	32.3716472° N	35.9368333° E	Pollen	120	Kaniewski et al. 2008
22	Preluca Tiganului, Romania	47.81333° N	23.5472168° E	Pollen	120	Feurdean et al. 2008
23	Basa de la Mora, France	42.5333° N	0.316666° E	Pollen, XRF	120	Perez-Sanz et al. 2013
24	Borreguilles de la Virgen, Spain	37.0541666° N	3.3777° W	Pollen	150	Jiménez-Moreno/ Anderson 2012
25	Penido Vello, Spain	43.5333° N	7.5666° W	Trace metals (Hg)	150	Martinez-Cortizas et al. 1999
26	Sägistalsee, Switzerland	46.679722° N	7.976388° E	Chrionomid	120	Heiri and Lotter 2005
27	Landschitzsee, Austria	47.256111° N	13.83833° E	Pollen	150	Schmidt et al. 2002
28	Compilation Ukraine	47.6° N	32.2° E	Pollen	100	Kremenetski 1995
29	Ohrid, Macedonia	40.5° N	20.71666° E	Pollen, Diatoms, TOC, etc.	46	Wagner et al. 2008
30	Vrana, Croatia	44.8° N	14.5° E	Pollen	?	Schmidt et al. 2000
31	GeoTü SL112, Levantine Basin	32.742° N	34.65033° E	Grain size, EM, forams	120	Hamann et al. 2008; Kuhnt et al. 2008

Nr. in map	Name, Location	Latitude	Longitude	Variables	Resolution (years)	References
32	NS-14, Agean Sea	36.648611° N	27.00777° E	CCC, FCC, Pollen	150	Triantaphyllou et al. 2000
33	AMC99-1, Adriatic Sea	42.86333° N	14.761166° E	FCC	120	Piva et al. 2008
34	SA03-9, Adriatic Sea	41.361666° N	17.317° E	FCC	120	Piva et al. 2008
35	ODP 963, Strait of Sicily	37.0358° N	13.1781° E	FCC, CCC	86	Incarbona et al. 2008
36	BS79-38, Tyrrhenian Sea	38.412° N	13.577° E	Alkenone, FCC, $\delta^{18}O$	100	Cacho et al. 2001; Sbaffi et al. 2004
37	GeoB 13731-1, Western Mediterranean and Alboran Sea (WM/AS)	35.4133° N	2.55366° W	XRF	86	Fink et al. 2013
38	MD95-2043, WM/AS	36.1433° N	2.62166° W	Alkenone, FCC, Diatoms, TOC	150	Cacho et al. 2001; Perez-Folgado et al. 2003; Moreno et al. 2004
39	MD99-2343, WM/AS	40.49733° N	4.02816° E	$\delta^{18}O$, XRF, Lithology, FCC, Coccos	150	Frigola et al. 2008
40	PB06, WM/AS	43.50833° N	3.8733° E	Lithology	25	Sabatier et al. 2012
41	TTR17-434G, WM/AS	36.205216° N	4.31225° W	Alkenone, LDI	86	Rodrigo-Gamiz et al. 2013
42	TTR12-293G, WM/AS	36.17356° N	2.74566° W	Lithology, XRF, Alkenone, LDI	120	Rodrigo-Gamiz et al. 2011; Rodrigo-Gamiz et al. 2013
43	GeoB 7625-2, Black Sea	41.445° N	31.0666° E	Dino, Lithology	50	Lamy et al. 2006; Verleye et al. 2009
44	GeoB 7622-2, Black Sea	41.535° N	31.166667° E	Lithology	50	Lamy et al. 2006
45	MD04-2788, Black Sea	41.527833° N	30.88333° E	XRF	7	Kwiecien et al. 2008
46	GeoB 5804-4, Red Sea	29.5017° N	34.9567° E	$\delta^{18}O$, clay	24	Arz et al. 2003; Lamy et al. 2006
47	SMP02-3, Iberian Margin	42.036783° N	9.0393833° W	C/N	150	Bernardez et al. 2008
48	Geo Tü KL 71, Marmara Sea	40.841833° N	27.763166° E	TOC, FCC	120	Sperling et al. 2003
49	MD 90-917, Adriatic Sea	41.297833° N	17.613° E	Pollen	?	Magny et al. 2013
50	MD04-2797, Strait of Sicily	36.95° N	11.6666° E	Pollen	?	Magny et al. 2013
51	MNB 3, Aegean Sea	39.25° N	25° E	FCC	150	Geraga et al. 2010
52	EUGC-3B, Iberian Margin	42.75175° N	9.037183° W	Biomarker	<60	Pena et al. 2010
53	Ledro, Italy	45.866° N	10.75° E	XRF	<61	Vanniere et al. 2013

Tab. 1 List of palaeoclimatic cores (cf. Fig. 1).

Tab. 1 Liste paläoklimatischer Kerne (vgl. Abb. 1).

in all sub basins of the Mediterranean Sea, yet they have various intensities from the east to the west. The Afro – south western Asian monsoonal rainfall regimes exert a strong influence over the eastern part of the Mediterranean (e.g. Ziv et al. 2004), while the NAO is one of the main influencing factors for rainfall patterns and amounts in Western Europe. The Iberian Peninsula is especially sensitive to changes in NAO (e.g. Trigo et al. 2004). During a positive

NAO mode, the westerly wind belt, bringing moisture from the Atlantic Ocean, is strengthened and diverted to the north, bringing moisture to Northern Europe and dryness to the south-western Mediterranean region (e.g. Hurrel 1995). On the other hand, a negative NAO mode results in a weakened and more southerly track for the westerly winds, bringing moisture to the south-western Mediterranean Sea. Additionally, the precipitation pattern in the (western) Mediterranean region is controlled by cyclogenesis, which is related to cold katabatic winds originating from the Siberian High during winter (e.g. Rogers 1997).

To assess the impact of a potentially climate-driven 4.2 ka BP event on western Mediterranean societies, an extensive dataset of terrestrial and marine palaeoclimate records was compiled from existing literature. This dataset initially comprised more than 150 individual proxy records from 110 sites located in the Mediterranean Sea and adjacent areas. These records encompass qualitative and quantitative proxy estimations of temperature and moisture availability based on geochemical, micro- and nannopalaeontological, botanical, and sedimentological analysis. Unfortunately, most records exhibited a temporal resolution too low to allow rapid climate changes, relating to an event of an expected duration of only two to three centuries, to be properly traced, or compared with detailed archaeological records. Taking into account the expected 300 year duration of the 4.2 ka BP event (Weiss 2012), only records with a temporal resolution of at least 125 years were retained in our compilation. This left approximately 80 records from 53 sites (Fig. 1; Tab. 1; Appendix), still sufficient for a comprehensive spatial picture. The age models of the different records were adopted from the literature. Dating density may still be poor in some records and the age models of some marine records require to be revised in the light of more recent findings concerning Mediterranean marine reservoir ages (Siani 2001). Furthermore, the proxy records were interpreted without regard to their potential seasonal bias, and this needs to be assessed in future studies. Nevertheless, this compilation provides an overview of the general climatic state at 4.2 ka BP in the Mediterranean region.

Climate changes within the timeframe 4.4 ka BP to 3.8 ka BP were examined in the individual records. Since the climate event probably occurred between 4.2 ka BP and 3.9 ka BP, this allowed for full capture of the range of the event, as well as previous and subsequent levels. This time window has also been proposed by M. Magny et al. (2013) as the interval where the climate oscillation related to the 4.2 ka BP event occurs in palaeoclimate records. In addition, the wide span accounts for the general dating inaccuracy of ±100 years normally associated with ^{14}C dated palaeoclimate records, due, for example, to uncertainties in reservoir ages. So far, the compilation allows drier or more humid and warmer or colder conditions to be distinguished, according to the common interpretation of the different proxies and/or according to the interpretation of the respective authors of the records. If both precipitation and temperature estimates were available at a site, the precipitation record was used for the compilation map. The observed changes between 4.4 ka BP and 3.8 ka BP were classified into »events« (rapid changes) and »transitions« (»long term« changes). The following criteria were used to define events: a) single excursions (minima/maxima) of the proxy records within the 4.4 ka BP to 3.8 ka BP timeframe; b) rapid transitions occurring between two data points in the investigated timeframe which are less than 125 years apart; c) gradual changes that culminate in a minimum/maximum between 4.4 ka BP and 3.8 ka BP; d) changes explicitly defined as events by the relevant authors. The following criterion was used to define transitions: a) »long-term« gradual changes that started within or before the investigated time period (4.4 ka BP to 3.8 ka BP), and b) that lasted longer than the investigated timeframe.

The circum-Mediterranean climate around 4.2 ka BP

Warm conditions are not necessarily associated with dryness, as in the case of the Aegean, where cold and dry conditions prevailed during the 4.2 ka BP event (Kotthoff et al. 2008; Schmiedl et al. 2010). Nevertheless, a strikingly coherent picture emerges from our compilation, showing dry or warm conditions in the circum-Mediterranean region between 4.4 ka BP and 3.8 ka BP and more humid or colder conditions further north (cf. Fig. 1), similar to conditions found during a modern positive NAO mode. These results accord well with other recent regional climate compilations from the Mediterranean region for this period. Although not fully unambiguous, a warm and dry episode around 4.2 ka BP can be inferred from the eastern Mediterranean compilation by M. Finné et al. (2011). A similar picture has been drawn by Magny et al. (2013) for the central Mediterranean area. Based on their compilation, a warm and dry episode prevailed in the southern central Mediterranean region at 4.2 ka BP, while more humid conditions were found in Northern Italy.

Further evidence for a strengthening of the westerly wind belt (associated with a positive NAO) around 4.2 ka BP comes from a core from near the Azores Islands in the mid-ocean subtropical North Atlantic (Fig. 2a; Repschläger et al. 2015). There, the 4.2 ka BP event is marked by a sharp transition, within 130 years (from 4.21 ka BP to 4.08 ka BP), characterised by a 13 % drop in the abundance of the subtropical foraminiferal species *Globigerinoides ruber*, an indicator for subtropical gyre water. According to the authors, its retreat from the site hints at a southward displacement of the Azores front and a contracted subtropical North Atlantic Gyre. As the latitudinal position of the front is controlled by the strength of the westerly wind (Volkov/Fu 2010), the observed change indicates an abrupt shift towards stronger westerlies.

Although profound and rapid climatic changes at 4.2 ka BP are found globally (Booth et al. 2005), the climate dynamics and hence their regional manifestations are complex, due to the interplay of high- and low-latitude and long- and short-term processes. On millennial timescales, the 4.2 ka BP event correlates with the well-known millennial-scale Bond cycles (Bond Event 3; Bond et al. 2001), which are related to freshwater anomalies in the North Atlantic that alter the oceanic and atmospheric circulation patterns. On longer timescales the 4.2 ka BP event occurs during the transition from the

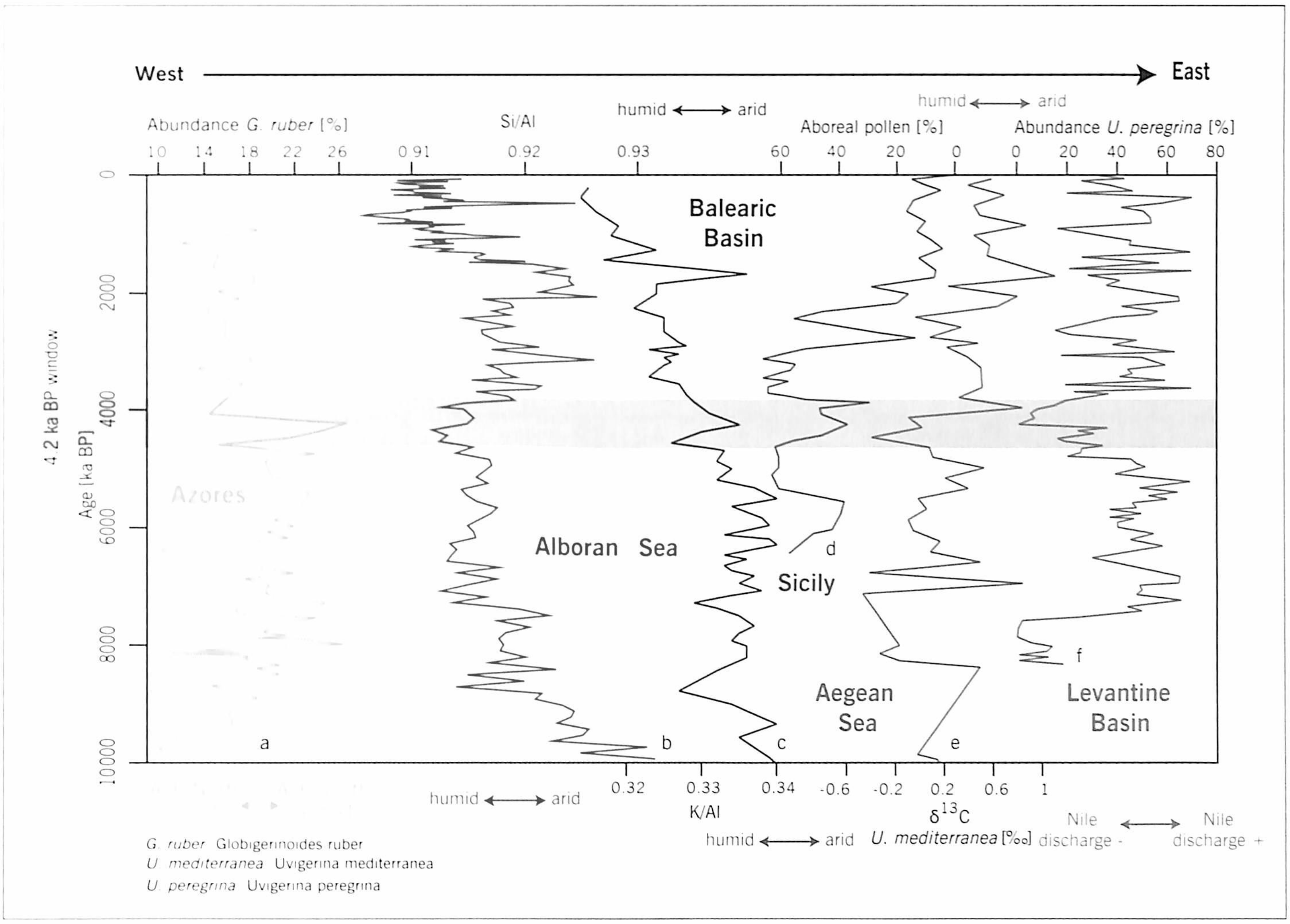


Fig. 2a–f West east transect across the Mediterranean Sea, showing selected palaeoclimatic records. a Abundance of foraminiferal species *Globigerinoides ruber*; b X ray fluorescence (XRF) based reconstruction of river runoff from southern Iberia; c X-ray fluorescence (XRF) record from a sediment core from the Balearic Basin; d pollen record from Lake Gorgo Basso in Sicily; e carbon isotope record from benthic foraminifera from a sediment core from the Aegean Sea; f abundance of *Uvigerina peregrina* from the Levantine Basin. Blue vertical bar indicates the time window 4.4 ka BP to 3.8 ka BP.

Abb. 2a–f *West Ost Transekt durch das Mittelmeer mit ausgewählten paläoklimatischen Daten. a Reichliches Vorkommen der Foraminiferenart* Globigerinoides ruber*; b Röntgenfluoreszenz Rekonstruktion der Wasserabflussmengen in Südiberien; c Röntgenfluoreszenz-Daten eines Sedimentkerns aus dem Balearen Becken; d Pollendaten aus dem Gorgo Basso See in Sizilien; e Kohlenstoffisotopendaten von benthischen Foraminiferen aus einem Sedimentkern aus der Ägäis; f Vorkommen von* Uvigerina peregrina *im Levantischen Becken. Der horizontale blaue Bereich markiert das Zeitfenster zwischen 4.4 ka BP und 3.8 ka BP.*

Middle to the Late Holocene, as characterised by a general, global climate reorganisation due to insolation changes (e.g. Steig 1999). In the Mediterranean realm, this transition is characterised by the gradual change from a humid Middle Holocene Climate Optimum to a dryer Late Holocene (e.g. Rohling/Rijk 1999).

During the time window of interest (cf. Fig. 1; 2a), climate changes of a transitional yet often abrupt and very rapid character are especially observed in the western Mediterranean and adjacent regions. In general, this shift is characterised by a permanent transition towards a drier climate, as observed, for example, in an abrupt increase of natural fire activity in southern Iberia (Carrión et al. 2007), or in a decreased river runoff from southern Iberia (Fig. 2b). The apparently contradictory temperature pattern in the western Mediterranean Alboran Sea during the 4.2 ka BP event, where studies show either no significant change or a climate cooling (cf. Fig. 1), may be explained by the seasonal bias of the proxies. Here the alkenone-based temperature reconstruction (cf. Fig. 1, site 38) may report annual average or warm season temperatures, whereas the laser desorption ionisation (LDI)-based reconstructions may show cold season temperatures (Fig. 1, sites 41 and 42; Rodrigo-Gamiz et al. 2013). Furthermore, an increased winter storm activity has been reconstructed in the western Mediterranean, based on storm layer frequencies in a lagoonal sediment core (Fig. 1, site 40; Sabatier et al. 2012). As well as reduced rainfall, therefore, cold winters and, increased storm activity during the cold season may increased the difficulties faced by local societies around 4.2 ka BP in the western Mediterranean.

In contrast to the western Mediterranean pattern, the 4.2 ka BP event in the central Mediterranean region (Italy, Sicily, Adriatic Sea) manifests as a pronounced single excursion in the palaeoclimatic reconstructions (see e.g. Fig. 2d). A pronounced dry spell from 4.1 ka BP to 3.8 ka BP in North-Western Italy has been reconstructed from a calcite flowstone, based on stable isotope, trace element, and fluorescence data (Fig. 1, site 4; Drysdale et al. 2006). Similarly, reduced winter precipitation between 4.2 ka BP and 3.8 ka BP

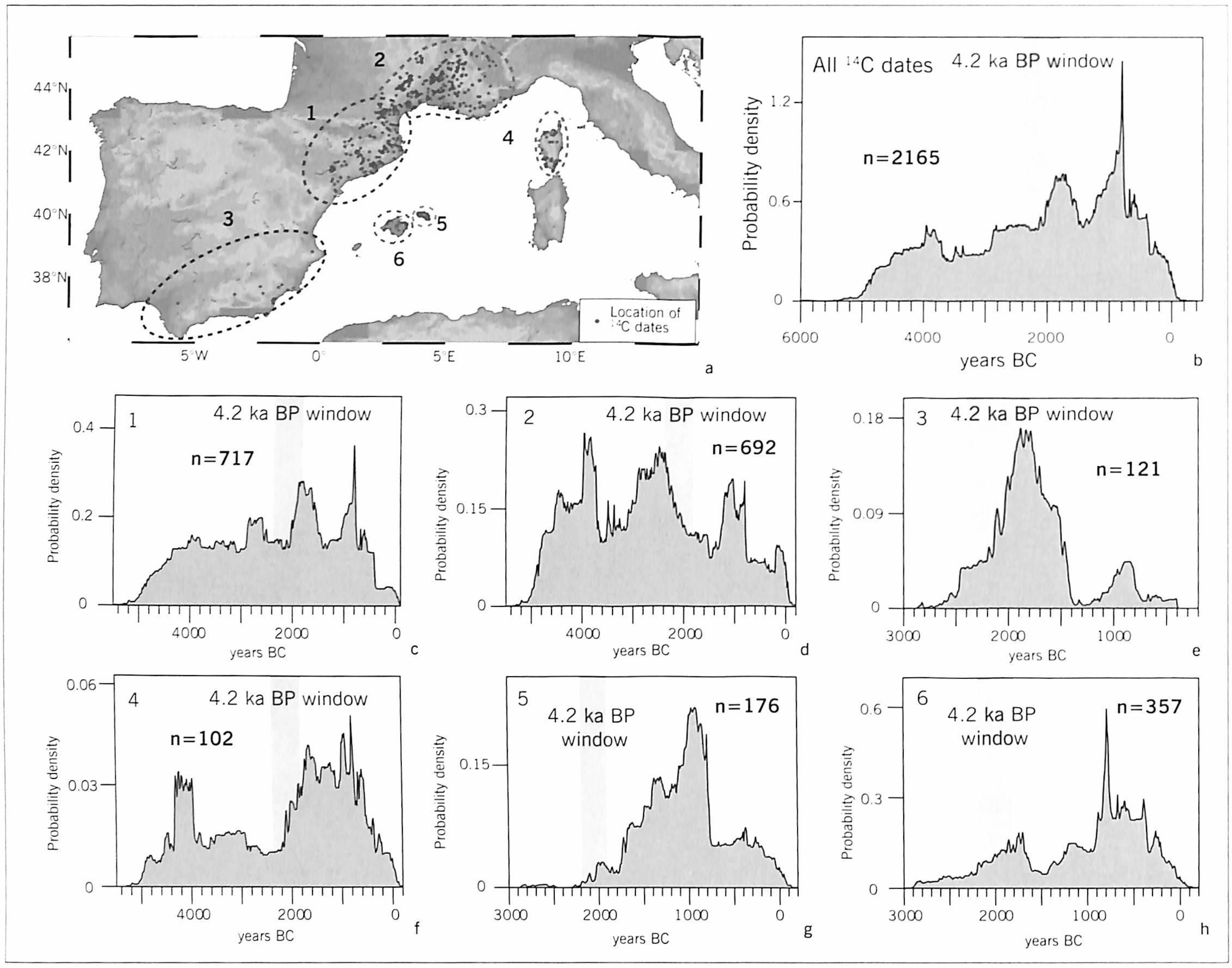


Fig. 3a–h Compiled archaeological ^{14}C data. a Map showing spatial distribution of all compiled ^{14}C data. Note that some locations contain more than one ^{14}C age. Different regions where individual sum-calibrations were performed are indicated and numbered. b Sum-calibration of all ^{14}C data (number = 2165); c sum-calibration of ^{14}C data from South-Eastern Spain and South-Western France (region number 1 on map; number = 717); d sum-calibration of ^{14}C data from South-Eastern France (region number 2 on map; number = 692); e sum-calibration of ^{14}C data from Southern Spain (region number 3 on map; number = 121); f sum-calibration of ^{14}C data from Corsica (region number 4 on map; number = 102); g sum-calibration of ^{14}C data from Minorca (region number 5 on map; number = 176); h sum-calibration of ^{14}C data from Majorca (region number 6 on map; number = 357). Blue vertical bar indicates the time window 4.4 ka BP to 3.8 ka BP, the same time window, which was investigated in the palaeoclimatic records.

Abb. 3a–h *Zusammenstellung archäologischer ^{14}C Daten. a Karte mit der Verbreitung aller ^{14}C Daten. Man beachte, dass von einigen Orten mehrere ^{14}C Daten vorliegen. In verschiedenen Regionen wurden einzelne Summenkalibrationen durchgeführt; diese sind eingekreist und nummeriert. b Summenkalibration aller ^{14}C Daten (Anzahl = 2165); c Summenkalibration der ^{14}C Daten aus Südostspanien und Südwestfrankreich (Region 1 auf der Karte; Anzahl = 717); d Summenkalibration der ^{14}C Daten aus Südostfrankreich (Region 2 auf der Karte; Anzahl = 692); e Summenkalibration der ^{14}C Daten aus Südspanien (Region 3 auf der Karte; Anzahl = 121); f Summenkalibration der ^{14}C Daten von Korsika (Region 4 auf der Karte; Anzahl = 102); g Summenkalibration der ^{14}C Daten von Menorca (Region 5 auf der Karte; Anzahl = 176); h Summenkalibration der ^{14}C Daten von Mallorca (Region 6 auf der Karte; Anzahl = 357). Der senkrechte blaue Bereich grenzt das Zeitfenster zwischen 4.4 ka BP und 3.8 ka BP ein. Dasselbe Zeitfenster wurde mithilfe der paläoklimatischen Daten untersucht.*

has been inferred from pollen counts from Lake Accesa in Central Italy (Fig. 1, site 11; Peyron et al. 2011). Although the low winter precipitation is accompanied by an increase in summer precipitation (Peyron et al. 2011), the 4.2 ka BP event at Lake Accesa has been identified as a non-season-specific short-term lake-level lowstand (see Magny et al. 2009). Therefore the net precipitation change seems to be negative. Furthermore, for the dry farming communities of the Mediterranean realm, changes in winter conditions (the season with the most precipitation) are potentially the most influential. Pronounced dryness along with strengthened southerly (African) winds between 4.4 ka BP and 3.8 ka BP have been reconstructed for Sicily, based on generally low arboreal pollen concentrations and the occurrence of North African pollen, respectively (Fig. 1, site 12; Tinner et al. 2009). Contrasting patterns of increased moisture availability, marking the alpine region in Northern Italy, have been reconstructed from various records (cf. Fig. 2), coinciding with increased pile construction activity on the part of resident lake dwelling communities.

Evidence for dryness in the Aegean region (cf. Fig. 1) is based on low $\partial^{13}C$ values of benthic foraminifers from the Aegean Sea between 4.4 ka BP and 4.0 ka BP, indicating a decreased runoff from the bordering landmasses in re sponse to decreased precipitation (Fig. 2e; Kuhnt et al. 2007), and on the sharp decrease of deciduous tree pollen in the borderlands of the Aegean Sea (Kotthoff et al. 2008). In the Black Sea region, too (cf. Fig. 1), a reduced frequency of clay layers between 4.25 ka BP and 3.90 ka BP in Black Sea sediment core GeoB 7622-2 (Fig. 1, site 44) indicates a reduced river runoff and hence reduced precipitation, at least in the southern borderlands of the Black Sea (Lamy et al. 2006).

Conventionally, the 4.2 ka BP event hypothesis has been proposed as an explanation for the potential collapse of Near Eastern and eastern Mediterranean societies (e.g. Weiss et al. 1993). Ever since, a growing body of evidence for extended drought in the region has emerged and an increasingly sharp and detailed picture of its magnitude and timing has been revealed by an array of independent proxy reconstructions. Our compilation once more underlines that the region became unambiguously drier at 4.2 ka BP (cf. Fig. 1). Underlying evidence includes quantitative estimates of precipitation change that show that the level of the Dead Sea dropped between 4.3 ka BP and 3.9 ka BP (Migowski et al. 2006) in response to a 50% reduction in rainfall (from 100 mm to 50 mm per year; Frumkin 2009). Reduced precipitation, related to a decline in monsoon activity, is also supported by reduced abundances of the benthic foraminifer *Uvigerina peregrina* between 4.2 ka BP and 3.8 ka BP in the Levantine Basin, indicating reduced Nile runoff (Fig. 2f; Schmiedl et al. 2010). Also, evidence for dry winds blowing from North Africa is found in the eastern basin (e.g. Box et al. 2008).

In summary, based on the compilation of circum-Mediterranean climate records, it can be inferred that the thoroughly investigated dry conditions at 4.2 ka BP found in the eastern Mediterranean[1], which are related to the collapse of eastern Mediterranean and Near Eastern societies (e.g. Bell 1971; Weiss et al. 1993; Weiss 2012), extend well into the western basin. However, although all the investigated climate records from the western Mediterranean and adjacent regions show considerable climate fluctuations that can be related to the 4.2 ka BP event, the low dating densities, dating inaccuracies, and/or uncertainties in the reservoir ages of the respective age models still hamper a conclusion concerning the exact timing and duration of the observed climate changes in this area.

Episodes of drought subsumed under the label »4.2 ka BP event« seem to have prevailed in the entire Mediterranean region, and could potentially have impacted on the economic stability of local societies owing to their inevitable influence on dryland farming (e.g. Lionello et al. 2006). The similar context of the so-called 8.2 ka BP event produced a well known drought in the eastern Mediterranean (Weninger et al. 2006). The climatic pattern observed in the (western) Mediterranean region, with humid conditions to the north and dry conditions to the south resembles, in various aspects, conditions found today during a positive NAO mode (strengthened westerly wind belt), as already noted by Magny et al. (2013) for the central Mediterranean area. Yet in our compilation, the boundary between dry and humid conditions is located at 45°N in the central Mediterranean rather than at the 40°N boundary proposed by Magny et al. (2013). In contrast to a well-defined 4.2 ka BP climatic »event« in the eastern and central Mediterranean, we observe a (rapid) climatic »transition« towards generally drier conditions in the western basin.

Severe winters with an increase in storm activity in the western Mediterranean around 4.2 ka BP may have posed an additional challenge to local societies. So far, scenarios of severe cooling in the western Mediterranean have been reconstructed and modelled for the Last Glacial Maximum and the millennial-scale Heinrich Events (e.g. Kageyama et al. 2001; Martrat et al. 2004; MARGO 2009). The question as to whether a similar bipartite pattern (warmer eastern and colder western Mediterranean) also prevailed during millennial-scale Holocene events (Bond events; Bond et al. 2001) and, in particular, the Bond event 3 that is linked to the 4.2 ka BP event cannot be solved here, but this should be considered as a potential scenario. Further research is needed to constrain the exact timing, duration, and magnitude of the 4.2 ka BP event in the western Mediterranean, and, in particular, to deduce seasonal changes that may have impacted on local ancient societies.

Population dynamics

Approach

Sum-calibrated ^{14}C ages of archaeological contexts have recently become a powerful proxy, which is increasingly employed to deduce changes in population density and/or human activities in a broader sense. So far, this approach has been applied to an array of European Neolithic to Bronze and Iron Age settings[2]. Arguably, a variety of shortcomings is inherent to this approach, including its failure to allow for the frequent ambiguity of the archaeological contexts of dated materials, for possible differences between natural vs. man-made signal carriers, for the uneven distribution of sampling in space and time, for possible differences between grave contexts vs. settlement and household contexts and for the nonlinearity of chronologies; its sensitivity to differential preservation and selective loss of materials; and, perhaps most important, its dependence on regional and temporal research intensity. A desirable random distribution is *per se* unachievable and, accordingly, the underlying data base is inevitably biased. These uncertain-

---

[1] Cullen et al. 2000; Stanley et al. 2003; Arz et al. 2006; Schmiedl et al. 2010.

[2] Shennan et al. 2013; Armit et al. 2014; Capuzzo et al. 2014; Balsera et al. 2015. This is not the place to discuss the method in full detail; however, there is a whole corpus of literature on the subject, see Armit et al. 2014; Buchanan et al. 2008; Collard et al. 2010; Gamble et al. 2005; Gkiasta et al. 2003; Hinz et al. 2012; Hoffmann et al. 2008; Johnstone et al. 2006; Kelly et al. 2013; Mulrooney 2013; Rick 1987; Riede 2009; Rieth et al. 2011; Shennan/Edinborough 2007; Shennan 2009; Shennan 2012; Tallavaara et al. 2010; Timpson et al. 2014; Whitehouse et al. 2014 in favour of the method, while Ballenger/Mabry 2011; Bamforth/Grund, 2012; Bayliss et al. 2007; Bleicher 2013; Chiverrell et al. 2011; Contreras/Meadows 2014; Crombé/Robinson 2014; Culleton 2008; Prates et al. 2013; Steele 2010; Williams 2012 take a critical approach.

ties require careful examination and filtering of the data sets, including pooling the data per site (i. e. each site will contribute then with the weight of 1 to the final sum calibration, irrespective of the number of ^{14}C samples taken) as well as crosschecking with independent quantitative population data. The main advantage of the approach clearly lies in the ever-increasing availability and quality of archaeological ^{14}C data and the statistical robustness of large data sets, the resulting absolute chronologies and the continuous nature of the records, where each single sample represents a two-dimensional record of a variable and time. Moreover the inherent independence of this proxy from regional archaeological settings allows the comparison of regional patterns for different cultural entities over wide distances, as well as the synchronisation of these patterns with patterns of environmental change. It is thus particularly well suited for exploring transitions in archaeology and past socio-environmental developments on a regional to supra-regional scale. For the south-eastern Iberian Peninsula, here represented by a relatively small data set (namely a subset limited to geo-referenced and published data), it certainly holds true that a strong focus on El Argar Culture has regionally biased the ^{14}C data base. In France, too, a strong research focus on the Neolithic period, including the Late Neolithic Bell Beaker phenomenon, may relatively underestimate the regional Early Bronze Age developments in Mediterranean France. Yet considering the multi-centennial scale of this study, such a bias must be of secondary significance and may even be advantageous, since at this scale even a highly restrictive research focus on a selected cultural unit will inevitably also reveal the lower and upper limits of its occupation, thus sharply depicting transitions to preceding and subsequent developments.

So far the RADON and RADON B data bases (Hinz et al. 2012; Kneisel et al. 2013) contain a total of >17 000 ^{14}C records. Spatially they cover Europe, and temporally they cover the Neolithic to Iron Age, but the spatio-temporal distribution of data is highly uneven, although steadily improving. For this reason, although only data displaying geo-references, and from safe archaeological contexts were included, the data set used in this study should be considered as a first approximation, since time-consuming filtering processes and definition of criteria are still under way.

A total of 2165 ^{14}C records, from the south-eastern and north-eastern Iberian Peninsula, Mediterranean France, the Balearic Islands and Corsica, met our criteria for use. The data set benefits in particular from data from existing data bases, including the Catalan data ^{14}C Catalunya Data Base[3] and the French data base, EUBAR.

Results

Sum calibrated ^{14}C data, based on a total of 2165 ^{14}C data records covering the south-east and north-east of the Iberian Peninsula, Mediterranean France, the Balearic Islands of Majorca and Menorca, and the Island of Corsica, display distinct patterns which may be tentatively interpreted in terms of changes in population density. On a regional scale, the single sequences show marked similarities as well as distinct differences. For the Late Copper Age, overall data (Fig. 3b) reveal a plateau of about 500 years' duration (4.8–4.3 ka BP), ending with a relative but subtle minimum around 4.2 ka BP, which marks the transition from the Copper to the Bronze Age and coincides with the climate event *sensu strictu*. Subsequently, in the second half of the broader interval where the climate transition is most likely to have occurred, a sharp increase is observed, suggesting a population boost which almost doubled the previous level of within less than 300 years. This peak is followed in turn by a rapid decline. Not surprisingly, a similar pattern is observed for north-eastern Iberia (Fig. 3c), which is represented by the largest random sample in the overall set (717 data, accounting for approx. one third of the total assemblage). A noteworthy difference in the north-eastern Iberian group (here also including the borderland of the French Pyrenees), as compared to the total assemblage, is, however, the Chalcolithic sequence, where a first population/activity maximum evolves between 4.8 ka BP and 4.4 ka BP. Subsequently values sharply decline and reach a minimum at 4.2 ka BP, prior to the general Early Bronze Age rise. This early peak is not observed in the other Iberian records, but is a dominant feature in the record of Mediterranean France (Fig. 3d). In south-eastern Iberia (Fig. 3e), after an initial rise, values remain stable and then rapidly almost triple immediately after 4.2 ka BP. A contemporary boost is also recorded on the Island of Corsica (Fig. 3f) and, though on very modest scale, on the Islands of Menorca and Majorca (Fig. 3g–h). In contrast, the record from Mediterranean France (Fig. 3d) reveals a very different and partially inverse course, with an earlier two-step boost occurring during the Chalcolithic, culminating as early as at 4.3 ka BP, and from then on steadily declining to reach its minimum by 3.8 ka BP.

Discussion

An Early Bronze Age population boost is thus jointly reported in all the regions considered, except for Mediterranean France, making it a very robust supra-regional feature. However, its magnitude varies greatly from region to region and evolves from different starting positions. Arguably, the patterns outlined above must be considered as preliminary, representing a working hypothesis while a proper filtering of the underlying database is pending, and should therefore be interpreted with caution. Yet the validity of a regional Early Bronze Age population boost is further supported by recent studies using the same proxy and based on a partially overlapping ^{14}C data base, as well as by independent evidence. Independent estimates of arable land and production evolution in south-eastern Iberia closely match the ^{14}C pattern (Fig. 4), supporting interpretations in terms of a boost in population. Accepted at face value, and within the

---

[3] See www.telearchaeology.org

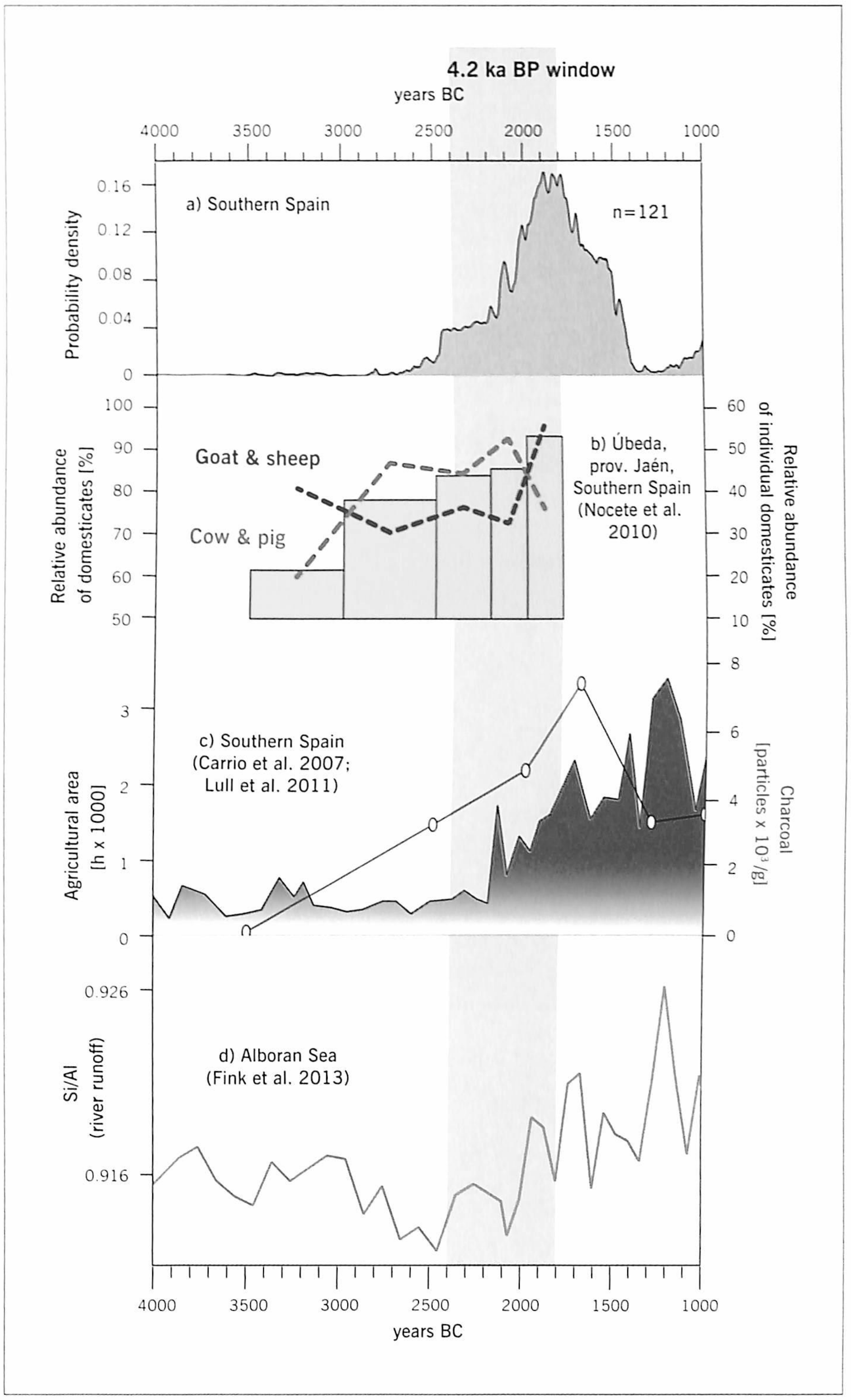


Fig. 4a–d Synthesis of socio-cultural and environmental (climatic) changes in southern Iberia. a Sum calibrated ^{14}C data from Southern Spain (this study, see Fig. 3); b subsistence changes record from Southern Spain (Úbeda, prov. Jaén) based on zooarchaeological remains; c modelled changes in the area used for agrarian activity in Southern Spain, and record of (natural) fire activity in the same region; d X-ray fluorescent (XRF) record from the Alboran Sea indicating river runoff from southern Iberia and hence precipitation.

Abb. 4a–d *Synthese der soziokulturellen und ökologischen (klimatischen) Veränderungen in Südiberien. a Summenkalibration der ^{14}C Daten aus Südspanien (vorliegende Untersuchung, s. Abb. 3); b Veränderungen in der Subsistenzgrundlage in Südspanien (Úbeda, Prov. Jaén) auf der Basis von archäozoologischen Überresten; c modellierte Veränderungen in den landwirtschaftlich genutzten Gebieten in Südspanien sowie Daten zu den (natürlichen) Brandereignissen in derselben Region; d Röntgenfluoreszenz-Daten vom Alborán-Meer, die auf Wasserabfluss und entsprechende Niederschlagsmengen in Südspanien hinweisen.*

dating accuracy of the climatic transition, they show that the south-eastern population, after a brief halt or decline, rose during a phase of obvious climate deterioration, characterised by dryness and probably more severe winter conditions (see above), demonstrating the efficiency of these societies in handling environmental change. The Late Copper Age sequences, in contrast, show highly diverse patterns, with individual regions peaking at different times. In North-Eastern Spain, an early boost may have been disrupted, at the onset of the drier climate conditions, for a 300 year period. It is thus very possible that the onset of a new climate regime, resulting in distinct environmental conditions, may initially have decelerated or delayed developments already under way.

V. Balsera et al. (2015) have pointed out a similar phenomenon, where regional differences in the progress of developments already initiated may be explained by differential environmental developments (i. e. the development of stone architecture settlements and ditched enclosures, which was disrupted in the south-east and here displaying a short-lived peak of c. 400 years throughout the middle of the 3rd millennium BC, but not in and south-west Iberia).

A collapse of the Late Copper Age population at 4.2 ka BP, which would be expected in a climate-deterministic view, is only weakly expressed in the overall data, if at all. This observation is again shared by Balsera et al. (2015), who invoke a more regional sequential »collapse« of Copper Age societies than hitherto assumed. We cannot decide whether the opposing trend in the Mediterranean French record, which shows steadily declining values after a Late Copper Age peak and lacks the Early Bronze Age peak, is due to a bias caused by lack of research interest, or in fact reflects a true population minimum during the Early Bronze Age and broad depopulation of the coastal zone. The latter interpretation is at least supported by the poor Early Bronze Age representation in the archaeobotanical subsistence record (Stika 2001; Kneisel et al. forthcoming). Here environmental conditions may have reached a threshold, but evidence to support such a scenario is so far also lacking in the regional climate and environmental records.

In the end it is not the climate itself that leads to the collapse or prosperity of a society; it is the breadth and efficiency of the strategies that society applies for coping with environmental change. Assuming that the proxy data for population development give us a tool to estimate the changes that those societies were subject to, then the next step is to compare the strategies deducible from the archaeological record to arrive at an explanation for the different trajectories.

Conclusions

Comparing climate and population patterns allows some tentative conclusions to be drawn, relating socio-environmental change with the 4.2 ka BP event in the western Mediterranean area:

The climate compilation yields a coherent pattern of drought, extending into the western Mediterranean and reaching as far north as 45° N. The interval of rapid change can be narrowed down to the period between 2200 BC and 2000 BC. The dating accuracy of western Mediterranean climate records is insufficient to allow for the reconstruction of a detailed sequence of events on a generational scale, which would require decadal time resolution.

Late Copper Age population growth was relatively slow, displaying a complex pattern at regional level. A discrete minimum marks the 4.2 ka BP event.

An Early Bronze Age population boost in the eastern Iberian Peninsula within dating accuracy of both population and climate records (starting from 2200 BC) coincided with, or was closely followed by, the rapid onset of a new climate regime, with generally drier conditions and probably cold winters and increased winter storm activity.

Inverse population patterns in Mediterranean France, displaying a population maximum in the Late Copper Age and gradually dwindling population data thereafter, are a so far unexplained.

The ^{14}C based patterns accord well with independent evidence of population evolution, including land use estimates and resource reconstructions, and lend further encouraging support to the ^{14}C proxy as a basis on which to reconstruct population density.

This article summarises the current state of an ongoing project. Although the dataset presented here may be regarded as preliminary, a seemingly robust pattern of archaeological and climatological patterns emerges from it. However, further work is needed, including expansion of the datasets, improvement of the chronologies, and statistical treatments (e.g. Monte Carlo Random Simulation), to validate the observed changes, especially in the western Mediterranean region.

Bibliography

Armit et al. 2014
I. Armit/G. T. Swindles/K. Becker/G. Plunkett/M. Blaauw, Rapid climate change did not cause population collapse at the end of the European Bronze Age. Proc. Nat. Acad. Scien. United States of Am. 111,48, 2014, 17045–17049, doi:10.1073/pnas.1408028111.

Arz et al. 2003
H. W. Arz/F. Lamy/J. Patzold/P. J. Muller/M. Prins, Mediterranean Moisture Source for an Early Holocene Humid Period in the Northern Red Sea. Science 300,5616, 2003, 118–121.

Arz et al. 2006
H. W. Arz/F. Lamy/J. Patzold, A pronounced dry event recorded around 4.2 ka in brine sediments from the northern Red Sea. Quaternary Research 66,3, 2006, 432–441, doi:10.1016/j.yqres.2006.05.006.

Ballenger/Mabry 2011
J. A. M. Ballenger/J. B. Mabry, Temporal frequency distributions of alluvium in the American Southwest: taphonomic, paleohydraulic, and demographic implications. Journal Arch. Scien. 38,6, 2011, 1314–1325, doi:10.1016/j.jas.2011.01.007.

Balsera et al. 2015
V. Balsera/J. Bernabeu Aubán/M. Costa Carame/P. Diaz Del Rio/L. Garcia Sanjuán/S. Pardo, The Radio Carbon Chronology of Southern Spain's Late Prehistory (5600–1000 cal BC): A Comparative Review. Oxford Journal Arch. 34,2, 2015, 139–156, doi:10.1111/ojoa.12053.

Bamforth/Grund 2007
D. B. Bamforth/B. Grund, Radiocarbon calibration curves, summed probability distributions, and early Paleoindian population trends in North America. Journal Arch. Scien. 39, 2012, 1768–1774, doi:10.1016/j.jas.2012.01.017.

Bar-Matthews et al. 2003
M. Bar-Matthews/A. Ayalon/M. Gilmour/A. Matthews/C. J. Hawkesworth, Sea–land oxygen isotopic relationships from planktonic foraminifera and speleothems in the Eastern Mediterranean region and their implication for paleorainfall during interglacial intervals. Geochimica et Cosmochimica Acta 67,17, 2003, 3181–3199.

Bayliss et al. 2007
A. Bayliss/C. Bronk Ramsey/J. van der Plicht/A. Whittle, Bradshaw and Bayes: Towards a Timetable for the Neolithic. Cambridge Arch. Journal 17, 2007, 1–28, doi:10.1017/S0959774307000145.

Bell 1971
B. Bell, The dark ages in ancient history I. The first Dark Age in Egypt. Am. Journal Arch. 75,1, 1971, 1–26, doi:10.2307/503678.

Bernárdez et al. 2008
P. Bernárdez/R. González-Alvarez/G. Francés/R. Prego/M. A. Bárcena/O. E. Romero, Late Holocene history of the rainfall in the NW Iberian peninsula evidence from a marine record. Journal Marine Systems 72, 2008, 366–382.

Bleicher 2013
N. Bleicher, Summed radiocarbon probability density functions cannot prove solar forcing of Central European lake level changes. The Holocene 23,5, 2013, 755–765, doi:10.1177/0959683612467478.

Björck et al. 2006
S. Björck/T. Rittenour/P. Rosen/Z. França/P. Moller/I. Snowball/S. Wastegård/O. Bennike/B. Kromer, A Holocene lacustrine record in the central North Atlantic: proxies for volcanic activity, short-term NAO mode variability, and long-term precipitation changes. Quaternary Scien. Rev. 25,1–2, 2006, 9–32, doi:10.1016/j.quascirev.2005.08.008.

Bond et al. 2001
G. Bond/B. Kromer/J. Beer/R. Muscheler/M. N. Evans/W. Showers/S. Hoffmann/R. Lotti-Bond/I. Hajdas/G. Bonani, Persistent solar influence on North Atlantic climate during the Holocene. Science 294,5549, 2001, 2130–2136, doi:10.1126/science.1065680.

Booth et al. 2005
R. K. Booth/S. T. Jackson/S. L. Forman/J. E. Kutzbach/E. A. Bettis III/J. Kreigs/D. K. Wright, A severe centennial-scale drought in midcontinental North America 4200 years ago and apparent global linkages. The Holocene 15,3, 2005, 321–328, doi:10.1191/0959683605hl825ft.

Box et al. 2008
M. R. Box/M. D. Krom/R. Cliff/A. Almogi-Labin/M. Bar-Matthews/A. Ayalon/B. Schillman/M. Paterne, Changes in the flux of Saharan dust to the East Mediterranean Sea since the last glacial maximum as observed through Sr-isotope geochemistry. Mineralogical Magazine 72,1, 2008, 307–311, doi:10.1180/minmag.2008.072.1.307.

Buchanan et al. 2008
B. Buchanan/M. Collard/K. Edinborough, Paleoindian demography and the extraterrestrial impact hypothesis. Proc. Nat. Acad. Scien. United States of Am. 105,33, 2008, 11651–11654, doi:10.1073/pnas.0803762105.

Buchvaldek et al. 2007
M. Buchvaldek/A. Lippert/L. Kosnar, Atlas zur Prähistorischen Archäologie Europas. Acta Inst. Prehist. Univ. Carolinae Pragensis. Praehistorica 27 (Prag 2007).

Cacho et al. 1999
I. Cacho/J. A. Flores/N. Shackleton, Dansgaard-Oeschger and Heinrich event imprints in Alboran Sea paleotemperatures. Paleoceanography 14,6, 1999, 698–705, doi:10.1029/1999PA900044.

Cacho et al. 2001
I. Cacho/J. O. Grimalt/M. Canals/L. Sbaffi/N. J. Shackleton/J. Schönfeld/R. Zahn, Variability of the western Mediterranean Sea surface temperature during the last 25,000 years and its connection with the Northern Hemisphere climatic changes. Paleoceanography 16,1, 2001, 40–52, doi:10.1029/2000PA000502.

Capuzzo et al. 2014
G. Capuzzo/E. Boaretto/J. A. Barceló, EUBAR: A Database of ^{14}C Measurements for the European Bronze Age. A Bayesian Analysis of ^{14}C-dated Archaeological Contexts from Northern Italy and Southern France. Radiocarbon 56,2, 2014, 851–869, doi:10.2458/56.17453.

Capuzzo 2014
G. Capuzzo, Space temporal analysis of radio carbon evidence and associated archaeological record: from Danube to Ebro Rivers and from Bronze to Iron Age. PhD thesis, Universidad Autonoma, Barcelona (Barcelona 2014). <http://hdl.handle.net/10803/283401> (16.06.2015).

Carrión et al. 2003
J. S. Carrión/P. Sánchez-Gómez/J. F. Mota/R. Yll/C. Chaín, Holocene vegetation dynamics, fire and grazing in the Sierra de Gádor, southern Spain. The Holocene 13,6, 2003, 839–849, doi:10.1191/0959683603hl662rp.

Carrión et al. 2007
J. S. Carrión/N. Fuentes/P. González-Sampériz/L. Sánchez Quirante/J. C. Finlayson/S. Fernández/A. Andrade, Holocene environmental change in a montane region of southern Europe with a long history of human settlement. Quaternary Scien. Rev. 26,11–12, 2007, 1455–1475, doi:10.1016/j.quascirev.2007.03.013.

Cheddadi et al. 1998
R. Cheddadi/H. F. Lamb/J. Guiot/S. Van Der Kaars, Holocene climatic change in Morocco: a quantitative reconstruction from pollen data. Climate Dynamics 14,12, 1998, 883–890.

Chiverrell et al. 2011
R. C. Chiverrell/V. R. Thorndycraft/T. O. Hoffmann, Cumulative probability functions and their role in evaluating the chronology of geomorphological events during the Holocene. Journal Quaternary Scien. 26,1, 2011, 76–85, doi:10.1002/jqs.1428.

Collard et al. 2010
M. Collard/K. Edinborough/S. Shennan/M. G. Thomas, Radiocarbon evidence indicates that migrants introduced farming to Britain. Journal Arch. Scien. 37,4, 866–870, 2010, doi:10.1016/j.jas.2009.11.016.

Constantin et al. 2007
S. Constantin/A.-V. Bojar/S.-E. Lauritzen/J. Lundberg, Holocene and Late Pleistocene climate in the sub-Mediterranean continental environment: A speleothem record from Poleva Cave (Southern Carpathians, Romania). Palaeogeography, Palaeoclimatology, Paleoecology 243,3–4, 2007, 322–338.

Contreras/Meadows 2014
D. A. Contreras/J. Meadows, Summed radiocarbon calibrations as a population proxy: a critical evaluation using a realistic simulation approach. Journal Arch. Scien. 52,4, 2014, 591–608, doi:10.1016/j.jas.2014.05.030.

Crombé/Robinson 2014
P. Crombé/E. Robinson, ^{14}C dates as demographic proxies in Neolithisation models of northwestern Europe: a critical assessment using Belgium and northeast France as a case-study. Journal Arch. Scien. 52, 2014, 558–566, doi:10.1016/j.jas.2014.02.001.

Cullen et al. 2000
H. M. Cullen/P. B. deMenocal/S. Hemming/G. Hemming/F. H. Brown/T. Guilderson/F. Sirocko, Climate change and the collapse of the Akkadian empire: Evidence from the deep sea. Geology 28,4, 2000, 379–382.

Culleton 2008
B. J. Culleton, Crude demographic proxy reveals nothing about Paleoindian population. Proc. Nat. Acad. Scien. United States of Am. 105,50, 2008, E111, doi:10.1073/pnas.0809092106.

Dalfes et al. 1997
H. N. Dalfes/G. Kukla/H. Weiss (eds.), Third millennium BC Climates Change and Old World Collapse. Proceedings of the NATO Advances Research Workshop on Third millennium BC climate Change and Old Word Collapse, held at Kemer, Turkey, September 19–24, 1994. NATO Advanced Stud. Inst. Ser. I: Global Environmental Change 49 (Berlin 1997).

Davis et al. 2003
B. A. S. Davis/S. Brewer/A. C. Stevenson/J. Guiot, The temperature of Europe during the Holocene reconstructed from pollen data. Quaternary Scien. Rev. 22,15–17, 2003, 1701–

1716, doi:10.1016/S0277-3791(03)00173-2.

Delgado-Raack/Risch forthcoming
S. Delgado-Raack/R. Risch, Social Change and Subsistence Production in the Iberian Peninsula during the 3rd and 2nd millennium BCE. In: J. Kneisel/W. Kirleis/M. Dal Corso/H. Scholz/N. Taylor/V. Tiedke (eds.), Setting the Bronze Age Table. Production, Subsistence, Diet and their Implications for European Landscapes. Proceedings of the International Workshop »Socio-Environmental Dynamics over the Last 12,000 Years: The Creation of Landscapes III« (15th–18th April 2011) in Kiel. Univforsch. Prähist. Arch. (Bonn forthcoming).

Di Rita/Magri 2009
F. Di Rita/D. Magri, Holocene drought, deforestation and evergreen vegetation development in the central Mediterranean: a 5500 year record from Lago Alimini Piccolo, Apulia, southeast Italy. The Holocene 19,2, 2009, 295–306.

Drăguşin et al. 2014
V. Drăguşin/M. Staubwasser/D. L. Hoffmann/V. Ersek/B. P. Onac/D. Veres, Constraining Holocene hydrological changes in the Carpathian-Balkan region using speleothem $\delta^{18}O$ and pollen-based temperature reconstructions. Climate of the Past 10, 2014, 381–427.

Drysdale et al. 2006
R. Drysdale/G. Zanchetta/J. Hellstrom/R. Maas/A. Fallick/M. Pickett/M. Cartwright/L. Piccini, Late Holocene drought responsible for the collapse of Old World civilizations is recorded in an Italian cave flowstone. Geology 34,2, 2006, 101–104, doi:10.1130/G22103.1.

Feurdean et al. 2008
A. Feurdean/S. Klotz/V. Mosbrugger/B. Wohlfarth, Pollen-based quantitative reconstructions of Holocene climate variability in NW Romania. Palaeogeography, Palaeoclimatology, Palaeocology 260,3–4, 2008, 494–504.

Fink et al. 2013
H. G. Fink/C. Wienberg/R. De Pol-Holz/P. Wintersteller/D. Hebbeln, Cold-water coral growth in the Alboran Sea related to high productivity during the Late Pleistocene and Holocene. Marine Geology 339, 2013, 71–82, doi:10.1016/j.margeo.2013.04.009.

Finné et al. 2011
M. Finné/K. Holmgren/H. S. Sundqvist/E. Weiberg/M. Lindblom, Climate in the eastern Mediterranean and adjacent regions, during the past 6000 years – A Review. Journal Arch. Scien. 38, 2011, 3153–3173, doi:10.1016/j.jas.2011.05.007.

Fletcher et al. 2007
W. J. Fletcher/T. Boski/D. Moura, Palynological evidence for environmental and climatic change in the lower Guadiana valley, Portugal, during the last 13 000 years. The Holocene 17.4, 2007, 481–494, doi:10.1177/0959683607077027.

Fohlmeister et al. 2013
J. Fohlmeister/N. Vollweiler/C. Spötl/A. Mangini, COMNISPA II: Update of a mid-European isotope climate record, 11 ka to present. The Holocene 23,5, 2013, 749–754.

Frigola et al. 2008
J. Frigola/A. Moreno/I. Cacho/M. Canals/F. J. Sierro/J. A. Flores/J. O. Grimalt, Evidence of abrupt changes in Western Mediterranean Deep Water circulation during the last 50kyr: A high-resolution marine record from the Balearic Sea. Quaternary Internat. 181,1, 2008, 88–104.

Frumkin 2009
A. Frumkin, Stable isotopes of a subfossil *Tamarix* tree from the Dead Sea region, Israel and their implications for the Intermediate Bronze Age environmental crisis. Quaternary Research 71,3, 2009, 319–328, doi:10.1016/j.yqres.2009.01.009.

Gamble et al. 2005
C. Gamble/W. Davies/P. Pettitt/L. Hazelwood/M. Richards, The Archaeological and Genetic Foundations of the European Population during the Late Glacial: Implications for »Agricultural Thinking«. Cambridge Arch. Journal 15, 2005, 193–223, doi:10.1017/S0959774305000107.

Geraga et al. 2010
M. Geraga/C. Ioakim/V. Lykousis/S. Tsaila-Monopolis/G. Mylona, The high-resolution palaeoclimatic and palaeoceanographic history of the last 24,000 years in the central Aegean Sea, Greece. Palaeogeography, Palaeoclimatology, Palaeoecology 287,1–4, 2010, 101–115.

Gkiasta et al. 2003
M. Gkiasta/T. Russell/S. Shennan/J. Steele, Neolithic transition in Europe: the radiocarbon record revisited. Antiquity 77,295, 2003, 45–62, doi:10.1017/S0003598X00061330.

Hamann et al. 2008
Y. Hamann/W. Ehrmann/G. Schmiedl/S. Krüger/J. B. Stuut/T. Kuhnt, Sedimentation processes in the Eastern Mediterranean Sea during the Late Glacial and Holocene revealed by end-member modelling of the terrigenous fraction in marine sediments. Marine Geology 248,1–2, 2008, 97–114.

Hassan 1986
F. A. Hassan, Holocene lakes and prehistoric settlements of the Western Faiyum, Egypt. Journal Arch. Science 13,5, 1986, 483–501.

Heiri/Lotter 2005
O. Heiri/A. F. Lotter, Holocene and Lateglacial summer temperature reconstruction in the Swiss Alps based on fossil assemblages of aquatic organisms: a review. Boreas 34,4, 2005, 506–516.

Hinz et al. 2012
M. Hinz/M. Furholt/J. Müller/D. Raetzel-Fabian/C. Rinne/K.-G. Sjörgen/H.-P. Wotzka, RADON – Radiocarbon dates online 2012. Central European database of ^{14}C dates for the Neolithic and Early Bronze Age. Journal Neolithic Arch. 14, 2012, <www.jungsteinsite.de> (16.06.2015).

Hoffmann et al. 2008
T. Hoffmann/A. Lang/R. Dikau, Holocene river activity: analysing ^{14}C-dated fluvial and colluvial sediments from Germany. Quaternary Scien. Rev. 27,21–22, 2008, 2031–2040, doi:10.1016/j.quascirev.2008.06.014.

Hurrell 1995
J. W. Hurrell, Decadal trends in the North Atlantic Oscillation: regional temperatures and precipitation. Science 269,5224, 1995, 676–679, doi:10.1126/science.269.5224.676.

Incarbona et al. 2008
A. Incarbona/E. Di Stefano/B. Patti/N. Pelosi/S. Bonomo/S. Mazzola/R. Sprovieri/G. Tranchida/S. Zgozi/A. Bonanno, Holocene millennial-scale productivity variations in the Sicily Channel (Mediterranean Sea). Paleoceanography 23, 2008.

IPCC 2013
International Panel on Climate Change 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Eds.: Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Cambridge, New York 2013).

IPCC 2014
International Panel on Climate Change 2014. Impacts, Adaption and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Eds.: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L. (Cambridge, New York 2014).

Jiménez-Moreno/Anderson 2012
G. Jiménez-Moreno/R. S. Anderson, Holocene vegetation and climate change recorded in alpine bog sediments from the Borreguiles de la Virgen, Sierra Nevada, southern Spain. Quaternary Research 77,1, 2012, 44–53.

Johnstone et al. 2006
E. Johnstone/M. G. Macklin/J. Lewin, The development and application of a database of radiocarbon-dated Holocene fluvial deposits in Great Britain. CATENA. Past Hydrological Events Related to Understanding Global Change 66,1–2, 2006, 14–23, doi:10.1016/j.catena.2005.07.006.

Kageyama et al. 2001
M. Kageyama/O. Peyron/S. Pinot/P. Tarasov/J. Guiot/S. Joussaume/G. Ramstein, The Last Glacial Maximum climate over Europe and western Siberia: a PMIP comparison between models and data. Climate Dynamics, 17,1, 2001, 23–43, doi:10.1007/s003820000095.

Kaniewski et al. 2008
D. Kaniewski/E. Paulissen/E. Van Campo/M. Al-Maqdissi/J. Bretschneider/K. Van Lerberghe, Middle East coastal ecosystem response to middle-to-late Holocene abrupt climate changes. Proc. Nat. Acad. Scien. 105,37, 2008, 13941–13946.

Kelly et al. 2013
R. L. Kelly/T. A. Surovell/B. N. Shuman/G. M. Smith, A continuous climatic impact on Holocene human population in the Rocky Mountains. Proc. Nat. Acad. Scien. United States of Am. 110,2, 2013, 443–447, doi:10.1073/pnas.1201341110.

Kim et al. 2004
J. Kim/N. Rimbu/S. Lorenz/G. Lohmann/S. Nam/S. Schouten/C. Rühlemann/R. Schneider, North Pacific and North Atlantic sea-surface temperature variability during the Holocene. Quaternary Scien. Rev. 23,20–22, 2004, 2141–2154, doi:10.1016/j.quascirev.2004.08.010.

Kneisel et al. 2013
J. Kneisel/M. Hinz/C. Rinne, RADON-B, 2013, <http://radon-b.ufg.uni-kiel.de> (18.06.2015).

Kneisel et al. forthcoming
J. Kneisel/W. Kirleis/M. Dal Corso/H. Scholz/N. Taylor/V. Tiedtke (eds.), Setting the Bronze Age Table. Production, Subsistence, Diet and their Implications for European Landscapes. Proceedings of the International Workshop »Socio-Environmental Dynamics over the Last 12,000 Years: The Creation of Landscapes III« (15th–18th April 2011) in Kiel. Univforsch. Prähist. Arch. (Bonn forthcoming).

Kotthoff et al. 2008
U. Kotthoff/U. C. Müller/J. Pross/G. Schmiedl/I. T. Lawson/B. van de Schootbrugge/H. Schulz, Lateglacial and Holocene vegetation dynamics in the Aegean region: an integrated view based on pollen data from marine and terrestrial archives. The Holocene 18, 2008, 1019–1032, doi:10.1177/0959683608095573.

Kremenetski 1995
C. V. Kremenetski, Holocene vegetation and climate history of southwestern Ukraine. Rev. Palaeobotany Palynology 85,3–4, 1995, 289–301.

Kuhnt et al. 2007
T. Kuhnt/G. Schmiedl/W. Ehrmann/Y. Hamann/C. Hemleben, Deep-sea ecosystem variability of the Aegean Sea during the past 22 kyr as revealed by Benthic Foraminifera. Marine Micropaleontology 64, 2007, 141–162, doi:10.1016/j.marmicro.2007.04.003.

Kuhnt et al. 2008
T. Kuhnt/G. Schmiedl/W. Ehrmann/Y. Hamann/N. Andersen, Stable isotopic composition of Holocene benthic foraminifers from the Eastern Mediterranean Sea: Past changes in productivity and deep water oxygenation. Palaeogeography Palaeoclimatology, Palaeoecology 268,1–2, 2008, 106–115.

Kuzucuoğlu et al. 2011
C. Kuzucuoğlu/W. Dörfler/S. Kunesch/F. Goupille, Mid- to late Holocene climate change in central Turkey: The Tecer Lake record. The Holocene 21,1, 2011, 173–188.

Kwiecien et al. 2008
O. Kwiecien/H. W. Arz/F. Lamy/S. Wulf/A. Bahr/U. Röhl/G. H. Haug, Estimated reservoir ages of the Black Sea since the last glacial. Radiocarbon 50,1, 2008, 99–118.

Lamy et al. 2006
F. Lamy/H. W. Arz/G. C. Bond/A. Bahr/J. Pätzold, Multicentennial-scale hydrological changes in the Black Sea and northern Red Sea during the Holocene and the Arctic/North Atlantic Oscillation. Paleoceanography 21,1, 2006, doi:10.1029/2005PA001184.

Lemcke/Sturm 1997
G. Lemcke/M. Sturm, Trace element measurements as proxy for the reconstruction of climate changes at Lake Van (Turkey): preliminary results. In: H. N. Dalfes/G. Kukla/H. Weiss (eds.), Third Millennium BC Climate Change and Old World Collapse. Proceedings of the NATO Advanced Research Workshop on Third Millennium BC Abrupt Climate Change and Old World Social Collapse, held at Kemer, Turkey, September 19–24, 1994. NATO Advanced Stud. Inst. Ser. I: Global Environmental Change 49 (Berlin 1997) 653–678.

Lemercier et al. 2014
O. Lemercier/R. Furestier/R. Gadbois-Langevin/B. Schulz Paulsson, Chronologie et periodisation des campaniformes en France méditerranéenne. In: I. Sénépart/F. Leandri/J. Cauliez/T. Perrin/E. Thirault (eds.), Chronologie de la Préhistoire récente dans le sud de la France: Acquis 1992–2012. Actualité de la recherche. Actes des 10^{e} Rencontres Méridionales de Préhistoire Récente (Porticcio, 18–20 octobre 2012) (Toulouse 2014), 175–195.

Lemmen/Wirtz 2012
C. Lemmen/K. W. Wirtz, Simulated climatically disturbed emergence of agricultures in Western Eurasia 8500–3000 BC. doi:10.1594/PANGAEA.779660.

Lionello et al. 2006
P. Lionello/P. Malanotte-Rizzoli/R. Boscolo (eds.), Mediterranean Climate Variability. Developments Earth Environmental Scien. 4 (Amsterdam, Oxford 2006).

Litt et al. 2012
T. Litt/C. Ohlwein/F. H. Neumann/A. Hense/M. Stein, Holocene climate variability in the Levant from the Dead Sea pollen record. Quaternary Scien. Rev. 49, 2012, 95–105.

Lull et al. 2011
V. Lull/R. Micó/C. Rihuete Herrada/R. Risch, El Argar and the Beginning of Class Society in the Western Mediterranean. In: S. Hansen/J. Müller (eds.), Sozialarchäologische Perspektiven. Gesellschaftlicher Wandel 5000–1500 v. Chr. zwischen Atlantik und Kaukasus. Internationale Tagung 15.–18. Oktober 2007 in Kiel. Arch. Eurasien 24 (Darmstadt 2011) 381–415.

Magny et al. 2009
M. Magny/B. Vannière/G. Zanchetta/E. Fouache/G. Touchais/L. Petrika/C. Coussot/A. V. Walter-Simonnet/F. Arnaud, Possible complexity of the climatic event around 4300–3800 cal. BP in the central and western Mediterranean. The Holocene 19,6, 2009, 823–833, doi:10.1177/0959683609337360.

Magny et al. 2013
M. Magny/N. Combourieu-Nebout/J. L. de Beaulieu/V. Bout-Roumazeilles/D. Colombaroli/S. Desprat/A. Francke/S. Joannin/E. Ortu/O. Peyron/M. Revel/L. Sadori/G. Siani/M. A. Sicre/S. Samartin/A. Simonneau/W. Tinner/B. Vannière/B. Wagner/G. Zanchetta/F. Anselmetti/E. Brugiapaglia/E. Chapron/M. Debret/M. Desmet/J. Didier/L. Essallami/D. Galop/A. Gilli/J. N. Haas/N. Kallel/L. Millet/A. Stock/J. L. Turon/S. Wirth, North–south palaeohydrological contrasts in the central Mediterranean during the Holocene: tentative synthesis and working hypotheses. Climate of the Past 9, 2013, 2043–2071, doi:10.5194/cp-9-2043-2013.

Marino et al. 2009
G. Marino/E. J. Rohling/F. Sangiorgi/A. Hayes/J. L. Casford/A. F. Lotter/M. Kucera/H. Brinkhuis, Early and middle Holocene in the Aegean Sea: interplay between high and low latitude climate variability. Quaternary Scien. Rev. 28,27–28, 2009, 3246–3262, doi:10.1016/j.quascirev.2009.08.011.

MARGO 2009
MARGO Project members, Constraints on the magnitude and patterns of ocean cooling at the Last Glacial Maximum. Nature Geoscience 2, 2009, 127–132, doi:10.1038/ngeo411.

Martínez-Cortizas et al. 1999
A. Martínez-Cortizas/X. Pontedevedra-Pombal/E. García-Rodeja/J. C. Nóvoa-Muñoz/W. Shotyk, Mercury in a Spanish peat bog archive of climate change and atmospheric metal deposition. Science 284,5416, 1999, 939–942.

Martrat 2004
B. Martrat/J. O. Grimalt/C. Lopez-Martinez/I. Cacho/F. J. Sierro/J. A. Flores/R. Zahn/M. Canals/J. H. Curtis/D. A. Hodell, Abrupt Temperature Changes in the Western Mediterranean over the Past 250,000 Years. Science 306,5702, 2004, 1762–1765, doi:10.1126/science.1101706.

Migowski et al. 2006
C. Migowski/M. Stein/S. Prasad/J. F. W. Negendank/A. Agnon, Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. Quaternary Research 66, 2006, 421–431.

Moreno et al. 2004
A. Moreno/I. Cacho/M. Canals/J. O. Grimalt/A. Sanchez-Vidal, Millennial-scale variability in the productivity signal from the Alboran Sea record, Western Mediterranean Sea. Palaeogeography Palaeoclimatology, Palaeoecology 211,3, 2004, 205–219.

Mulrooney 2013
M. A. Mulrooney, An island-wide assessment of the chronology of settlement and land use on Rapa Nui (Easter Island) based on radiocarbon data. Journal Arch. Scien. 40,12, 2013, 4377–4399, doi:10.1016/j.jas.2013.06.020.

Nocete et al. 2010
F. Nocete/R. Lizcano/A. Peramo/E. Gomez, Emergence, collapse and continuity of the first political system in the Guadalquivir Basin from the fourth to the second millennium BC: The long-term sequence of Ubeda (Spain). Journal Anthr. Arch. 29,2, 2010, 219–237, doi:10.1016/j.jaa.2010.03.001.

Onac et al. 2002
B. P. Onac/S. Constantin/J. Lundberg/S. E. Lauritzen, Isotopic climate record in a Holocene stalagmite from Urşilor Cave Romania. Journal Quaternary Scien. 17,4, 2002, 319–327.

Pena et al. 2010
L. D. Pena/G. Francés/P. Diz/M. Esparza/J. O. Grimalt/M. A. Nombela/I. Alejo, Climate fluctuations during the Holocene in NW Iberia High and low latitude linkages. Continental Shelf Research 30, 2010, 1487–1496.

Pérez-Folgado et al. 2003
M. Pérez-Folgado/F. J. Sierro/J. A. Flores/I. Cacho/J. O. Grimalt/R. Zahn/N. Shackleton, Western Mediterranean planktonic foraminifera events and millennial climatic variability during the last 70 kyr. Marine Micropaleontology 48,1–2, 2003, 49–70.

Pérez-Obiol et al. 2011
R. Pérez-Obiol/G. Jalut/R. Julià/A. Pèlachs/M. J. Iriarte/T. Otto/B. Hernández-Beloqui, Mid-Holocene vegetation and climatic history of the Iberian Peninsula. The Holocene, 21, 2011, 75–93, doi:10.1177/0959683610384161.

Pérez-Sanz et al. 2013
A. Pérez-Sanz/P. González-Sampériz/A. Moreno/B. Valero-Garcés/G. Gil-Romera/M. Rieradevall/P. Tarrats/L. Lasheras-Álvarez/M. Morellón/A. Belmonte/C. Sancho/M. Sevilla-Callejo/A. Navas, Holocene climate variability, vegetation dynamics and fire regime in the central Pyrenees: the Basa de la Mora sequence (NE Spain). Quaternary Scien. Rev. 73, 2013, 149–169.

Peyron et al. 2011
O. Peyron/S. Goring/I. Dormoy/U. Kotthoff/J. Pross/J. L. De Beaulieu/R. Drescher-Schneider/N. Vanniere/M. Magny, Holocene seasonality changes in the central Mediterranean region reconstructed from the pollen sequences of Lake Accesa (Italy) and Tenaghi Philippon (Greece). The Holocene 21,1, 2011, 131–146, doi:10.1177/0959683610384162.

Piva et al. 2008
A. Piva/A. Asioli/F. Trincardi/R. R. Schneider/L. Vigliotti, Late-Holocene climate variability in the Adriatic Sea (Central Mediterranean). The Holocene 18,1, 2008, 153–167.

Prates et al. 2013
L. Prates/G. Politis/J. Steele, Radiocarbon chronology of the early human occupation of Argentina. Quaternary Internat. 301, 2013, 104–122, doi:10.1016/j.quaint.2013.03.011.

Repschläger et al. 2015
J. Repschläger/M. Weinelt/H. Kinkel/N. Andersen/D. Garbe-Schönberg/C. Schwab, Response of the central subtropical North Atlantic surface hydrography on Deglacial and Holocene AMOC changes. Paleoceaonography, 30,5, 2015, 456–476, doi:10.1002/2014PA002637.

Rick 1987
J. W. Rick, Dates as Data: An Examination of the Peruvian Preceramic Radiocarbon Record. Am. Ant. 52, 1987, 55–73, doi:10.2307/281060.

Riede 2009
F. Riede, Climate and Demography in Early Prehistory: Using Calibrated ^{14}C Dates as Population Proxies. Human Biology 81,2–3, 2009, 309–337, doi:10.3378/027.081.0311.

Riehl et al. 2008
S. Riehl/R. Bryson/K. Pustovoytov, Changing growing conditions for crops during the Near Eastern Bronze Age (3000–1200 BC): the stable carbon isotope evidence. Journal Arch. Scien. 35,4, 2008, 1011–1022.

Rieth et al. 2011
T. M. Rieth/T. L. Hunt/C. Lipo/J. M. Wilms

hurst, The 13th century polynesian colonization of Hawai'i Island. Journal Arch. Scien. 38,10, 2011, 2740–2749, doi:10.1016/j.jas.2011.06.017.

Rimbu et al. 2004
N. Rimbu/G. Lohmann/S. J. Lorenz/J. H. Kim/R. R. Schneider, Holocene climate variability as derived from alkenone sea surface temperature and coupled ocean-atmosphere model experiments. Climate Dynamics 23,2, 2004, 215–227, doi:10.1007/s00382-004-0435-8.

Roberts et al. 2008
N. Roberts/M. D. Jones/A. Benkaddour/W. J. Eastwood/M. L. Filippi/M. R. Frogley/H. F. Lamb/M. J. Leng/J. M. Reed/M. Stein/L. Stevens/B. Valero-Garcés/G. Zanchetta, Stable isotope records of Late Quaternary climate and hydrology from Mediterranean lakes: the ISOMED synthesis. Quaternary Scien. Rev. 27,25–26, 2008, 2426–2441.

Roberts et al. 2011
N. Roberts/W. J. Eastwood/C. Kuzucuoğlu/G. Fiorentino/V. Caracuta, Climatic, vegetation and cultural change in the eastern Mediterranean during the mid-Holocene environmental transition. The Holocene 21,1, 2011, 147–162.

Rodrigo-Gámiz et al. 2011
M. Rodrigo-Gámiz/F. Martínez-Ruiz/F. J. Jiménez-Espejo/D. Gallego-Torres/V. Nieto-Moreno/O. Romero/D. Ariztegui, Impact of climate variability in the western Mediterranean during the last 20,000 years: oceanic and atmospheric responses. Quaternary Scien. Rev. 30,15–16, 2011, 1–17.

Rodrigo-Gámiz et al. 2013
M. Rodrigo-Gámiz/F. Martinez-Ruiz/S. W. Rampen/S. Schouten/J. S. Sinninghe Damste, Sea surface temperature variations in the western Mediterranean Sea over the last 20 kyr: a dual-organic proxy ($U^{K'}_{37}$ and LDI) approach. Paleoceanography 29,2, 2013, 87–98, doi:10.1002/2013PA002466.

Rogers 1997
J. C. Rogers, North Atlantic Storm Track Variability and Its Association to the North Atlantic Oscillation and Climate Variability of Northern Europe. Journal Climate 10, 1635–1647, doi:10.1175/1520-0442(1997)010<1635:NASTVA>2.0.CO;2.

Rohling/De Rijk 1999
E. J. Rohling/S. De Rijk, Holocene Climate Optimum and Last Glacial Maximum in the Mediterranean: the marine oxygen isotope record. Marine Geology 153,1–4, 1999, 57–75, doi:10.1016/S0025-3227(98)00020-6.

Sabatier et al. 2012
P. Sabatier/L. Dezileau/C. Colin/L. Briqueu/F. Bouchette/P. Martinez/G. Siani/O. Raynal/U. v. Grafenstein, 7000 years of paleostorm activity in the NW Mediterranean Sea in response to Holocene climate events. Quaternary Research 77,1, 2012, 1–11, doi:10.1016/j.yqres.2011.09.002.

Sadori et al. 2011
L. Sadori/S. Jahns/O. Peyron, Mid-Holocene vegetation history of the central Mediterranean. The Holocene 21,1, 2011, 117–129.

Sbaffi et al. 2004
L. Sbaffi/F. C. Wezel/G. Curzi/U. Zoppi, Millennial- to centennial-scale palaeoclimatic variations during Termination I and the Holocene in the central Mediterranean Sea. Global Planetary Change 40,1–2, 2004, 201–217.

Schmiedl et al. 2010
G. Schmiedl/T. Kuhnt/W. Ehrmann/K.-H. Emeis/Y. Hamann/U. Kotthoff/P. Dulski/J. Pross, Climatic forcing of eastern Mediterranean deep-water formation and benthic ecosystems during the past 22 000 years. Quaternary Scien. Rev. 29,23–24, 2010, 3006–3020, doi:10.1016/j.quascirev.2010.07.002.

Schmidt et al. 2000
R. Schmidt/J. Müller/R. Drescher-Schneider/R. Krisai/K. Szeroczynska/A. Barić, Changes in lake level and trophy at Lake Vrana, a large karstic lake on the Island of Cres (Croatia), with respect to palaeoclimate and anthropogenic impacts during the last approx. 16,000 years. Journal Limnology 59,2, 2000, 113–130.

Schmidt et al. 2002
R. Schmidt/K. A. Koinig/R. Thompson/C. Kamenik, A multi proxy core study of the last 7000 years of climate and alpine land-use impacts on an Austrian mountain lake (Unterer Landschitzsee, Niedere Tauern). Palaeogeography, Palaeoclimatology, Palaeoecology 187,1–2, 2002, 101–120.

Shennan 2009
S. Shennan, Evolutionary Demography and the Population History of the European Early Neolithic. Human Biology 81,2–3, 2009, 339–355, doi:10.3378/027.081.0312.

Shennan 2012
S. Shennan, Demographic Continuities and Discontinuities in Neolithic Europe: Evidence, Methods and Implications. Journal Arch. Method Theory 20,2, 2012, 300–311, doi:10.1007/s10816-012-9154-3.

Shennan/Edinborough 2007
S. Shennan/K. Edinborough, Prehistoric population history: from the Late Glacial to the Late Neolithic in Central and Northern Europe. Journal Arch. Scien. 34,8, 2007, 1339–1345, doi:10.1016/j.jas.2006.10.031.

Shennan et al. 2013
S. Shennan/A. Timpson/K. Edinborough/S. Colledge/T. Kerig/K. Manning/M. G. Thomas/S. S. Downey, Regional population collapse followed initial agriculture booms in mid-Holocene Europe. Nature Commun. 4, 2013, 1–8, doi:10.1038/ncomms3486.

Siani 2001
G. Siani, Mediterranean Sea Surface Radiocarbon Reservoir Age Changes Since the Last Glacial Maximum. Science 294,5548, 2001, 1917–1920, doi:10.1126/science.1063649.

Sperling et al. 2003
M. Sperling/G. Schmiedl/C. Hemleben/K. C. Emeis/H. Erlenkeuser/P. M. Grootes, Black Sea impact on the formation of eastern Mediterranean sapropel S1? Evidence from the Marmara Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 190, 2003, 9–21.

Stanley et al. 2003
J. D. Stanley/M. D. Krom/R. A. Cliff/J. C. Woodward, Short contribution: Nile flow failure at the end of the Old Kingdom, Egypt: Strontium isotopic and petrologic evidence. Geoarchaeology 18,3, 2003, 395–402, doi:10.1002/gea.10065.

Steele 2010
J. Steele, Radiocarbon dates as data: quantitative strategies for estimating colonization front speeds and event densities. Journal Arch. Scien. 37,8, 2010, 2017–2030, doi:10.1016/j.jas.2010.03.007.

Steig 1999
E. J. Steig, Mid-Holocene climate change. Science 286,5444, 1999, 1485–1487, doi:10.1126/science.286.5444.1485.

Stika 2001
H.-P. Stika, Archäobotanische Ergebnisse der Grabungskampagne 1988 in Fuente Álamo. In: H. Schubart/V. Pingel/O. Arteaga (eds.), Fuente Alamo Teil 1. Die Grabungen von 1977 bis 1991 in einer bronzezeitlichen Höhensiedlung Andalusiens. Madrider Beitr. 25 (Mainz 2001) 263–336.

Tallavaara et al. 2010
M. Tallavaara/P. Pesonen/M. Oinonen, Prehistoric population history in eastern Fennoscandia. Journal Arch. Scien. 37,2, 2010, 251–260, doi:10.1016/j.jas.2009.09.035.

Timpson et al. 2014
A. Timpson/S. Colledge/E. Crema/K. Edinborough/T. Kerig/K. Manning/M. G. Thomas/S. Shennan, Reconstructing regional population fluctuations in the European Neolithic using radiocarbon dates: a new case study using an improved method. Journal Arch. Scien. 52, 2014, 549–557, doi:10.1016/j.jas.2014.08.011.

Tinner et al. 2009
W. Tinner/J. F. N. van Leeuwen/D. Colombaroli/E. Vescovi/W. O. van der Knaap/P. D. Henne/S. Pasta/S. D. Angelo/T. La Mantia, Holocene environmental and climatic changes at Gorgo Basso, a coastal lake in southern Sicily, Italy. Quaternary Scien. Rev. 28,15–16, 2009, 1498–1510, doi:10.1016/j.quascirev.2009.02.001.

Triantaphyllou et al. 2009
M. V. Triantaphyllou/A. Antonarakou/M. Dimiza/C. Anagnostou, Calcareous nannofossil and planktonic foraminiferal distributional patterns during deposition of sapropels S6, S5 and S1 in the Libyan Sea (Eastern Mediterranean). Geo Marine Letters 30,1, 2009, 1–13.

Trigo et al. 2004
R. M. Trigo/D. P. Vázquez/T. J. Osborn, North Atlantic Oscillation influence on precipitation, river flow and water resources in the Iberian Peninsula. Internat. Journal Climatology 24,8, 2004, 925–944, doi:10.1002/joc.1048.

Vannière et al. 2013
B. Vannière/M. Magny/S. Joannin/A. Simonneau/S. B. Wirth/Y. Hamann/E. Chapron/A. Gilli/M. Desmet/F. S. Anselmetti, Orbital changes, variation in solar activity and increased anthropogenic activities: controls on the Holocene flood frequency in the Lake Ledro area, Northern Italy. Climate of the Past 9, 2013, 1193–1209.

Verleye et al. 2009
T. J. Verleye/K. N. Mertens/S. Louwye/H. W. Arz, Holocene salinity changes in the southwestern Black Sea: a reconstruction based on dinoflagellate cysts. Palynology 33,1, 2009, 77–100.

Volkov/Fu 2010
D. L. Volkov/L. L. Fu, On the Reasons for the Formation and Variability of the Azores Current. Journal Physical Oceanography 40,10, 2010, 2197–2220, doi:10.1175/2010JPO4326.1.

Wagner et al. 2009
B. Wagner/A. F. Lotter/N. Nowaczyk/J. M. Reed/A. Schwalb/R. Sulpizio/V. Valsecchi/M. Wessels/G. Zanchetta, A 40,000 year record of environmental change from ancient Lake Ohrid (Albania and Macedonia). Journal Paleolimnology 41,3, 2009, 407–430.

Weiss 2012
H. Weiss, The Northern Levant During the Intermediate Bronze Age: Altered Trajectories. In: A. E. Killebrew/M. L. Steiner (eds.), The Oxford Handbook of the Archaeology of the Levant: c. 8000–332 BCE (Oxford 2013).

Weiss et al. 1993
H. Weiss/M. A. Courty/W. Wetterstrom/F. Guichard/L. Senior/R. Meadow/A. Curnow, The Genesis and Collapse of Third Millennium North Mesopotamian Civilization. Science 261,5124, 1993, 995–995, doi:10.1126/science.261.5124.995.

Weninger et al. 2006
B. Weninger/E. Alram-Stern/E. Bauer/L. Clare/

U. Danzeglocke/O. Joris/C. Kubatzki/G. Rollefson/H. Todorova/T. van Andel, Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. Quaternary Research 66,3, 2006, 401–420, doi:10.1016/j.yqres.2006.06.009.

Weninger et al. 2009
B. Weninger/L. Clare/E. J. Rohling/O. Bar-Yosef/U. Bohner/M. Budja/M. Bundschuh/A. Feurdean/H.-G. Gebel/O. Joris/J. Linstadter/P. Mayewski/T. Muhlenbruch/A. Reingruber/G. Rollefson/D. Schyle/L. Thissen/H. Todorova/C. Zielhofer, The impact of rapid climate change on prehistoric societies during the Holocene in the Eastern Mediterranean. Doc. Praehist. 36, 2009, 7–59, doi:10.4312/dp.36.2.

Whitehouse et al. 2014
N. J. Whitehouse/R. J. Schulting/M. McClatchie/P. Barratt/T. R. McLaughlin/A. Bogaard/S. Colledge/R. Marchant/J. Gaffrey/M. J. Bunting, Neolithic agriculture on the European western frontier: the boom and bust of early farming in Ireland. Journal Arch. Scien. 51, 2014, 181–205, doi:10.1016/j.jas.2013.08.009.

Wick et al. 2003
L. Wick/G. Lemcke/M. Sturm, Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: high-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey. The Holocene 13,5, 2003, 665–675.

Williams 2012
A. N. Williams, The use of summed radiocarbon probability distributions in archaeology: a review of methods. Journal Arch. Scien. 39,3, 2012, 578–589, doi:10.1016/j.jas.2011.07.014.

Zanchetta et al. 2007
G. Zanchetta/R. N. Drysdale/J. C. Hellstrom/A. E. Fallick/I. Isola/M. K. Gagan/M. T. Pareschi, Enhanced rainfall in the Western Mediterranean during deposition of sapropel S1: stalagmite evidence from Corchia cave (Central Italy). Quaternary Scien. Rev. 26,3–4, 2007, 279–286.

Zimmermann 2012
A. Zimmermann, Cultural cycles in Central Europe during the Holocene. Quaternary Internat. 274, 2012, 251–258, doi:10.1016/j.quaint.2012.05.014.

Ziv et al. 2004
B. Ziv/H. Saaroni/P. Alpert, The factors governing the summer regime of the eastern Mediterranean. Internat. Journal Climatology 24,14, 2004, 1859–1871, doi:10.1002/joc.1113.

Source of figures

1 authors
2 a Repschlager et al. 2015; b Fink et al. 2013; c Frigola et al. 2008; d Tinner et al. 2009; e Kuhnt et al. 2007; f Schmiedl et al. 2010
3 authors; data from the RADON and RADON B databases
4 authors; a data from RADON and RADON B databases; b Nocete et al. 2010; c Lull et al. 2011; Carrion et al. 2007; d Fink et al. 2013
Tab. 1 authors
Appendix 1 authors

Addresses

PD Dr. Mara Weinelt
Christian-Albrechts-Universität Kiel
Institut für Ur- und Frühgeschichte
Johanna-Mestorf-Str. 2–6
24118 Kiel
Germany
mweinelt@gshdl.uni-kiel.de

Dr. Martin Hinz
Christian-Albrechts-Universität Kiel
Institut für Ur- und Frühgeschichte
Johanna-Mestorf-Str. 2–6
24118 Kiel
Germany
martin.hinz@ufg.uni-kiel.de

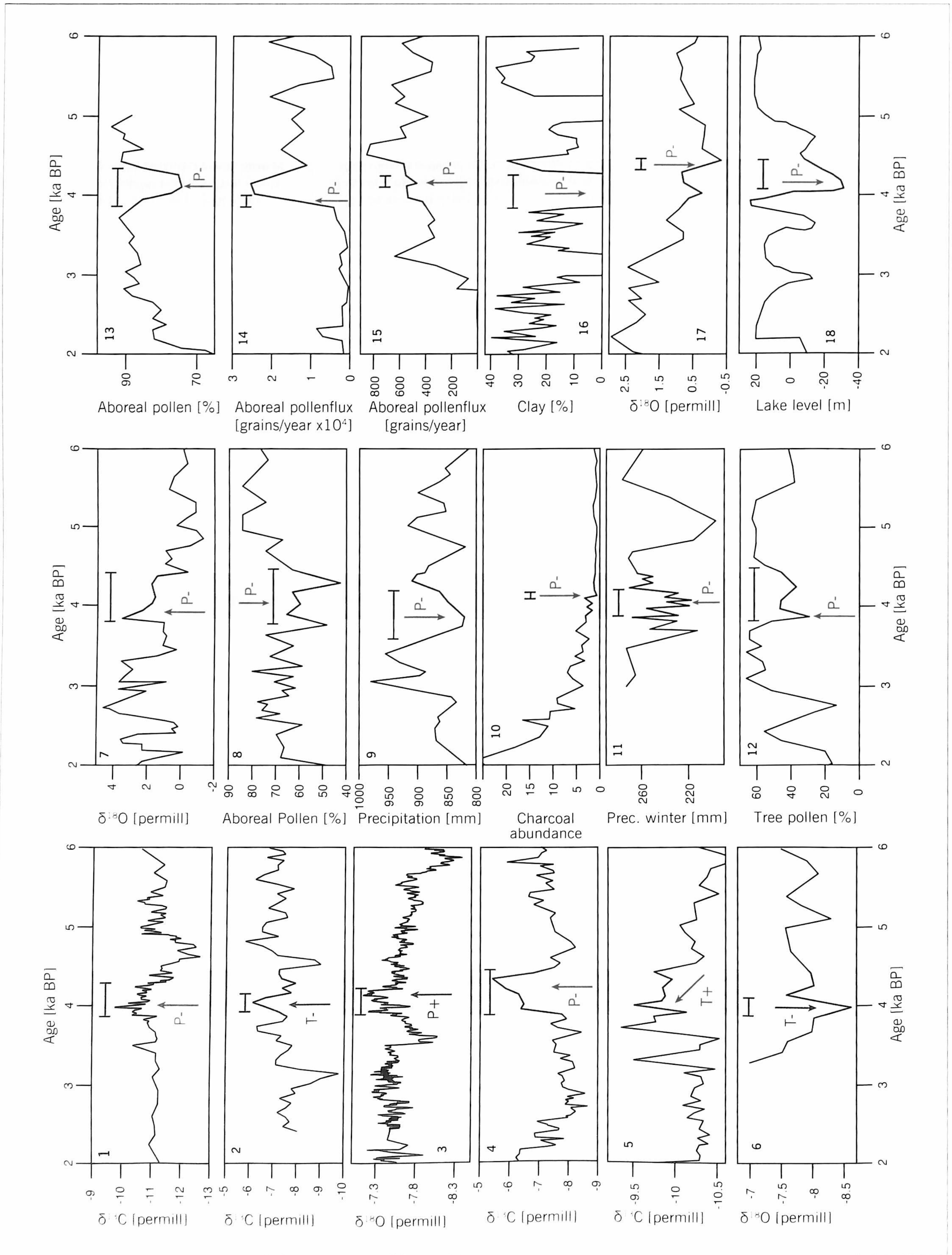
Dr. Christian Schwab
Christian-Albrechts-Universität Kiel
Graduate School of Human Development in Landscapes
Leibnizstr. 3
24118 Kiel
Germany
cschwab@gshdl.uni-kiel.de

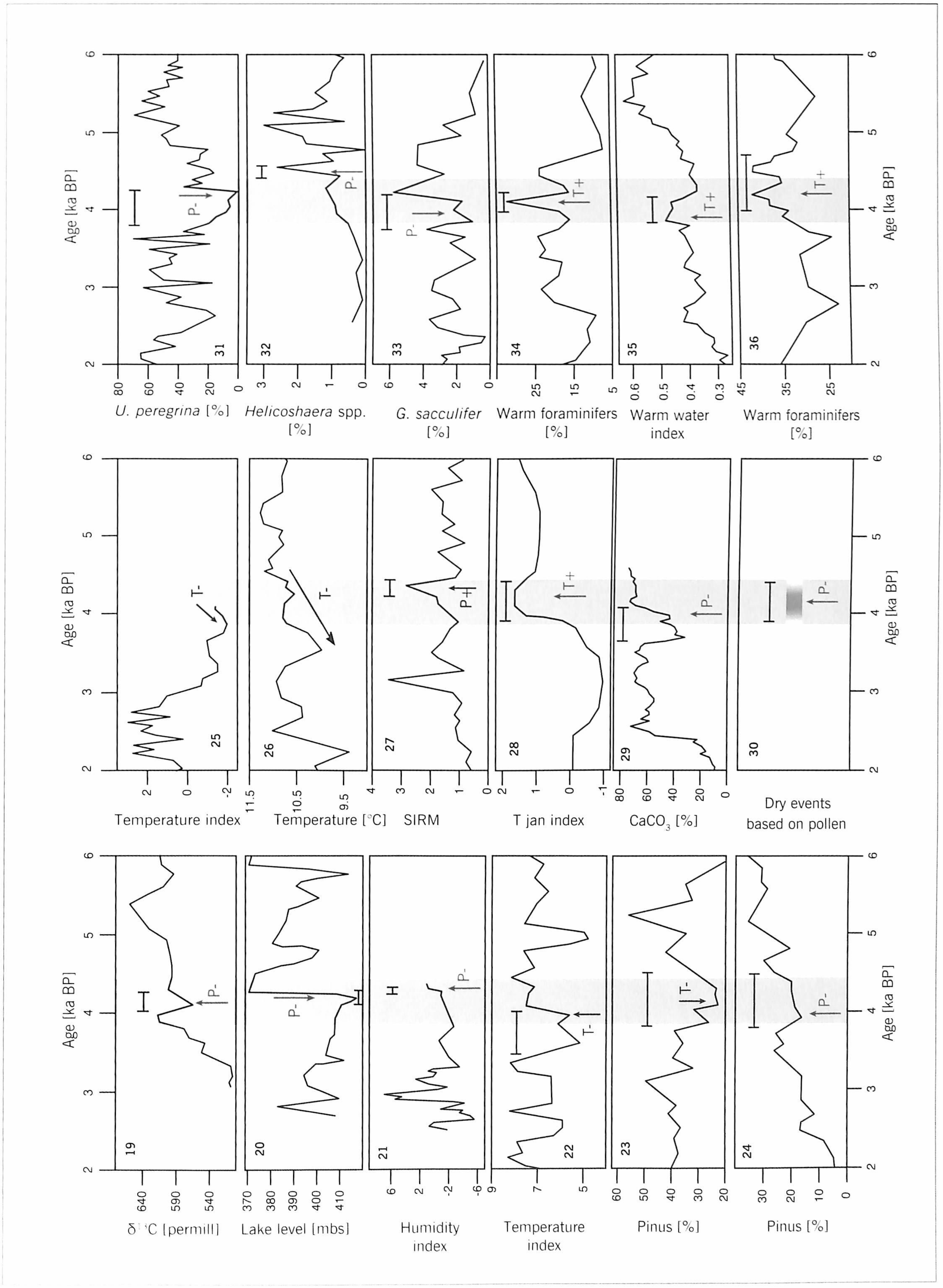
Dr. Jutta Kneisel
Christian-Albrechts-Universität Kiel
Graduate School of Human Development in Landscapes
Leibnizstr. 3
24118 Kiel
Germany
jutta.kneisel@ufg.uni-kiel.de

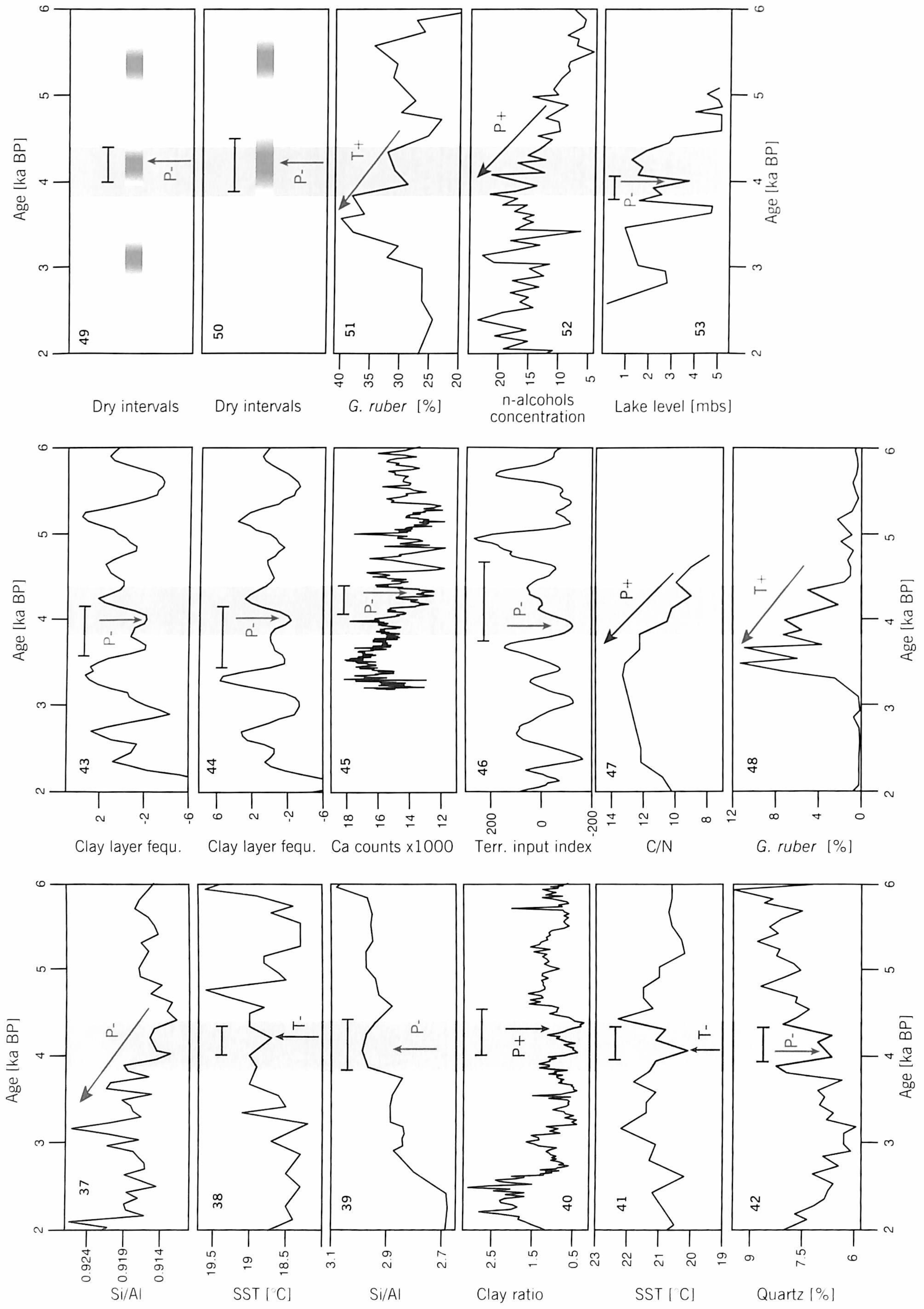
Appendix 1 (next page) Selected palaeoclimatic records from the individual sites shown in figure 1. The numbers of the records correspond to the numbers in figure 1 and table 1. Interpreted changes are shown as arrows. Vertical arrows correspond to an event (the duration of the event is indicated as a horizontal bar). Oblique arrows correspond to a transition. Interpretation of proxies in terms of precipitation and temperature is given. P+/P- correspond to increase/decrease of precipitation respectively. T+/T- correspond to increase/decrease in temperature respectively. Although a cold event is shown in record 32, the observed changes are within the error of the estimation and therefore no significant change is indicated in figure 1.

Anhang 1 (nächste Seite) Ausgewählte paläoklimatische Daten der in Abbildung 1 kartierten Fundstellen. Die Nummerierung entspricht jener in Abbildung 1 und Tabelle 1. Interpretierte Veränderungen sind durch Pfeile gekennzeichnet. Senkrechte Pfeile entsprechen einem Ereignis (die Dauer des Ereignisses ist mittels eines horizontalen Streifens angezeigt). Schräge Pfeile weisen auf einen Übergang hin. Die Interpretation der Proxydaten bezieht sich auf Niederschlagsmenge und Temperatur. P+/P- bezeichnen eine Zu- oder Abnahme der Niederschlagsmenge. T+/T- beziehen sich auf eine Zu- oder Abnahme der Temperatur. Während sich im Datensatz 32 ein Kaltereignis abzeichnet, bewegen sich die beobachteten Veränderungen im Bereich der normalen Abweichung, sodass in Abbildung 1 keine wesentliche Veränderung festgestellt werden kann.

Appendix


Age [ka BP]
13
Aboreal pollen [%]
14
Aboreal pollenflux [grains/year x10⁴]
15
Aboreal pollenflux [grains/year]
16
Clay [%]
17
δ¹⁸O [permill]
18
Lake level [m]
7
δ¹⁸O [permill]
8
Aboreal Pollen [%]
9
Precipitation [mm]
10
Charcoal abundance
11
Prec. winter [mm]
12
Tree pollen [%]
1
δ¹³C [permill]
2
δ¹³C [permill]
3
δ¹⁸O [permill]
4
δ¹³C [permill]
5
δ¹³C [permill]
6
δ¹⁸O [permill]
P-
P+
T-
T+


Age [ka BP]
U. peregrina [%]
Helicoshaera spp. [%]
G. sacculifer [%]
Warm foraminifers [%]
Warm water index
Warm foraminifers [%]
Temperature index
Temperature [°C]
SIRM
T jan index
CaCO$_3$ [%]
Dry events based on pollen
δ¹³C [permill]
Lake level [mbs]
Humidity index
Temperature index
Pinus [%]
Pinus [%]
P-
P+
T+
T-
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36


49
50
51
52
53
Age [ka BP]
2
3
4
5
6
P-
T+
P+
Dry intervals
Dry intervals
G. ruber [%]
40 35 30 25 20
n-alcohols concentration
20 15 10 5
Lake level [mbs]
1 2 3 4 5
43
44
45
46
47
48
Clay layer fequ.
2 -2 -6
Clay layer fequ.
6 2 -2 -6
Ca counts x1000
18 16 14 12
Terr. input index
200 0 -200
C/N
14 12 10 8
G. ruber [%]
12 8 4 0
37
38
39
40
41
42
Si/Al
0.924 0.919 0.914
SST [°C]
19.5 19 18.5
Si/Al
3.1 2.9 2.7
Clay ratio
2.5 1.5 0.5
SST [°C]
23 22 21 20 19
Quartz [%]
9 7.5 6
T-