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End Neolithic Water Management in Central Germany Based on Geoarchaeological and Palaeobotanical Analyses of Wells at the Roitzschjora site, Northern Saxony

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In memory of Dr. Falko Turner (20.05.1980 –10.01.2017), an energetic scholar and loyal friend

Abstract

The End Neolithic period is often discussed as a phase of settlement expansion into marginal sandy areas. A reliable water supply must have been a crucial factor in this settlement process, especially in the dry regions of Central Germany where the study site is located. In this investigation, we present the results of palaeobotanical, sedimentological and archaeological analyses performed on three small well features dating from approx. 2600 to 2135 cal BC, i.e. associated with the Corded Ware Culture. Remains of charred pieces of cereal, charcoal, artefacts, as well as the presence of pollen types indicative for ruderal vegetation prove that the refill process of these wells occurred in the context of local settlement activities. In spite of their small extent and existence as not necessarily continuous bodies of water, these small structures may have nevertheless been sufficient enough to sustain a small community over a longer period of time. Our results question the vulnerability of End Neolithic societies to small-scaled hydrological changes and challenge the idea of climatic changes being the decisive drivers of settlement dynamics.

Introduction

Archaeological and palaeobotanical studies examining the economy of Neolithic cultural groups of the late 3rd millennium BC in Central Germany are still rare. Better preservation is one of the main reasons, why studies have so far focused on the wetland sites of Southwestern Germany (Rösch 1990; Herbig 2009; Lechterbeck et al. 2014) and Switzerland (Jacomet et al. 2016). Research in dry, sandy areas is not only hampered by bad preservation, but also by the relatively small number of known settlement sites that have yielded suitable environmental on-site records such as small well features (Brozio et al. 2014). Therefore, the reconstruction of economic and ecological patterns is still mainly confined to palynological analyses from off-site records in lake sediments or mires and may not mirror small-scale landscape developments.

Against this backdrop, the application of geoarchaeological and palaeoecological analyses on three small well structures of an End Neolithic settlement site in Roitzschjora, Central Germany strengthens our insights not only in terms of water management and settle-

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ment structures, but also concerning the local development of economy and landscape during this period. Thus, the main aims of this study are (i) to reveal the construction and use of the wells in detail, (ii) to supplement off-site information by on-site data on the local Neolithic environment and (iii) to test whether palaeobotanical and palaeolimnological methods can be applied to the sediments within a well. Understanding the function of these small-scale water wells is especially important with regard to the discussion on the adaptability of End Neolithic societies to marginal environments as well as their supposedly high vulnerability to hydrological changes.

The Roitzschjora site

The Roitzschjora site (51°34'36"N/12°29'28"E) is situated in the lowlands of Northern Saxony in Central Germany, approximately 30 km northwest of Leipzig. As this region is located in the rain shadow of the Harz Mountains, the mean annual precipitation of about 520 mm (Fig. 1) ranges among the lowest within Germany (mean precipitation 720 mm; Klein/Menz 2003). Situated on a Weichselian river terrace of the Mulde River, a tributary of the Elbe River, the site is threatened by ongoing gravel mining and has therefore been excavated by the Archaeological Heritage Office of Saxony since 2011 (Schmalfuß 2014). Archaeological structures and artefacts at this site indicate several phases of human presence including mainly features from the End Neolithic and Middle to early Late Bronze Age. Human presence during medieval periods is indicated by an isolated well dated to the early 9th century AD (Schmalfuß/Tolksdorf 2016). During the field campaigns from 2013 to 2014, six small well constructions were discovered in a shallow topographic depression. Based on first archaeological results and corroborated by ^{14}C dates, three of these structures can be ascribed to the End Neolithic (Fig. 1) and were sampled for further geoarchaeological and palaeobotanical analyses (Fig. 2).

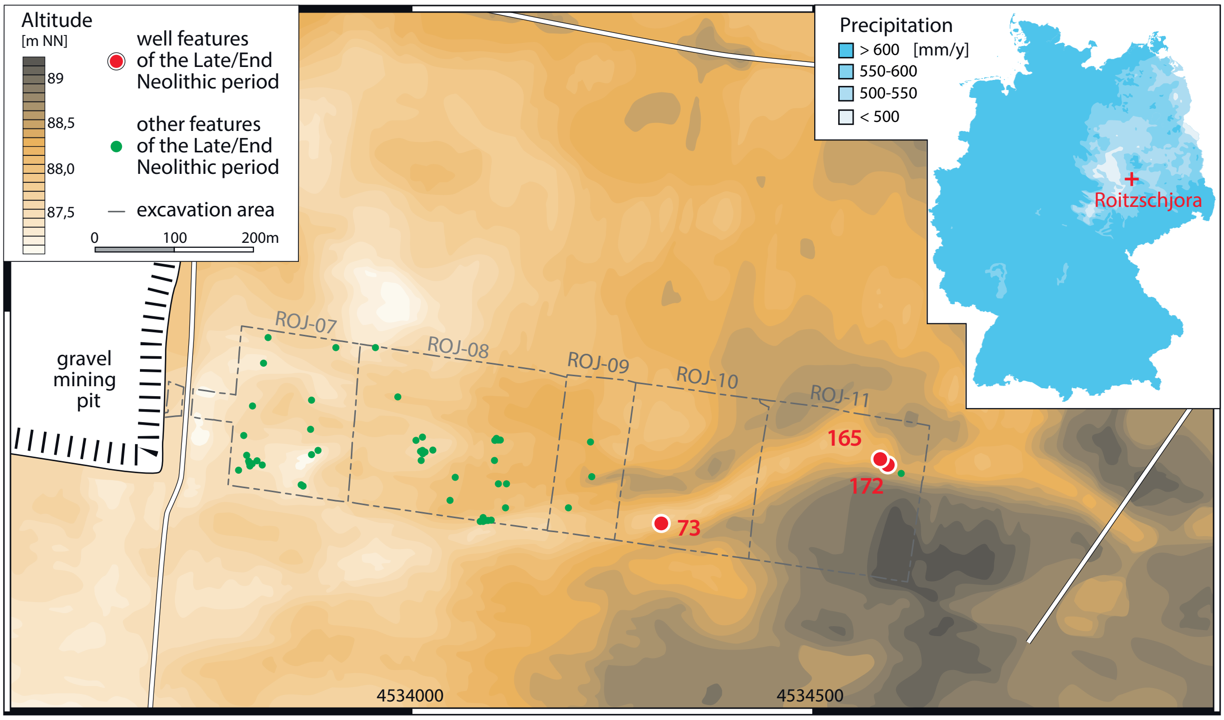


Fig. 1. Site topography and position of the features ROJ-10, 73, ROJ-11, 165 and ROJ-10, 172.

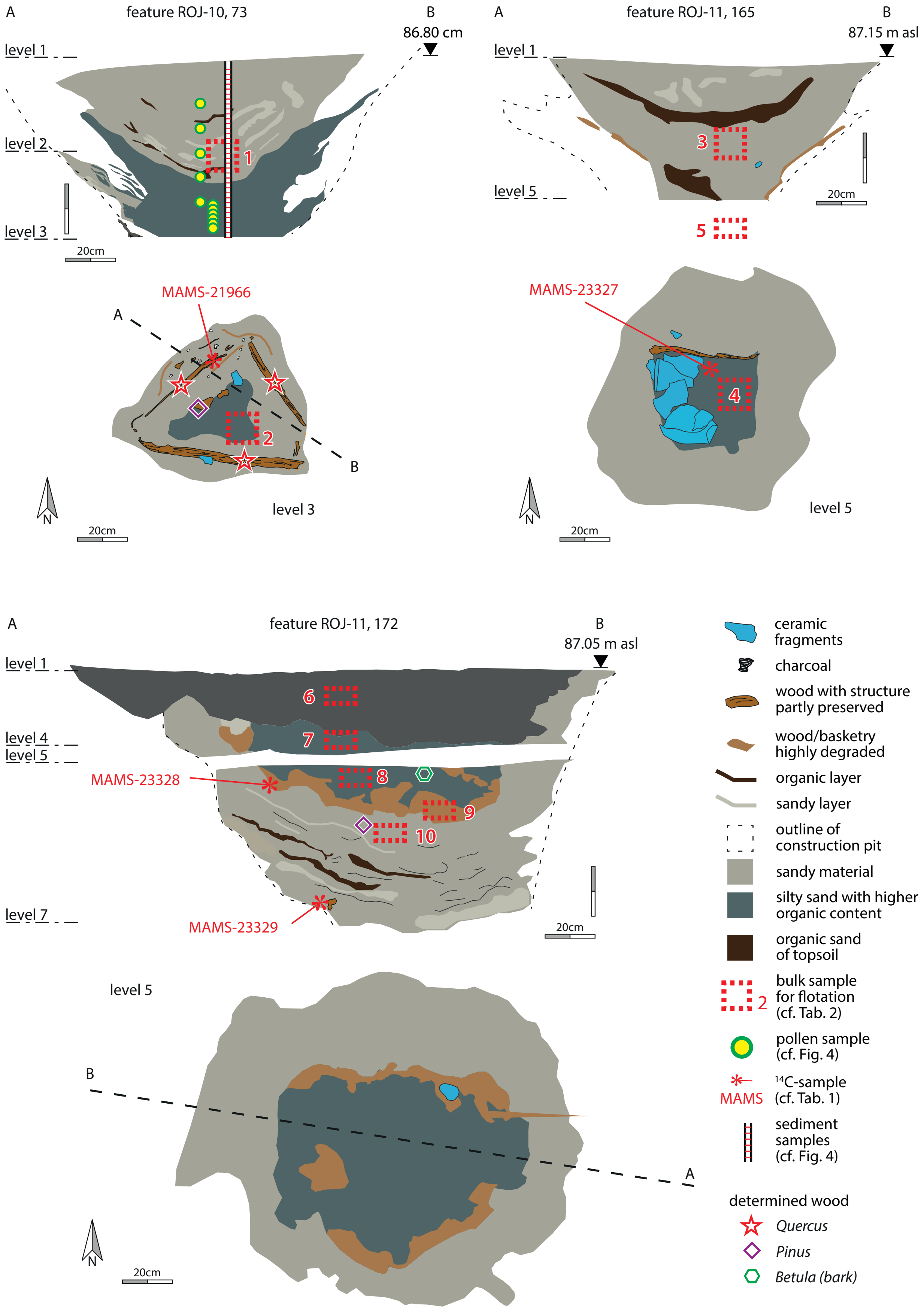


Fig. 2. Stratigraphy of the features and positions of samples.

Materials and Methods

Archaeological features

The archaeological features had been built within circular construction pits with diameters between 120 cm to 200 cm on the first excavation level and about 80 cm on the basal level at a depth of 80 to 120 cm (Fig. 2). Although the preservation of the timbers was bad in the sandy sediments and the outlines of the construction pits were hardly visible, some observations on the inner construction elements and sedimentation history were still possible. In feature ROJ-10, 73, the remains of a triangular wooden construction and only two small ceramic shards were recorded at basal level 3, while a construction with square outlines must have existed at least down to excavation level 2. At least two main phases of sedimentation are recorded with a lower unit presenting a higher proportion of silty material and an upper unit where sandy material prevails. While feature ROJ-11, 165 was very similar with regard to its dimensions, the lowermost construction had the shape of a square box construction. Large fragments of a nearly complete ceramic vessel as well as parts of another highly fragmented one formed a compact horizontal layer at about 10 cm above the lowest layer of silty material. A vessel shoulder decorated with parallel vertical incisions was uncovered from the upper infill sediments (Fig. 3). The sandy sediments above these artefacts are separated by a small layer of more silty and organic sediment at about 20 cm below excavation level 1. Therefore, at least three phases of sedimentation must have occurred within this structure, interrupted by phases of stability as indicated by the artefact layer and the organic sediment in the upper part.

Fig. 3. Ceramics from ROJ-11, feature 165.

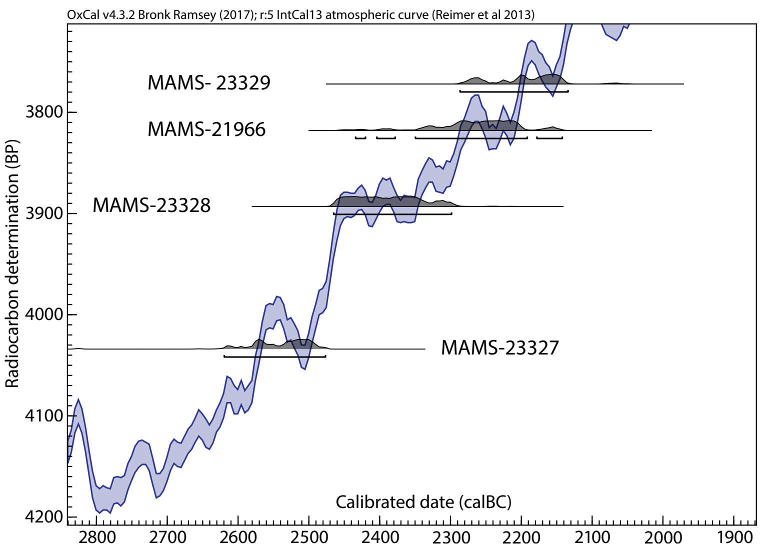
Within the largest well feature ROJ-11, 172, the remains of a bowl-shaped wooden structure made in basketry technique were excavated at a depth of 40–60 cm below level 1 (lower boundary of the topsoil). The irregular outlines and partially overlapping wooden layers indicate that the original structure must have been squeezed and compressed during subsequent sedimentation. This basketry structure is superimposed on 40 cm of sediments with intercalating organic and sandy layers that must be older according to stratigraphy.

Chronology

For chronological analyses, remains of the wooden constructions were sampled in order to carry out ^{14}C-analyses. While one sample was taken from feature ROJ-10, 73 and from feature ROJ-11, 165, two samples were taken from ROJ-11, 172 to provide information about the time interval between both phases of construction observed in the stratigraphy. While a minimum age is provided for the lower part of the pit by a wooden fragment of the lowermost infill sediments, another sample was taken from the basketry structure as a superimposed building phase. All samples were AMS-dated in the Klaus-Tschira-Laboratory of the CEZ Mannheim and subsequently calibrated using the IntCal13 (Reimer 2013) dataset and the OxCal software package. As the ^{14}C dates in ROJ-11, 172 are in stratigraphical relation, Bayesian statistics (Bronk Ramsey 2009) were used to explore their chronological positions (Tab. 1).

Tab. 1. ^{14}C results of the End Neolithic well features and plot of ^{14}C results on the IntCal13 curve.

LabNo.	Material and archaeological context	^{14}C [BP]	^{14}C (calibrated; 1σ) [cal BC]	^{14}C (calibrated; 2σ) [cal BC]	$\delta^{13}C$ [‰]
MAMS-21966	ROJ-10, feature 73, north-western plank of triangular wooden construction	3818 ± 30	2298 – 2202	2435 – 2421 2405 – 2379 2360 – 2192 2179 – 2143	-33.9
MAMS-23327	ROJ-11, feature 165, small twig from lower infill sediment	4034 ± 24	2579 – 2559 2579 – 2559	2620 – 2477	-26.9
MAMS-23328	ROJ-11, feature 172, wooden remain from upper structure made in basketry technique	3893 ± 22	2458 – 2397 2385 – 2347	2466 – 2299	-30.9
	Bayesian model age			*2252 – 2210 (1ó) 2339 – 2202 (2ó) 2423 – 2201 (3ó)*	
MAMS-23329	ROJ-11, feature 172, wooden remain from basal sediment below structure made in basketry technique	3772 ± 23	2273 – 2258 2208-2190	2287 – 2135	-31.0
	Bayesian model age			*2333 – 2247 (1ó) 2401 – 2216 (2ó) 2460 – 2206 (3ó)*	



Sediments

Analyses of grain sizes and loss-on-ignition (LOI) were performed on samples taken from ROJ-10, feature 73 at intervals of 2 cm. After drying the material for 24h at 100°C, the LOI was calculated as weight-loss after heating at 550°C for two hours (Heiri et al. 2001). This parameter is widely used to estimate the varying content of organic material. Having tested the residues by HCl to be free of carbonates, grain size fractions >2 mm were measured by Laser-diffraction at the University of Greifswald (Fritsch Analysette 22 Micro Tec). While a high content of silt (0.02-0.63 µm) is regarded to indicate the prevalence of aeolian or stillwater sedimentation, dominance of the coarse sand fraction (0.63-2 mm) suggests input from surrounding material, e.g. by collapse of the structure (Fig. 4).

Macro-remains

Bulk samples of varying sizes were taken for macrobotanical analyses from all three features at different depths during the excavation (Fig. 2). The organic material was extracted by flotation and sieving (mesh width: 2, 1, 0.5, and 0.25 mm). Plant macro-remains were determined with x6.3 to x40 magnification using standard literature (Cappers et al. 2012) and the reference collection at the Laboratory of Archaeobotany, Institute of Prehistoric Archaeology, University of Frankfurt/Main (Tab. 2). *Juncus*-seeds were determined according to Körber-Grohne (1964). The microscopic identification of wood was performed on fresh cut sectional, radial and tangential sections using an incident light microscope based on the literature (Schweingruber 1978) and the reference collection.

The taxa were recorded with regard to the anatomical part, preservation in charred or uncharred condition, and quantity. For wood, bark, charcoal and buds, only the presence (1–10 counts) or abundance (> 10 counts) is given. Attribution of the taxa to ecological units and nomenclature is based on Oberdorfer (2001).

The macro-botanical samples from well ROJ-10, feature 73 were scanned for fossil remains of chironomid larvae using standard methods described in Brooks et al. (2007). Sediment samples (~ 8 g) were disaggregated in 10% potassium hydroxide and heated to 75°C for 15–20 minutes. Samples were passed through a 100 µm sieve and washed with demineralised water. The residues were transferred to a Bogorov sorting tray (Gannon 1971) and checked for the presence of chironomid larvae head capsules and other botanical/zoological macrofossils at x30 magnification. Larvae of Chironomidae (Diptera, Insecta) belong to the most abundant organisms in freshwater habitats and colonize all kinds of permanent and temporary water bodies (e.g. Armitage et al. 1995). Accordingly, the presence/absence of their macrofossils provides excellent indicators for the presence/absence of the continuous existence of water within the well.

Palynology

Twelve samples were extracted for palynological analyses from feature 73 at 2 cm intervals from the lowest part at a depth of 72–58 cm and 10 cm spacing up to 18 cm below the first excavation level. Sample preparation followed the standard acetolysis procedure

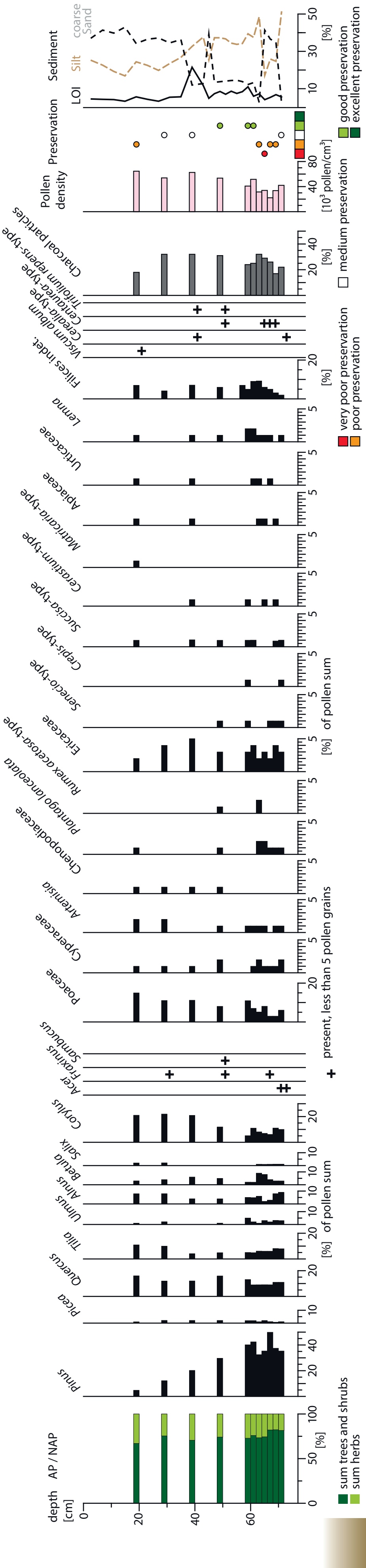


Fig. 4. Pollen analysis and sedimentological parameter of ROJ-10, feature 73.

(Erdtman 1954; Berglund/Ralska-Jasiewiczowa 1986) and the identification of the palynomorphs was based on the standard reference literature (Faegri/Iversen 1989; Beug 2004). Due to bad preservation and fragmentation during sample processing, charcoal particles were only recorded by their number but not subdivided into size classes. The pollen sum exceeds 500 pollen grains in all samples, except from 66–68 cm depth, where only 420 grains were counted due to bad preservation and low pollen concentration. Lycopodium spores were added to estimate the concentration of pollen in the sediment.

Results and discussion

Palaeoenvironmental context of the well features

Microscopical assessment of the pollen samples from feature ROJ-10, 73 revealed extreme differences in the preservation of the palynomorphs even in adjacent samples (Fig. 4). Together with the observed rising pollen concentration above 62 cm depth, this may indicate changing sedimentation environments and preservation conditions. The sandy layer reflects a phase with a considerable input of weathered pollen, possibly in a short period of time, while the silty material probably represents a phase of slower sedimentation with higher shares of aeolian transport. Moreover, preservation conditions are especially bad in layers with a higher coarse sand content due to a higher intensity of oxidation and decomposition in layers with a greater void volume. The dominating taxon is *Pinus*, but pollen grains of *Quercus*, *Tilia, Alnus* and *Ulmus* also occur in considerable amounts, while *Fagus* pollen is absent in all samples. In particular, the value of *Pinus* pollen decreases noticeably in the upper samples, whereas *Corylus* and Poaceae increase. The dominance of *Pinus* in the pollen spectra and its presence among macro-remains are in good accordance with palynological results from the area of Brandenburg (Küster/Warmbrunn 2000; Wolters 2002; Jahns et al. 2013) that indicate a predominance of this species on sandy sites since the Late Glacial. Indicators for the local forest composition are provided by remains of *Pinus* (features 73 and 172), *Populus* (feature 165) as well as *Betula* and *Quercus* (feature 172). Regarding the considerable proportion of *Quercus*, *Tilia* and *Ulmus,* it is likely that these species formed forest stands in the nearby Mulde Valley and in the loess-areas to the south. The absence of *Fagus* is of particular relevance in terms of biostratigraphy. Certain environmental factors probably delayed its spread in Central Germany until the later Subboreal period (Jahns et al. 2013), thereby the upper layers of feature 73 must be assigned to the early Subboreal or even earlier. This biostratigraphical position in is good accordance with the ^{14}C results of 2435–2143 cal BC.

Remains of *Triticum dicoccon/monococcum* were recovered from features 73 and 165, comprised of one spikelet fork and the charred fragment of a lower glume (Tab. 2). Additionally, sample 4 from feature 165 contained a single grain of *Triticum aestivum /durum/ turgidum*-type. Unfortunately, distinctive chaff remains for the latter are missing and made a more specific identification impossible. The sporadic occurrence of Cerealia-type and *Centaurea*-type pollen in the palynological samples is an indicator of nearby fields, while patches of open areas are indicated by typical ruderal taxa such as *Artemisia, Plantago lanceolata* and Chenopodiaceae (Behre 1981). Pollen grains of *Succisa*-type point towards opened areas on the valley floor, perhaps related to grazing activities.

Tab. 2. Results of the macroremains analyses.

archaeological feature			**73**		**165**			**172**				
depth [cm]			55	70-72	50-55	70	80	15-20	30-40	50	60	70
excavation level/ subdivision of sediment layer			2	3-bottom	3-4	5	5-bottom	1-4	5-6	6-7/ layer I	6-7/ layer II	6-7/layer III
sample size [litre]			0.15	1	3	0.6	3	3	3.5	2	4	4
sample No.			1	2	3	4	5	6	7	8	9	10
Sample preparation for chironomid larvae			x	x	·	·	·	·	·	·	·	·
taxonomy	anatomy	preser-vation	·	·	·	·	·	·	·	·	·	·
Triticum aestivum/durum/ turgidum	FS	ch	·	·	·	1	·	·	·	·	·	·
Triticum dicoccon/ monococcum	TSF	ch	·	·	·	1	·	·	·	·	·	·
	LG	ch	·	1	·	·	·	·	·	·	·	·
Triticum monococcum	TSF	u	·	·	·	·	1	·	·	·	·	·
Pinus sylvestris	ND	ch	·	·	·	·	·	·	·	·	1	·
	W	ch	·	1	·	·	·	·	·	·	·	·
Betula sp.	IFS	ch	·	·	·	·	·	·	·	1	1	·
Quercus sp.	FS	ch	·	·	·	·	·	·	1	·	1	·
cf. *Populus* sp.	B	u	·	·	1	·	·	·	·	·	·	·
Chenopodium album- type	FS	u	·	·	·	5	15	·	1	·	1	19
	FS	ch	·	·	·	·	·	·	2	·	1	·
Lysimachia vulgaris	FS	ch	·	·	·	·	·	·	·	·	1	·
Juncus effuses / Juncus conglomeratus	FS	+++	+++	·	·	·	·	·	·	·	·	·
wood *(indet.)*	-	u	+	+	·	+	·	·	+	·	++	·
	-	ch	·	·	+	+	+	++	+	+	++	+
bark (*indet.*)	-	u	·	·	·	·	·	·	+	·	++	·
rhizome (*indet.*)	-	ch?	·	·	7	·	·	·	15	3	19	·
fruits / seeds (*indet.*)	FS	u	·	·	·	·	·	·	·	·	1	·
	FS	ch	·	·	1	·	·	·	8	·	8	·
bud (*indet.*)	B	ch	·	+	·	·	·	·	+	+	·	·

Anatomy: FS=fruit/seed, TSF= terminal spikelet forks, LG= lower glumes, ND=needle, IFS= infructescence, B=bud; W=wood; preservation: ch=charred, u=uncharred; quantity: + = present, ++ = numerous

The presence of *Triticum dicoccon/monococcum* during the Late/End Neolithic has been proven for Central Germany both in the form of caryopses imprints on ceramics from various sites (Matthias/Schultze-Motel 1967; Matthias/Schultze-Motel 1969; Matthias/Schultze-Motel 1971) and only recently as charred grains in a massive layer of various charred cereal types in a settlement pit (Conrad et al. 2014) at the Paschkowitz site, located 65 km southwest of Roitzschjora. In Paschkowitz, *Triticum dicoccon/monococcum* was associated with hulled barley (*Hordeum vulgare*) in a massive layer of charred cereals in a settlement pit (Conrad et al. 2014). The botanical remains at Roitschjora are also in good accordance with spectra ascribed to the following Early Bronze Age (Aunjetitzer/Unetice Culture) from the nearby open cast mining area at Zwenkau. Here, *Triticum aestivum*, *T. dicoccon*, *T. monococcum*, *Panicum miliaeceam* and *Papaver somniferum* have been identified (Küster 1997).

Construction, use and taphonomy of the well features in their regional context

Based only on the ^{14}C dates, we cannot establish whether these structures coexisted at least to some extent or if they represent a chronological sequence with shifting locations. The results of the ^{14}C dates (Tab. 1) confirm that all three features date to the late 3rd millennium BC with feature ROJ-11, 165 being the oldest structure from the mid-3rd millennium (2620–2477 cal BC). While feature ROJ-10, 73 can only be ranged between the late 25th and the 22nd century BC (2435–2143 cal BC), the dates from feature ROJ-11, 172 are in stratigrapical and technological order that allows for further statistical analysis by a Bayesian approach. Based on the fact that the upper structure was superimposed on 40 cm of layered sediments, its nature as a secondary construction can be substantiated. Therefore, the wooden fragment from the lower sediment unit needs to be older as no post-depositional relocation or disturbance could be observed. Although the ^{14}C results of the upper construction seem to be older, a recalculation of the dates including their stratigraphical relationship would provide possible age intervals between the 25th and the 24th century BC for the lower sediments and between the late 25th and the 23rd century BC for the upper construction (Tab. 1). However, the chronological relationship between ROJ-10, 73 and ROJ-11, 172 cannot be resolved.

The observation of a later construction phase within an already partly filled well structure in features 165 and 172 indicates that phases of rebuilding or reusing older and still visible structures occurred. Both the LOI and the grain size analysis from ROJ-10, 73 indicate sedimentation that also occurred here in at least two main phases. The lowermost sample is dominated by silty material and indicates deposition with a share of aeolian sediments in an open structure. It is covered by a sandy layer that may derive from an episodic input of local sand, probably resulting from a partial collapse of the structure, followed again by layers dominated by silt. The high organic content at a depth of about 40 cm indicates a temporarily stable surface that is covered by sandy sediments deriving from a collapse of the open structure. In spite of these different infill dynamics, the number of charcoal particles remains on a comparatively stable level and may indicate ongoing human activity around this structure. Regarding the preservation of thin-walled *Juncus effuses / Juncus conglomeratus* seeds in the samples prepared for chironomid analyses, it seems unlikely that the robust chironomid larvae head capsulae could have completely decomposed. *Juncus* taxa typically grow under periodically moist but not aquatic conditions and their dominance is an indicator of open, relatively nutrient-rich stands with a high but variable water level that did not necessarily provide a continuous water body required for chironomidae. Our combined results suggest that the wells were possibly used for a comparatively short time only, rapidly silting up or desiccating thereafter. During or after their use, these wells provided stands for ruderal plant taxa such as *Chenopodium album* and *Juncus effuses / Juncus conglomeratus*.

Well constructions dating to the late 3rd millennium have been sparsely documented in Germany so far (Fig. 5), and their investiga-

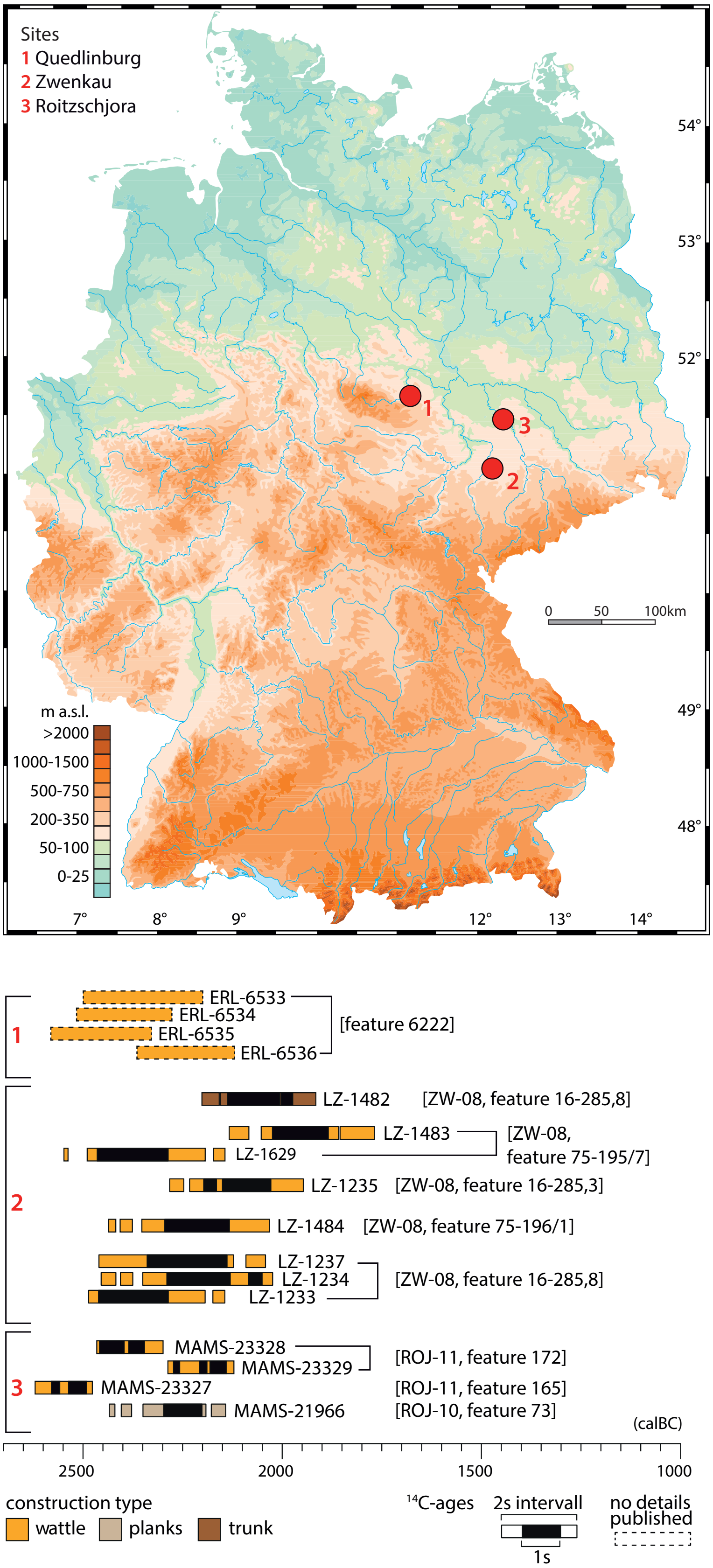


Fig. 5. Comparable constructions from Germany and their chronological positions in the End Neolithic.

tion has been restricted to large-scale excavations, for example, in the open cast mining field at Zwenkau (Campen 1997; Stäuble/Hiller 1998; Hansen 2010) or during the construction of a road at Quedlinburg (Peters 2006). The relatively shallow and light construction types of End Neolithic wells have attracted much less attention compared to the early Neolithic LBK types and their infill sediments (Herbig et al. 2013; Tegel et al. 2012). Therefore, the well structure of Quedlinburg, where a pit of 2.3x2.5 m diameter and a depth of 3 m below the topsoil revealed traces of a wooden installation at the basal layers in the form of a polygonal wattle structure (Peters 2006), provides the only comparison in the wider region regarding the chronology and analyses of the infill sediments. It showed that airborne pollen types, like that of *Pinus,* were underrepresented as were arboreal pollen in general. Together with the absence of diatoms, it was concluded that this well may not have been a permanent and open water body but was perhaps covered and only of periodic use for fetching water. These observations correspond to the absence of Chironomids and the presence of *Juncus* remains in feature ROJ-10, 73, although the presence of arboreal pollen does not support a permanent cover of the structure. In spite of these parallels, the spectrum of macro-remains retrieved from the Quedlinburg well is possibly affected by the admixture of younger material and cannot be used for comparison. The set of cultural plants, including *Avena sativa*, *Hordeum vulgare*, *Lens culinaris*, *Pisum sativum*, and *Vicia faba,* seems to be younger than the archaeological structure, especially as muskmelon (*Cucumis melo*) is present, which has not been identified north of the Alps prior to the Roman period thus far (Strank/Meurers-Balke 2008).

Having used such light constructions for their water supply, it seems questionable whether End Neolithic or Early Bronze Age societies were as vulnerable to small hydrological changes as previously maintained. Although the disruptive effect of increasing aridity around 2.2 BC (4.2 ka BP event) has been discussed for areas and cultural settings as diverse as the Eastern Mediterranean (Roberts et al. 2011), Egypt (Stanley et al. 2003; Welc/Marks 2014), the Red Sea (Arz et al. 2006), western Asia and India (Staubwasser et al. 2003; Staubwasser/Weiss 2006) and Northern America (Booth et al. 2005), the hydrology of this period is still poorly understood for Central Europe and changes may have been relatively slight in some areas (Roland et al. 2014). The analysis of local hydrological archives in Northern and Central Germany and Poland indicates that the groundwater table may have been comparatively lower during the second half of the 3rd millennium BC (Kaiser et al. 2012; Wieckowska et al. 2012), although further studies need to substantiate the duration and intensity of this drier period and its effects on contemporary communities. Overall light constructions with not even permanent water bodies seem to have sufficiently supplied settlement areas in the dry area of Central Germany at least seasonally, and they are in accordance with the observed settlement expansion into marginal sandy areas of Eastern Saxony during the Corded Ware Culture (Hock 2010).

Conclusion

Over the last decade, a number of small sunken structures dating to the mid- to late 3rd millennium BC have been discovered in Central Germany. Although the absence of fossils of aquatic organisms in the infilling sediments indicates that they did not necessarily provide a permanent water body, their connection to a local water supply is conclusive. While various construction types are observed among these small wells, archaeological, sedimentological and palaeobotanical analyses indicate their refill in the context of local settlement activities. These small structures provide important on-site records for a reconstruction of the local land-use history and can contribute, in particular, to our understanding of prehistoric water supply regimes.

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