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The Milky Way: Mobility and Economy at the Turn of the 3rd Millennium in Southern Central Europe

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In the light of discussions surrounding the social changes attributed to the arrival of the Corded Ware culture in central Europe, here we investigate the economic strategies of one of the cultural complexes of the immediately preceding Late Neolithic. The Cham culture of southern Bavaria is characterised by a variety of economic choices but problems remain in synthesising and combining archaeozoological and archaeobotanical evidence. Using lipid residue analysis from Cham culture pottery excavated at the unenclosed settlement of Riedling, Lower Bavaria, we succeed in identifying a dairying economy at this time. Compound-specific lipid radiocarbon dates are then combined with other samples to provide a formal estimate for the duration of activity at Riedling and the first Bayesian chronological model for the Cham culture as a whole. Although data are currently not fine-grained enough to distinguish between competing models for site permanence, we suggest that the Cham culture pattern fits into a wider central European trend of greater mobility and economic flexibility in the pre-Corded Ware horizon, concluding that key economic strategies previously associated with 'steppe invasions' were already present in the preceding centuries. Finally, the demonstrated use of cups for milk-based products, as opposed to alcoholic drinks as previously suggested, leads us to propose possible alternative uses and users for these items.

Keywords: Riedling, Cham culture, Bavaria, pottery use, Late Neolithic economy, organic residues, compound-specific radiocarbon dates, Bayesian modelling

THE LATE NEOLITHIC IN CENTRAL EUROPE

The emergence of the so-called Corded Ware culture in large parts of eastern, central, and northern Europe (*c.* 2900–2000 cal BC; Furholt 2014, 68) is thought to coincide with a substantial population influx in these regions. Largely based on genetic data (Haak *et al.* 2015), this was initially cast as a rapid take-over, where resident 'Neolithic' societies were dramatically altered, perhaps even entirely superseded, by 'Bronze Age' migrants from the steppe – although in the European terminology, the Corded Ware culture is placed in the Final Neolithic. This transition is linked with substantial social and economic changes, such as the introduction of the nuclear family as a basic social building block, a strongly gender-segregated burial rite (said to go hand-in-hand with more patriarchal social structures), the symbolic valorisation of male warriorhood, an economic system geared towards increased mobility, and the emergence

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of Indo-European languages (Kristiansen *et al.* 2017). In particular, it has been argued, the expanded use of secondary products, such as milk, from an increasing range of domesticates (Scott *et al.* 2022) enabled steppe populations to expand widely across Europe and Asia (Wilkin *et al.* 2021).

Since then, two important caveats have emerged. First, genetic evidence suggests considerable diversity in this transition, with the proportions of 'Neolithic' and 'Steppe' genomes varying through time and regionally (eg, Linderholm *et al.* 2020; Papac *et al.* 2021; Allentoft *et al.* 2022; Gerber *et al.* 2022), suggesting a patchwork picture rather than a wave-like migration with complete take-over. In addition, these population movements took place against a background of general mobility, with several migration events creating the 'Steppe' signature, including a possible influx of European populations into the steppe (Wang *et al.* 2019; Furholt 2021). At the same time, networks of interaction and innovation exchange with steppe groups had been active in south-eastern and eastern central Europe for some time before the emergence of the Corded Ware (Gerling *et al.* 2012; Kaiser & Winger 2015).

This raises significant questions regarding the nature of the pre-Corded Ware horizon, the Late Neolithic in central European terminology. For example, did these important changes and transitions towards a more mobile settlement system, a greater importance of herding and dairying, and new social structures, begin substantially earlier? This scenario might imply that, rather than a destructive 'wave' of new migrants, the appearance of the Corded Ware culture was the culmination of a process of widespread interaction and convergence that, amongst others, included the introduction of new genetic signatures to central Europe.

Answering this question will require a substantial effort from an archaeological point of view, as the Late Neolithic is very unevenly researched in different regions. Here, we address questions of economy and subsistence for one of these regional pre-Corded Ware groupings, the Cham culture, primarily found in southern Bavaria and Bohemia. Using mainly lipid analysis from one of the most extensively excavated unenclosed Cham culture sites, Riedling in Lower Bavaria, we show that a full dairying economy is established at this time, suggesting that important steps towards the Final Neolithic way of life had been taken some time before the arrival of the first Corded Ware material (and possibly people) in the area.

THE CHAM CULTURE

Settlement system and networks

The Cham culture (Fig. 1) was first identified in 1951 by Hans-Jürgen Hundt, based on its characteristic pottery (for more details on research history, see Zuber 2019), with further research in the late 1980s and early 1990s resulting in the publication of the enclosure at Dobl and the identification of four regional groupings in Bavaria (Burger 1988). However, difficulties in defining the limits of the Cham culture were noted, as it shares pottery characteristics with both neighbouring groups and some further afield (Maier 1964, 81–2; Burger 1988, 131–5).

Four chronological phases were subsequently identified (Matuschik 1992; 1999), characterised by a gradual transition towards pottery displaying roughened surfaces and a decrease of ornaments consisting of applied plastic cordons all over the vessel body (although they remain present around the rim). Attempts at absolute dating (Ottaway 1999, 242; Gohlisch 2005, 131–42) were hampered by a plateau on the calibration curve beginning around 3350 cal BC, which makes it challenging to support internal phasing suggestions. Given these difficulties, most researchers prefer a simpler division into an early style with more lavish decoration, and a later style characterised by more roughened pottery and cord impression, a development spanning *c.* 3200–2750 cal BC (Gohlisch 2005, 143–9, 192; for different chronological models, see Engelhardt 2011, 153).

Pottery similar to the Cham style can, amongst others, be found in the central German Wartberg culture, the Bohemian Řivnáč culture, the Austrian/Slovakian Jevišovice culture, and in south-west Germany (eg, Goldberg III and Horgen; see, for instance, Burger 1988, 132, 210–43; Engelhardt 2002, 255; contributions to Gohlisch & Reisch 2001). In Bavaria, the early Cham style also overlaps with the so-called Baden-complex of east central Europe, dated to the second half of the 4th millennium BC (Furholt 2008; Raßhofer 2018), from which some stylistic elements were adopted. The Baden culture is often associated with the use of secondary products including milk and wheeled transport (Sherratt 1981; Craig *et al.* 2003; Greenfield 2010).

All this makes it difficult to define a coherent 'Cham culture' with strict boundaries to neighbouring regions and other ceramic styles. It rather seems that there was

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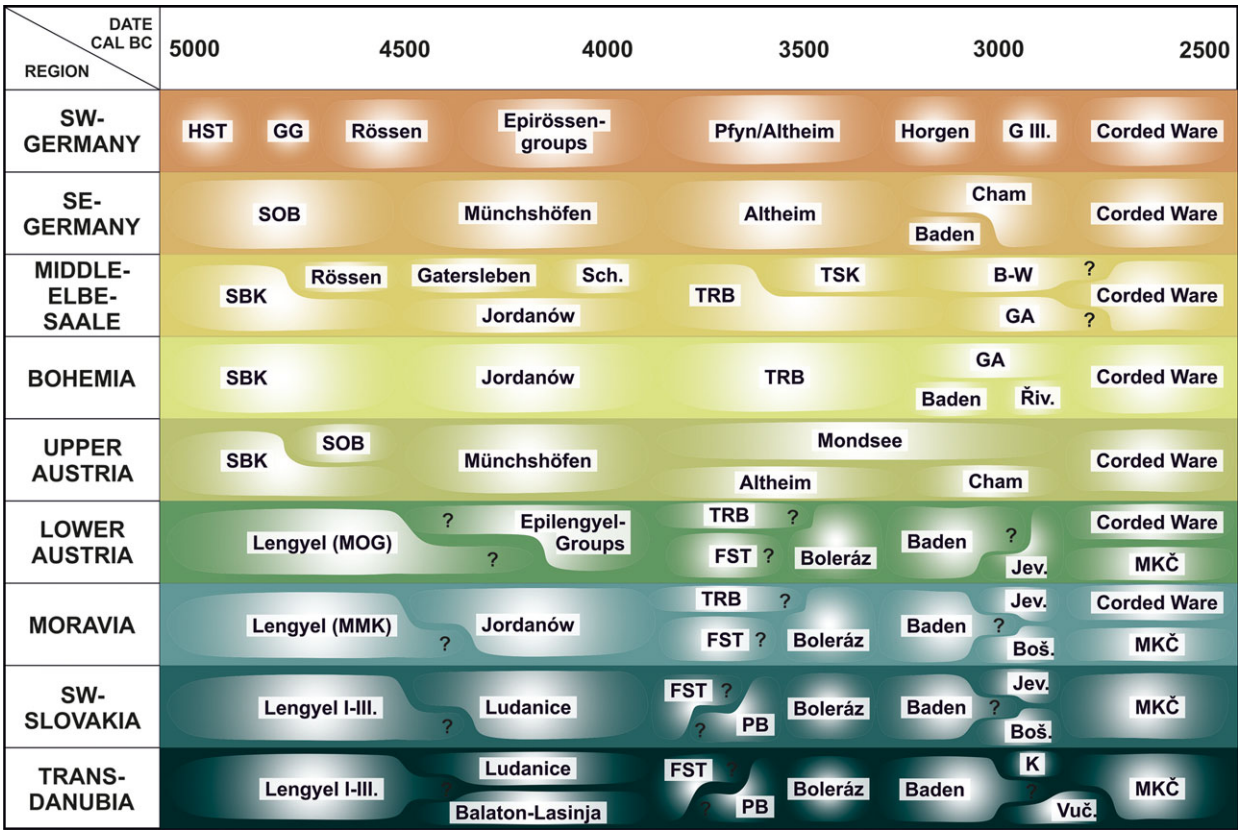

Fig. 1.
Chronology chart, showing the approximate date and duration of the Cham culture in the wider context of other central European cultures. In each row, the more defined shadings denote the period of maximum occurrence of a particular pottery style, but this should not be taken to imply sharp breaks between 'cultures' and/or their pottery styles, either spatially or chronologically (drawing: M. Szilágyi). *Abbreviations*: B-W: Bernburg-Walternienburg; Boš.: Bošáca; FST: Furchenstichkeramik; GA: Globular Amphora; G III.: Goldberg III.; GG: Großgartach; HST: Hinkelstein; Jev.: Jevišovice; Vuč.: Vučedol; K: Kostolac; MKČ: Makó-Kosihy-Čaka; MMK: Moravian Painted Pottery (after Czech *Moravská Malovaná Keramika*); MOG: Moravian – East Austrian Group (after German: *Mährisch-Ostösterreichische Gruppe*); PB: Protoboleráz; Řiv.: Řivnáč; SBK: Stroked Pottery (after German *Stichbandkeramik*); Sch.: Schiepzig; SOB: South Bavarian Middle Neolithic (after German *Südostbayerisches Mittelneolithikum*); TRB: Funnel Beaker (after German *Trichterbecher*); TSK: Tiefstichkeramik. Information has been synthesized from the following sources: Buchvaldek *et al.* 2007; Čataj 2016; Fowler *et al.* 2015, fig 1.1; Furholt 2008; Gleser 2016; Hofmann & Gleser 2019; Keefer 1993; Lenneis *et al.* 1995; Müller *et al.* 2019; Neustupný *et al.* 2013; Otten *et al.* 2015; Pavlů & Zápotocká 2013; Raczky 1995; Raßhofer 2018; Riedhammer 2016; Schwarz 2013; Seidel 2019; Whittle 1996)

a widely shared Late Neolithic pottery repertoire, with some shapes particularly popular in given regions but present in lower numbers elsewhere. In addition, it is relatively common in Cham culture assemblages to find shapes otherwise most closely associated with other cultural complexes, such as the cups with wavy rims known as Wellenrandtassen (eg, Behrens 1973, 102, Abb. 44. n). Given this 'polythetic' character of the material (Matuschik 1999, 90), the overall impression is one of openness to innovation and experimentation, at least as far as pottery is concerned. In accordance with central European usage (eg, Lüning 1972; for discussion see, for example, Hein 2019), we have retained the term 'culture' to describe Cham material (and that of other archaeological groupings) and its geographic and chronological

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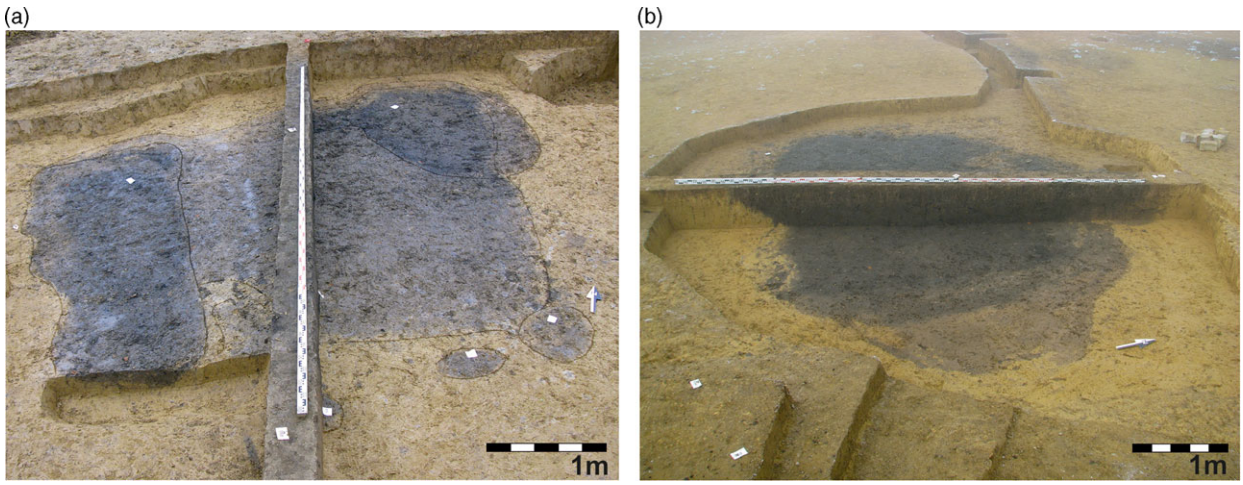

Fig. 2.
Cham culture pit huts excavated at Riedling: a. Feature 575; b. Feature 652 (edited by M. Szilágyi, photos by ArcTRon/ArcTeam)

extent, but explicitly reject the notion that these *material culture patterns* in any way reflect an internally coherent, *bounded social group*.

Other aspects of Cham cultural life are less well understood than its pottery. For example, the range and duration of settlement sites is not clear. Excavated examples are skewed towards enclosed sites, mostly either short stretches of ditch sealing off a promontory (or, in the case of Dietfurt, a drier area surrounded by boggy ground), or single- or double-ditched, generally circular enclosures of modest extent (0.1–0.5 ha). Of the *c*. 20 published enclosures, 11 include a 'destruction horizon' – a substantial charcoal layer, sometimes with charred posts and other large wooden elements (often interpreted as the remains of a palisade), large quantities of daub, and secondarily burnt artefacts, such as substantial portions of vessels and stone tools. This is then often topped by a 'clearance horizon' with unburnt material (large sherds, almost complete objects, etc), interpreted as the removal of partly damaged buildings and their contents. Often this is the last episode of ditch infill (see descriptions in Uenze 1985; Matuschik & Werner 1986; Hoppe 1998; Ottaway 1999, 19–25). These sequences have generally been interpreted as signs of an attack, after which the sites were abandoned (Uenze 2001, 52; Engelhardt 2011, 153–4). More research is needed on the duration of use of these sites but we can exclude a unified horizon of large-scale violence, as not all are contemporary on typological grounds.

In contrast to enclosures, open sites are rarely fully excavated and consist of a few pits or pit huts, often identified by chance or as part of rescue excavations, and rarely published in detail (see, for instance, Nagel 2001; Wandling 2001; Engelhardt 2002; 251; 2011, 151; Gohlisch 2005, 43). Domestic architecture is also not well understood. At Dietfurt, Harry Gohlisch (2001) used hearths to suggest possible house locations, reconstructing a loose row-like layout and other, more cluster-like arrangements. Pit houses were identified elsewhere, for example at Köfering (Nagel 2001) and Burgerroth (belonging to the closely related Burgerroth group; Link 2016; 2018). Cham pit huts are generally square, measuring 4 × 4 to 6 × 6 m, and sometimes have a small sunken area or pit in the centre of the floor (Fig. 2). Where geophysical prospection has been undertaken, as at Burgerroth or at Landersdorf Hinterer Berg (Bogner 2017), the suggested locations of dwellings are often more loosely spaced than at Dietfurt. The situation is similar for the related cultural groups in adjacent areas (Hofmann in prep.).[1] In all these cases, it remains unclear whether all buildings on a site are contemporaneous or show several sequential episodes of occupation.

On current evidence, several models for the extent of mobility inherent in the settlement system can be proposed. It is tempting, for example, to see open sites

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as relatively short-lived, as architectural investment was low and feature density modest. Following the pattern established for the Alpine Foreland wetland sites of this period (see, for example, Hofmann *et al.* 2016), sites may have shifted more than once in each generation, although within a restricted territory. The mobility of individual households, or indeed individuals, may have been greater than that. However, to date, the Alpine Foreland lacks definitively dated enclosure sites. The role of enclosures in the Cham culture remains uncertain. It is possible that they functioned as central places for an area around them, as suggested by Matuschik (1991, 48), and so were potentially more permanent. While enclosures needed some effort to build, they are small compared to those from earlier periods and are not associated with any special buildings or with mortuary activity (for which there is generally virtually no evidence). Even if these sites functioned as meeting places, there are as yet no indications of a hierarchical settlement system in which enclosures could, for example, control a surrounding territory. Some were apparently periodically attacked and burnt down, or deliberately decommissioned, after which their population dispersed. Overall, there seems to be a substantial degree of fluctuation and impermanence in the settlement system but the precise rhythms of site establishment and abandonment and of the density of settlements at any one time are unknown.

The Cham economy

While the overall picture of relatively short-duration Cham settlements thus seems plausible, economic choices are still hard to pin down. Settlements of this time in the Alpine Foreland, for example, apparently maintained permanent field plots but paired this with a high degree of economic flexibility between contemporary households and household groups, who vary in the degree to which they rely on different kinds of resources (eg, Schlichtherle *et al.* 2010; Doppler *et al.* 2011). Whether any of this applies to Cham culture communities is difficult to establish. Systematic field-walking surveys of the southern German lower mountain ranges (Valde Nowak 2002; Valde Nowak & Kienlin 2002) showed that the chronological horizon of the Cham culture was the first period in which these environments were more consistently frequented, while fewer find spots are known from the lowlands (Schmotz 2019, 70–1; Zuber 2019), probably partly because unenclosed Cham sites are hard to identify during survey. A similar pattern of increased upland use at this time has been noted in other regions (eg, Pelisiak 2016). Strontium isotope data from the earlier Münchshöfen culture (*c.* 4400–4000 cal BC) in southern Bavaria already suggest upland use, while increased variation in stable isotope signatures indicates a diversification of economic strategies (Perutka *et al.* 2021). Taking into account the distribution of known sites, this trend was substantially intensified in the Cham culture.

There are several possible reasons for this, for instance the prospection for – and exploitation of – regional lithic sources for polished and chipped stone tools (eg, Krondorfer *et al.* 2019). An increased reliance on herding and transhumance is also possible, although hard to substantiate. Several Cham culture settlements have seen archaeobotanical and/or archaeozoological study but the data are not always easy to compare and there has been little systematic flotation. Agriculture was practised and barley, emmer, and einkorn are attested from archaeobotanical samples or as impressions in pottery. Wheat species and pulses were less important, and various wild plants were collected (see Appendix S1). There may hence be a shift towards hardier cereal varieties like barley. Grinding stones from Cham contexts provide indirect evidence for plant use. However, the relative importance of agriculture, and of the different cultivars, cannot currently be quantified.

There is also considerable inter-site variability in the frequency of different domesticated animal species and the relative importance of wild and domesticated resources (Appendix S1). Domesticates generally make up over 60% of the bone assemblages (note that different methods of quantification have been used), with cattle or pig the most frequent species. At the Galgenberg, the mortality profile for horses (both sexes and all ages represented) and the frequency of the remains led Glass (1999) to suggest a domesticated or at least managed herd. Among the wild species are red deer and boar, alongside a range of smaller fur-bearing animals, birds, and fish, as well as the occasional large herbivore such as elk. The overall impression is one of variability. This could suggest adaptation to specific, local ecological niches or, alternatively, a resilient, broad-based economic system that could react quickly to climatic fluctuations and other challenges. In this case, and if settlements were short-lived, what we see as economic variability may be the result of short snapshot views into a flexible system. Addressing this further would require good dating

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for correlation with various climate indicators as well as careful contextualisation of sites into their local environment.

Our picture of the Cham economy is also limited by the absence, to date, of isotopic studies, particularly on animal bone (given the dearth of human remains). However, recent large-scale and comprehensive excavation of an unenclosed Cham settlement at Riedling, Bavaria, provided a rare opportunity to use organic residue analysis of pottery to investigate Late Neolithic diet and subsistence practices. Furthermore, compound-specific lipid dating on four of the Cham potsherds was carried out, yielding, for the first time, direct dates for dairying practices by Cham culture groups and providing valuable information on the antiquity of dairying in Late Neolithic Europe.

THE SITE OF RIEDLING

Riedling-Oberpiebing lies on the early slopes of the low tertiary hills overlooking the fertile loess-dominated Gäuboden plain of Lower Bavaria, an area densely settled since the Early Neolithic. The site was excavated by the companies ArcTron and ArcTeam between 2007 and 2012 in advance of loam extraction and yielded two Younger Neolithic enclosures dating to the Münchshöfen culture (*c.* 4400–3900 cal BC), as well as numerous pits and pit complexes of that date (Hofmann & Husty 2019; Szilágyi *et al.* 2020; Perutka *et al.* 2021). Some 800–1000 years after the site was abandoned, eight Cham culture pit houses were built and material deposited in still visible stretches of the earlier enclosure B (Fig. 3).

Riedling is exceptional in providing a large-area excavation of an unenclosed Cham settlement site. No post-built structures could be identified, but the pit houses correspond to those documented at other sites. Most are now relatively shallow (depths between 0.3 m and 1.3 m), square to rectangular features with 4–5 m long sides; some have a depression at their base. As observed elsewhere, the buildings are quite far from each other, from 8–10 up to 50–60 m, forming loose clusters and rows.

Riedling also yielded a small assemblage of animal bones dating to the Cham culture but only 44 of these could be attributed to species. Cattle and pig are represented, but it is not clear whether these are wild or domesticated. In line with other Cham sites, where aurochs are rare, most of the cattle are probably domestic, making this the most common species. In comparison, pigs are relatively rare (Ewersen in prep.). As the site was excavated under rescue conditions, no systematic programme of archaeobotanical sampling was carried out.

The Cham pottery at Riedling

Almost 7500 sherds could be assigned to the Late Neolithic settlement at Riedling based on diagnostic shapes and decoration. Most of the sherds assigned to the Cham culture ($n = 5566$, 75%) were found in the pit houses, which each generally contained between 500 and 1000 sherds. Pits yielded far fewer sherds ($n = 452$, 6%) with only two features (283 & 581) providing more than 100 fragments. Almost one-fifth ($n = 1451$, 19%) of the Late Neolithic sherds were found admixed in Münchshöfen features, most often in the upper layers of enclosure B.

A basic typology (Fig. 4) was compiled, based on more than 340 sherds, allowing the reconstruction of pot shapes and/or decoration. Thick-walled pots and large storage vessels make up the first main group. A common type is the S-profiled storage vessel but pots with inverted rim also occur frequently. The second group consists of bowls and cups which are varied in shape and appearance. These small to medium vessels are generally of fine quality. The fragmented state of the material sometimes made it difficult to distinguish small bowls from cups as this depends on the presence of a handle. Bowls can be divided into simple conical and hemispherical, slightly S-profiled variants. In general, cups are smaller and of better quality than bowls and fall into five main categories: shallow conical, carinated, with cylindrical upper part and a wide handle on the carination, large with horn-shaped handles (Řivnáč-cup; with parallels in the eponymous Řivnáč culture in Bohemia), and single-handled cups or dippers. A special variant of conical cups with a wavy rim has associations with the central German Bernburg culture. Among other types are miniature vessels and a large, thick-walled amphora or barrel-shaped vessel. The latter has no parallels in Bavaria, only a few Baden period amphorae or hanging vessels found in the Carpathian Basin are distant reminders (eg, Horváth 2013, 205–7 for Balatonőszöd). Preliminary XRF analysis of 11 stylistically 'non-local' sherds (Helfert & Ramminger in prep.) revealed that all were probably locally produced.

In terms of decoration, the Late Neolithic assemblage is characterised by varied plastic applications.

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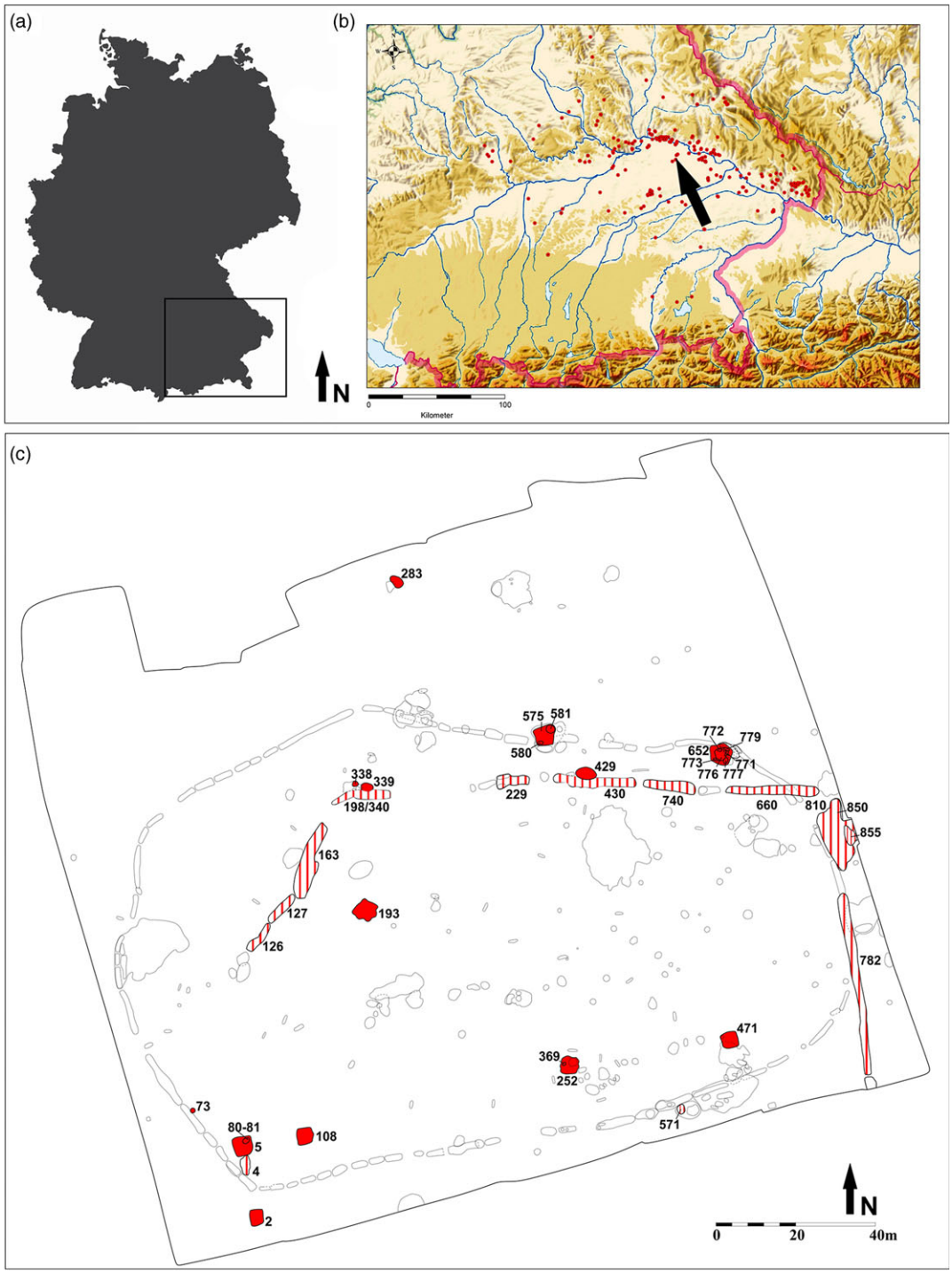

Fig. 3.
Location and plan of Riedling: Top: location of Riedling within the distribution of the Cham culture (base map: Bayerisches Landesamt für Denkmalpflege; map of Germany: freepik.com); bottom: Cham features at Riedling. Key: red: Cham features; red stripes: Münchshöfen features with a considerable amount of Cham pottery (mapping: M. Szilágyi, base map data from ArcTRon/ArcTeam)

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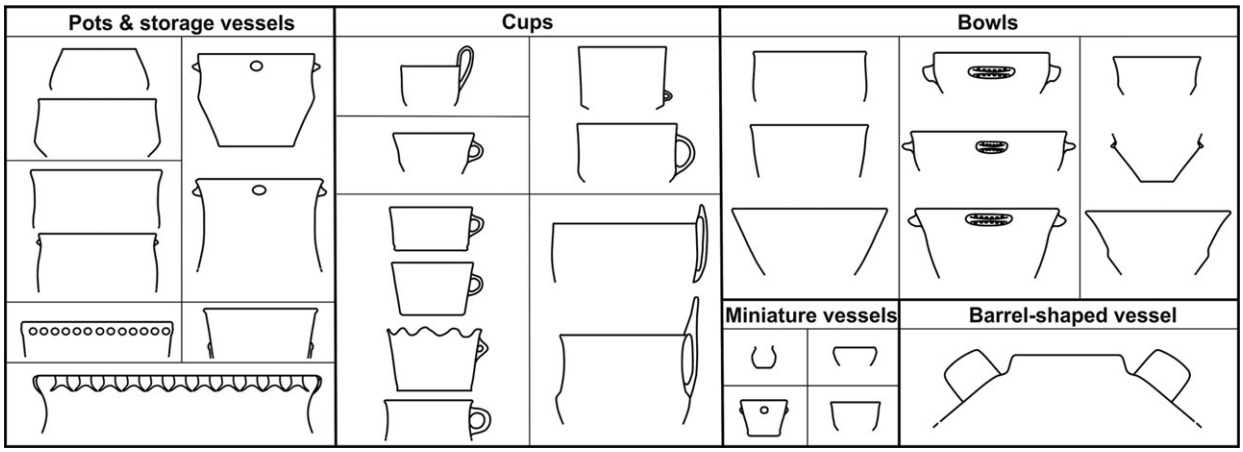

Fig. 4.
Schematic representation of the main pottery shapes characteristic of the Cham culture (drawing: M. Szilágyi)

Rounded or oval pointed knobs of different shape and size occur frequently, as do lugs and horizontally flattened long knobs with multiple vertical perforations. The wide and large handles on or around the belly line of certain vessel types can also be considered decorative, as can the *ansa lunata* or *ansa cornuta*-like large handles. Applied cordons, some with finger impressions or incisions that resemble arcade rims, are also characteristic, while incised decorations (lines and dots) are very rare.

The Riedling assemblage includes some traits common to the Cham culture in general, but also lacks many of the shapes, technological choices (eg, mica temper) and characteristic decorative elements, like cordon motifs. Notably, the proportion of non-local stylistic elements is rather high. Alongside answering questions of economy, a further aim of compound-specific lipid analysis was thus to generate absolute dates closely associated with the Cham pottery at Riedling to place it more precisely within the Cham culture through a Bayesian statistical analysis.

ADDRESSING CHAM CULTURE ECONOMY AND DATING: METHODS

Organic residue analysis of Cham pottery

The majority of potsherds sampled for lipid analysis were from cooking pots found in pit houses. Care was taken to select sherds with diagnostic Late Neolithic features. A total of 49 Cham potsherds were investigated according to well-established analytical procedures described in Appendix S2 (Correa-Ascenio & Evershed 2014) (Fig. 5). The overall lipid recovery rate was 39% (Table 1; $n = 19$). The mean lipid concentration (Table 1) was 1.0 mg g^{-1}, with a maximum lipid concentration of 4.9 mg g^{-1} (RIE068, a conical cup). A number of potsherds contained high concentrations of lipids (eg, RIE065, 3.1 mg g^{-1}, RIE068, 4.9 mg g^{-1}, RIE105, 2.2 mg g^{-1}, and RIE109, 4.1 mg g^{-1}, Table 1), demonstrating excellent preservation and indicating that these vessels were subjected to sustained use in processing high lipid-yielding commodities. The lipid extracts mainly comprised the free fatty acids ($n = 19$), palmitic ($C_{16:0}$) and stearic ($C_{18:0}$), typical of a degraded animal fat (Fig. 6; Evershed *et al.* 1997; Berstan *et al.* 2008).

GC-C-IRMS analyses were carried out on the 19 FAMEs (fatty acid methyl esters, Table 1 and Fig. 6) to determine the $\delta^{13}C$ values of the major fatty acids, $C_{16:0}$ and $C_{18:0}$, and ascertain the source of the lipids extracted. The $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids reflect their biosynthetic and dietary origin, allowing non-ruminant and ruminant adipose and ruminant dairy products to be distinguished (Copley *et al.* 2003; Dunne *et al.* 2012). Notably, ruminant dairy fats are differentiated from ruminant adipose fats when they display $\Delta^{13}C$ values of less than –3.1 ‰ (Dunne *et al.* 2012). The majority of lipid residues ($n = 13$, 68%) plot firmly within the ruminant dairy region with $\Delta^{13}C$ values of less than –3.1 ‰ (Fig. 7; Table 1) confirming that these vessels were used to process secondary products such as milk, butter, and cheese. Three vessels were used to process

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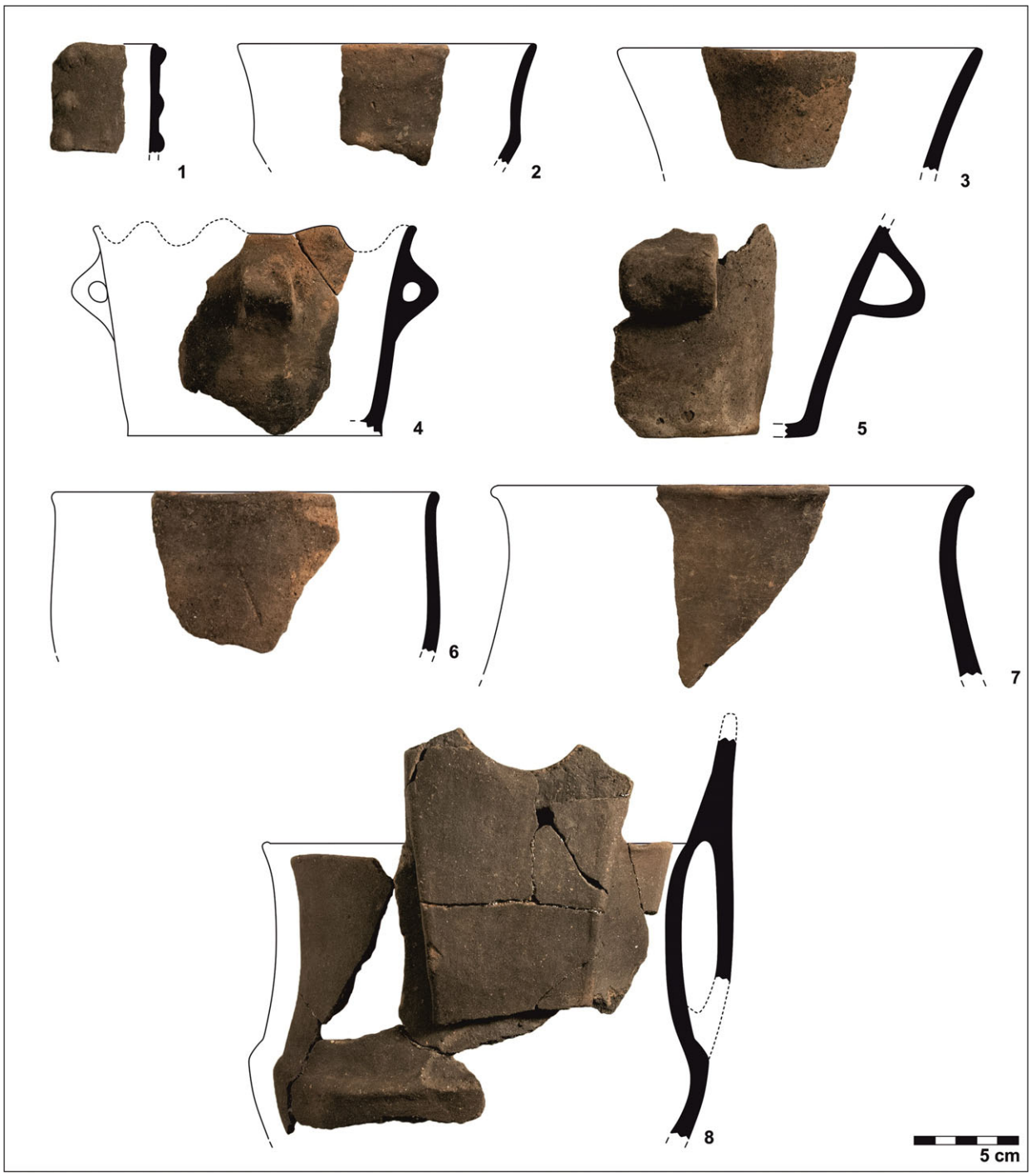

Fig. 5.
Examples of vessels from Riedling chosen for lipid residue analysis: 1. RIE105; 2. RIE078; 3. RIE065; 4. RIE066; 5. RIE068; 6. RIE074; 7. RIE088; 8. RIE109 (photos and drawing: M. Szilágyi)

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TABLE 1. CHAM VESSELS FROM RIEDLING SAMPLED FOR LIPID ANALYSIS

La. No.	*Context no.*	*Feature type*	*Find no.*	*Vessel type*	*Lipid concentration ($\mu g\ g^{-1}$)*	$\delta^{13}C_{16:0}$	$\delta^{13}C_{18:0}$	$\Delta^{13}C$	*Attribution*
RIE062	5	Pit house	337	Deep bowl	54.6	–29.7	–34.8	–5.1	Ruminant dairy
RIE063	5	Pit house	367	Late Neolithic pot (indet.)	262.6	–28.4	–33.4	–5.0	Ruminant dairy
RIE065	108	Pit house	973	Conical cup	3105.9	–28.1	–30.9	–2.8	Ruminant adipose
RIE066	108	Pit house	973	Deep cup	46.0	–28.4	–32.9	–4.5	Ruminant dairy
RIE068	108	Pit house	973	Conical cup	4906.4	–28.3	–32.6	–4.3	Ruminant dairy
RIE070	108	Pit house	825	Late Neolithic pot (indet.)	219.8	–28.9	–34.1	–5.2	Ruminant dairy
RIE074	108	Pit house	826	Slightly curved deep bowl	68.8	–27.6	–30.1	–2.5	Ruminant adipose
RIE075	108	Pit house	961	Small conical bowl	69.5	–28.6	–30.5	–1.9	Ruminant adipose
RIE077	252	Pit house	2061	Late Neolithic pot (indet.)	202.2	–27.2	–31.9	–4.8	Ruminant dairy
RIE078	252	Pit house	2061	Late Neolithic pot (indet.)	620.2	–27.9	–32.4	–4.5	Ruminant dairy
RIE079	252	Pit house	2061	Late Neolithic pot (indet.)	608.6	–28.3	–33.2	–4.8	Ruminant dairy
RIE081	252	Pit house	2063	Conical cup with large handle	64.2	–27.6	–32.3	–4.7	Ruminant dairy
RIE083	252	Pit house	2062	Conical bowl	818.6	–28.1	–33.4	–5.3	Ruminant dairy
RIE084	252	Pit house	2062	Late Neolithic pot	639.0	–28.4	–31.6	–3.2	Ruminant dairy
RIE088	252	Pit house	2060	S-profiled pot	1186.3	–28.5	–31.0	–2.5	Ruminant adipose
RIE095	850	Pit	5728	Barrel-shaped vessel	134.0	–25.9	–32.3	–6.4	Ruminant dairy
RIE102	471	Pit house	2538	Conical cup with large handle	260.5	–27.9	–33.7	–5.9	Ruminant dairy
RIE105	471	Pit house	2710	Cup with wavy rim	2213.7	–28.4	–33.6	–5.2	Ruminant dairy
RIE109	660/885	Pit house	5319	Large cup with *ansa lunata* handle	4101.2	–28.6	–31.4	–2.9	Ruminant adipose

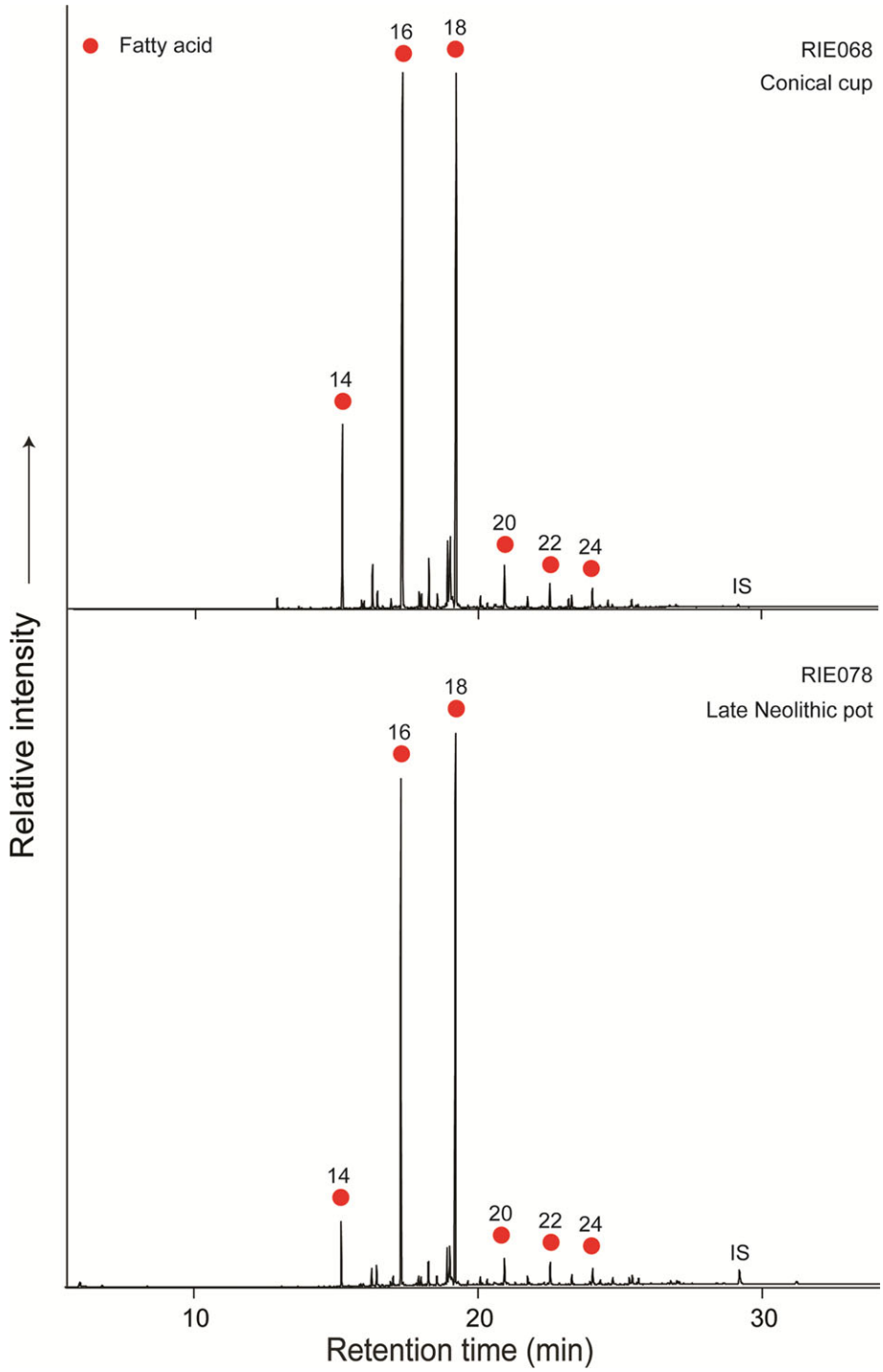

Fig. 6.
Partial gas chromatogram of acid-extracted FAMEs from Riedling pottery extracts RIE068 and RIE078. Circles, *n*-alkanoic acids (fatty acids, FA); IS, internal standard, C_{34} *n*-tetratriacontane. Numbers denote carbon chain length

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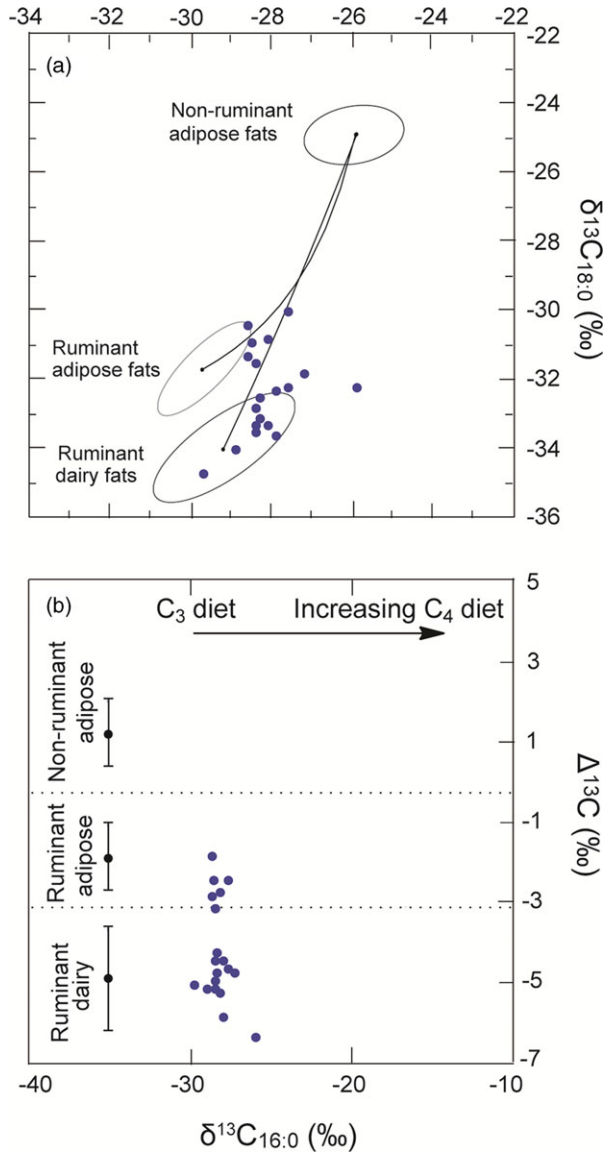

Fig. 7.
Graphs showing: a. $\delta^{13}C$ values for the $C_{16:0}$ and $C_{18:0}$ fatty acids for archaeological fats extracted from Riedling Cham culture ceramics. The three fields correspond to the $P = 0.684$ confidence ellipses for animals raised on a strict C_3 diet in Britain (Copley *et al.* 2003). Each data point represents an individual vessel; b. the $\Delta^{13}C$ ($\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) values from the same potsherds. The ranges shown here represent the mean ± 1 s.d. of the $\Delta^{13}C$ values for a global database comprising modern reference animal fats from Africa (Dunne *et al.* 2012), UK (animals raised on a pure C_3 diet) (Dudd and Evershed 1998), Kazakhstan (Outram *et al.* 2009), Switzerland (Spangenberg *et al.* 2006), and the Near East (Gregg *et al.* 2009)

ruminant carcass products (RIE074, RIE075, and RIE088, with $\Delta^{13}C$ values of –2.5, –1.9 and –2.5 ‰, respectively, Table 1). A further three vessels (RIE065, RIE109, and RIE084 with $\Delta^{13}C$ values of –2.8, –2.9 and –3.2 ‰, respectively, Table 1) plot between the ranges of ruminant dairy and carcass products, suggesting mixing of these products, either contemporaneously or over the lifetime of the vessel.

Alongside the majority Cham cooking pots, four specialist vessels were analysed, RIE065, RIE066, RIE068, and RIE105, comprising a conical cup, deep cup, conical cup, and a cup with wavy rim, respectively (Fig. 5: 3–5, 1). Notably, three of these vessels (RIE065, RIE068 and RIE105, the two conical cups and the cup with wavy rim) yielded high concentrations of lipids at 3.1, 4.9 and 2.2 mg g^{-1}, respectively, with one holding either meals made from meat, possibly stews or broths (RIE065, ruminant carcass fats), and the other two containing some form of (liquid or solid?) dairy product (RIE068 & RIE105). The deep cup (RIE066) also contained dairy products but had a very low lipid concentration at 0.04 mg g^{-1}.

Remarkably, none of the vessels analysed was used to process non-ruminant (pig) products. Furthermore, any possible exploitation of aquatic resources was investigated using the GC-MS in selected ion monitoring (SIM) mode to check for the presence of biomarkers, namely ω-(o-alkylphenyl) alkanoic acids (APAAs) and vicinal dihydroxy acid (DHYAs), which originate from the degradation of poly- and monounsaturated fatty acids found in marine or freshwater fats and oils. These are routinely used to detect marine product processing (eg, Hansel *et al.* 2004; Craig *et al.* 2007; Hansel & Evershed 2009; Cramp & Evershed 2014; Cramp *et al.* 2014). Evidence of aquatic biomarkers was not found in the Cham vessels, suggesting either that fish were not part of the diet or, alternately, that they were processed and consumed in other ways, such as salting, smoking, and so on.

Compound-specific lipid radiocarbon analyses

Compound-specific radiocarbon analyses were carried out to place the ceramic material at Riedling within the Cham culture sequence and to obtain direct dates on dairy exploitation (see Appendix S2 for methodology). Four vessels containing high concentrations

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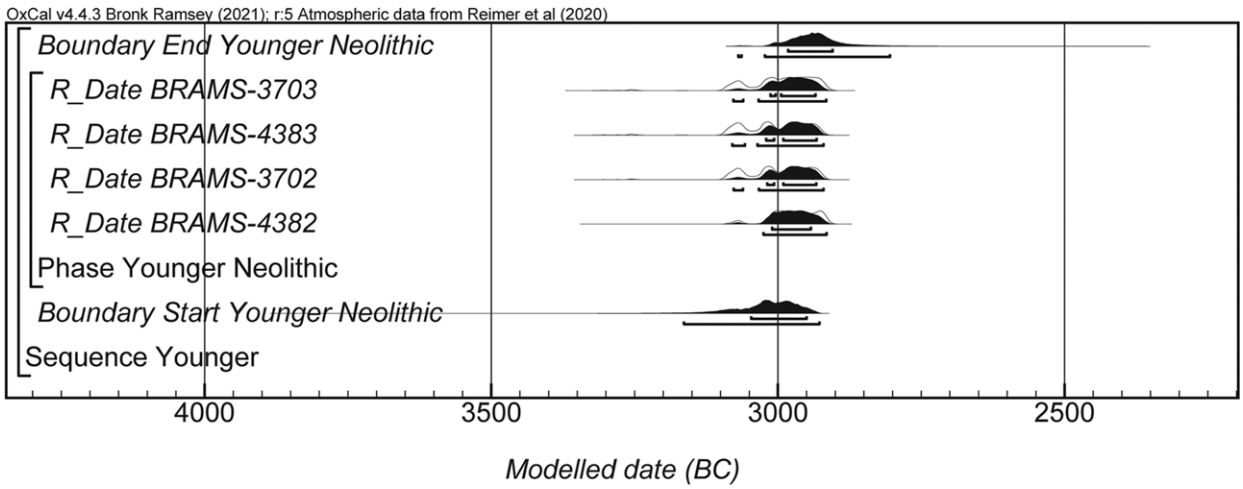

Fig. 8.
Probability distributions of radiocarbon dates on potsherds from the Cham culture phase of Riedling. Calibration was performed in OxCal v4.4.3 (Bronk Ramsey 2009) against IntCal20 (Reimer *et al.* 2020). Each distribution represents the relative probability that an event occurs at a particular time, those not related to specific samples correspond to aspects of the model. Brackets and keywords define the model exactly, the light grey colour represents the simple radiocarbon calibration and dark grey the results of the model (plot: E. Casanova)

of animal products (Table 1), RIE65 (a conical cup containing ruminant adipose fats), RIE68 (a conical cup containing ruminant dairy fats), RIE88 (an S-profiled pot containing ruminant adipose fats) and RIE105 (a cup with wavy rim containing ruminant dairy fats) were radiocarbon dated.

All potsherds provided consistent ^{14}C measurements on the $C_{16:0}$ and $C_{18:0}$ FAs, save for RIE68 which was re-measured, providing consistent measurements the second time. The ^{14}C measurements on the two FAs were combined to provide a date of 4366 ± 22 BP (BRAMS-4382, RIE65), 4394±22 BP (BRAMS-3702, RIE68), 4398±22 BP (BRAMS-4383, RIE88), and 4383±30 BP (BRAMS-3703, RIE105). These radiocarbon dates are statistically identical ($T' = 1.3$, $T'(0.05) = 7.8$, $\upsilon = 3$).

The ^{14}C dates were modelled against the IntCal20 calibration curve (Reimer *et al.* 2020). The results presented in Figure 8 suggest that the exploitation of ruminant adipose and dairy products by people using Cham material occurred between 3164–2928 cal BC (95% probability), probably in 3047–2950 cal BC (68% probability) for the earliest estimate, and 3023–2805 cal BC (95% probability), probably in 2982–2905 cal BC (68% probability) for the latest estimate.

Chronological modelling of Cham culture dates

The table in Appendix S3 details legacy radiocarbon measurements from sites from Bavaria associated with Cham pottery. These measurements were collated from existing literature; in some cases it was not possible to identify relevant details about the radiocarbon measurements (for example the nature of the sample submitted for measurement, or the stable isotope values produced during the measurement process).

From this dataset, we identified measurements produced on short-life samples or charcoal which were associated with Cham pottery. We excluded measurements from our analysis that were reported as associated with Cham material culture but had apparently been produced on residual or intrusive samples, with age estimates that are much older or much younger than the expected dates in the second half of the 4th and beginning of the 3rd millennium.

Following this assessment, we have identified 62 measurements from 13 sites (including Riedling) which we believe to be accurate estimates for the use of Cham pottery (Appendix S3). We have included these results in the analysis of the chronology of Cham pottery using OxCal v4.4 (Bronk Ramsey 2009) and the IntCal20 calibration dataset (Reimer *et al.* 2020). We have included results from an individual

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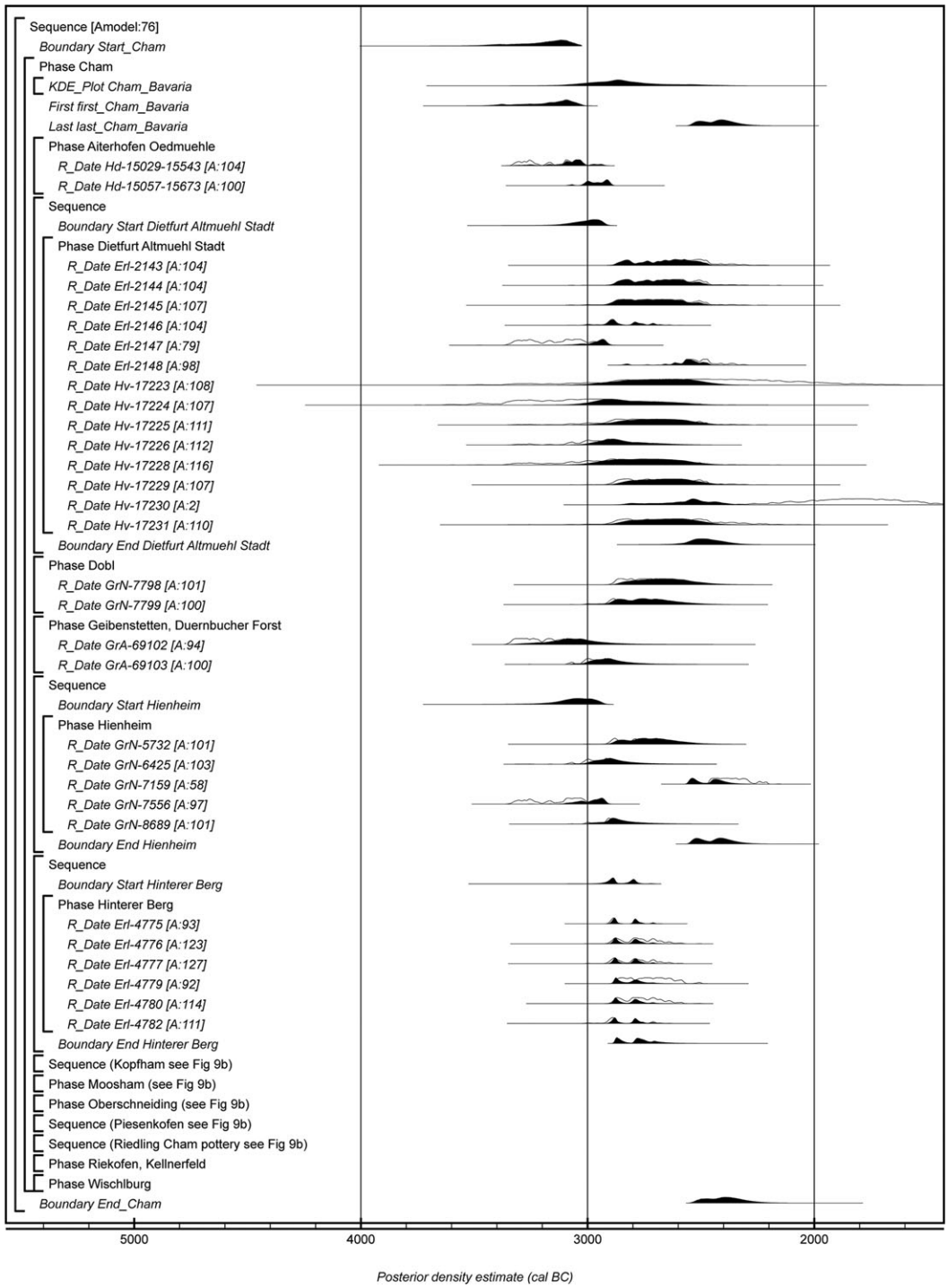

Fig. 9.
(above & opposite). Probability distributions for radiocarbon measurements associated with the use of Cham material culture in Bavaria. The brackets and CQL2 key words define the model, as does the code given in Appendix S4 (plot: S. Griffiths)

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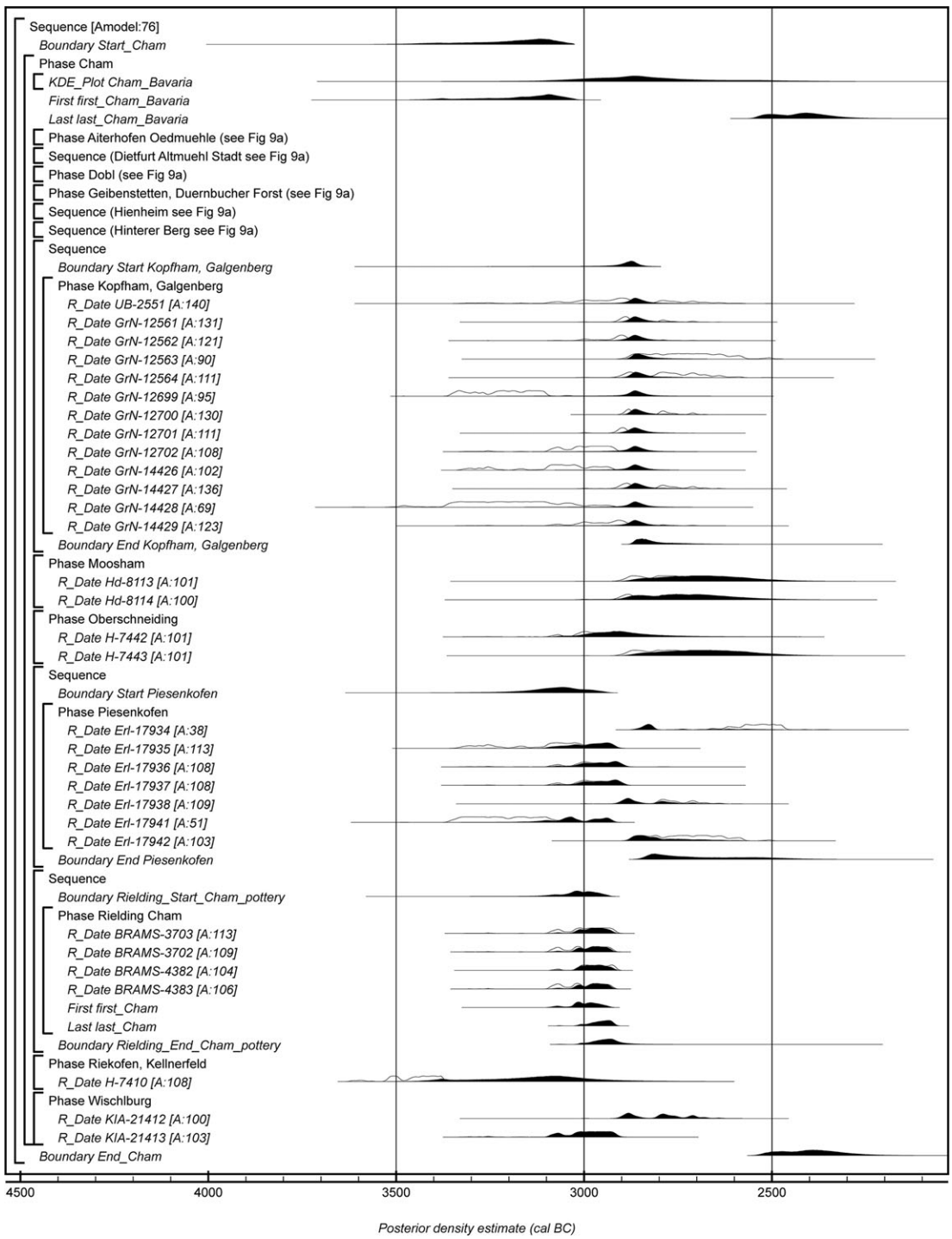

Fig. 9.
(Continued)

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site in a Boundary-defined Phase model where there are four or more measurements. Measurements on charcoal or charred woody tissue which may be subject to an 'old wood' effect have been incorporated using the charcoal outlier approach developed by Dee and Bronk Ramsey (2014) using the notation Outlier_Model("Charcoal",Exp(1,-10,0),U(0,3),"t"); and identifying measurements on unidentified charcoal as having an old wood 'outlier' effect on their ages (probability = 1). We also include an estimate for the distribution of Cham-related activity over time calculated using the Kernel Density Estimate function using the default settings within OxCal (Bronk Ramsey 2017; see Appendix S2 for further details and Appendix S4 for the code used). Kernel Density Estimates (KDE) are a non-parametric estimate for the distribution of underlying distribution of data points (in this case radiocarbon measurements), which accounts for some of the noise that would otherwise derive from the shape of the calibration curve (and is constrained in this case by the overarching Boundary-defined uniform Phase model).

We estimate that Cham material culture in Bavaria was first used at the sites listed in *3445–3030 cal BC (95%* probability; *Start*_Cham), and the end of activity associated with Cham material occurred in *2540–2230 cal BC* (*95% probability*; *End_Cham*) (Fig. 9). Overall, we have evidence that Cham material culture was used in Bavaria for some *505–1045 years* (*95% probability*; *duration_Cham*; figure not shown). The first directly dated use of Cham material culture in Bavaria occurred in *3405–3020 cal BC* (*95% probability*), most probably in *3220–3030 cal BC* (*68% probability*; *first_Cham_Bavaria*), while the last directly dated event in our dataset occurred in *2550–2285 cal BC* (*95% probability*), most probably in *2530–2470 cal BC* (*23% probability*) or in *2450–2355 cal BC* (*45% probability*; *last_Cham_Bavaria*) (Fig. 9). The first evidence we currently have for the use of Cham material culture in Bavaria probably occurred between the last decade of the 33rd century cal BC and the first three quarters of the 31st century cal BC. It was last in use between the late 26th century cal BC and mid-24th century cal BC. Our KDE estimate for the currency of Cham material culture suggests a peak in Cham-associated activity around 2900 cal BC (Fig. 10). This corresponds with the proposed earliest activity associated with the Corded Ware culture, estimated to span *c.* 2900–2000 cal BC (Furholt 2014, 68).

Our analysis of the results associated with Cham material culture from Riedling is consistent with this peak in the early 3rd millennium cal BC. We estimate the first directly dated event associated with Cham pottery at Riedling occurred in the 31st or 30th centuries cal BC – in *3045–2930 cal BC* (*88% probability*, or *3085–3055 cal BC, 7% probability*), or most probably in *3030–2960 cal BC* (*68% probability*; *first_Cham*), while the last such event probably occurred in *3015–2910 cal BC* (*95% probability*), most probably in *2980–2920 cal BC* (*68% probability*; *last_Cham*) (Fig. 11). It seems that activity associated with Cham pottery ended in the 30th century cal BC. With our current data, the use of Cham pottery at Riedling appears relatively short-lived, between *1–110 years* (*95% probability*), but most probably between *1–50 years* (*duration_Cham_pottery*; figure not shown). It should, however, be emphasised that there are relatively few measurements from Riedling and that some measurement on materials from mixed Münschhöfen and Cham contexts were excluded from this analysis.

Additional direct-radiocarbon measurements on Cham pottery and other contemporaneous pottery styles would help ensure the full span of the Cham culture and its relationship to other ceramic traditions are more robustly understood. The results presented here suggest a possible chronological overlap between the use of Cham and Corded Ware pottery in southern Germany.

Summary of results

In summary, lipid analysis has revealed the exploitation of ruminant adipose and dairy products at Riedling, with the clear dominance of milk lipids suggesting a strong reliance on secondary products. Compared to the results for the preceding Münchshöfen culture phase, when dairy was not represented (Dunne *et al.* in prep.), this suggests that a shift towards a dairying economy had taken place by Cham times. Our dating programme suggests that people using Cham material were indeed present in Bavaria until the onset of the Corded Ware horizon, but the data are currently not detailed enough to reliably identify any chronological overlap.

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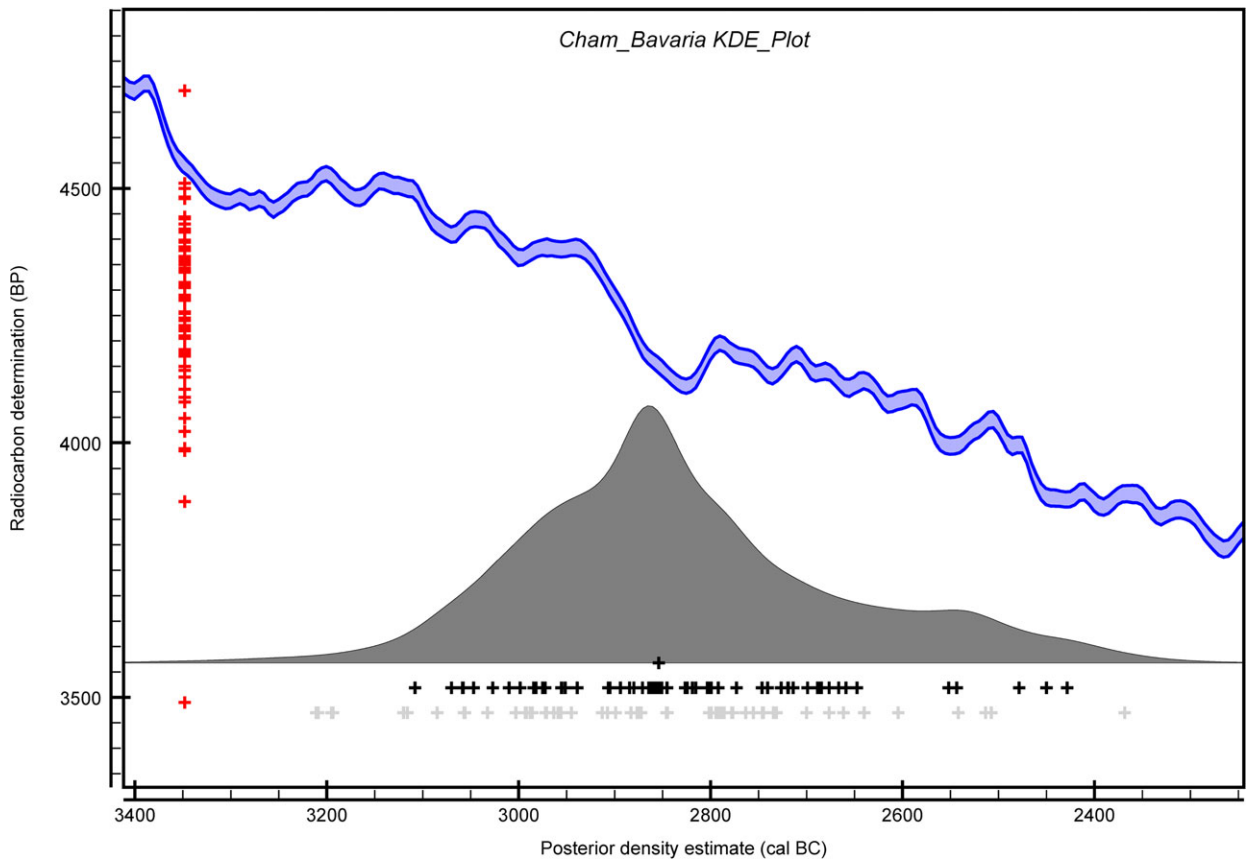

Fig. 10.
The output of the KDE_Plot as calculated in the model shown in Fig. 9. The distribution provides an estimate for the underlying distribution of the radiocarbon measurements within the overall Boundary-defined uniform Phase model for Cham pottery in Bavaria (plot: S. Griffiths)

DISCUSSION

The Cham culture economy in its wider context

Although we have only been able to sample vessels from one Cham culture site so far, the dominance of ruminant dairy lipids, lesser amounts of ruminant carcass fats, together with the absence of porcine fats, all support the scenario of an economic strategy focused on secondary products, possibly implying a higher degree of herding-related mobility, at least for parts of the population. This could be an adaptation to either climatically or socially more volatile situations but would also have been a factor in maintaining the far-flung contacts indicated by Cham pottery. Through such networks, new ideas, and practices – and potentially new genes – could have begun to reach Bavaria before the archaeologically visible beginning of the Corded Ware phenomenon. Indeed, elements of the Corded Ware burial rite could already have been introduced into Bavaria at the end of the Cham culture but this currently relies on a few, not formally modelled, radiocarbon dates from unfurnished burials (eg, Engelhardt 1998).

The scenario of increased mobility as part of a more sustained exploitation of secondary products remains speculative but demonstrates the necessity for a programme of lipid analysis at a wider range of sites, alongside a synthesis of all Cham culture faunal assemblages, isotopic analysis on animal bones, and a systematic dating programme to reliably distinguish regional from chronological patterning. However, this

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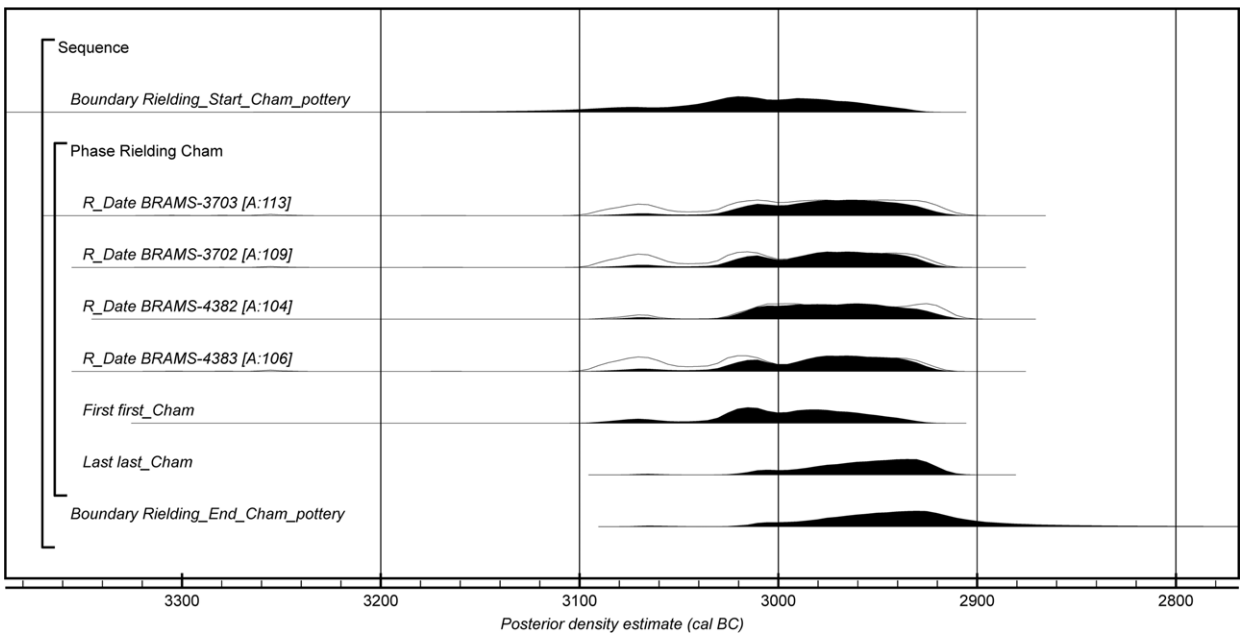

Fig. 11.
The detail of the model shown in Fig. 9 for the results robustly associated with Cham pottery from Riedling. The brackets and CQL2 key words define the model, as does the code given in Appendix S4 (plot: S. Griffiths)

characterisation of Cham culture economy and mobility is not out of place in the wider central European Neolithic horizon of this time.

For instance, the long-term isotopic study of human dietary patterns in the Middle Elbe-Saale area by Münster *et al.* (2018, 10) indicates an increasing use of animal products in the diet, which is consistent with the evidence for intensified dairying practices presented here. In Bavaria, protein analysis on a small number of surface residues on pottery from the wetland settlement of Pestenacker, associated with the Altheim culture and dendrochronologically dated into the 35th century BC, also suggests some possible exploitation of dairy products, although this was a very small sample size (Oudemans *et al.* 2019). Ruminant dairy fats were identified in pottery from the Swiss lake village site of Arbon-Bleiche 3 (Spangenberg *et al.* 2006, 11), dated to the Horgen culture (*c.* 3400–2700 BC), which roughly parallels Cham chronologically. Further north, pottery of the Globular Amphora culture (*c.* 3100–2300 BC) from the megalithic grave of Wangels and a domestic site at Oldenburg, northern Germany, yielded evidence for the exploitation of dairy products (Weber *et al.* 2020). The Globular Amphora culture is also particularly well known for cattle burials (eg, Pollex 1999; Szmyt 2006).

In general, this time horizon sees variability in economic choices, both spatially and chronologically. This is best demonstrated by the circum-Alpine lake village horizon with its short, sub-generational, settlement phases, where small groups of households within each site made their own choices regarding which resources to focus on (eg, Doppler 2013; Ebersbach *et al.* 2017). At a broader level, Jörg Schibler (Schibler 2006; Schibler *et al.* 1997; Kerdy *et al.* 2019) has argued that Horgen period groups reacted flexibly to deteriorating climatic conditions by first increasing reliance on game for their meat supply and later intensifying pig husbandry. The role of cereal cultivation and, in particular, whether this happened either as part of a slash-and-burn or an intensive garden-style cultivation regime, is still debated (see, for instance, Jacomet *et al.* 2016), but there was possibly experimentation with diverse strategies alongside the continued exploitation of wild plant resources. Recent isotopic work (Siebke *et al.* 2020) also suggests marked regional differences in protein consumption patterns. While this level of work is yet to be paralleled in other regions of central

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Europe, our expectation is that a thorough inter-regional exercise synthesising the available data would reveal a general trend towards flexibility and diversification (as also suggested by comparative isotopic studies, eg, Scheibner 2021, 315–6).

So far, then, there is no reason to suggest a unitary horizon of behaviour across central Europe at this time. For example, the extent of symbolic elaboration accorded to cattle in the Globular Amphora culture area is not paralleled in either the Alpine Foreland or the Cham culture. Similarly, the very presence of cattle in itself need not imply a particularly mobile lifestyle (see, for example, Winter-Schuh *et al.* 2018). On the Great Hungarian Plain, increasing human mobility and a greater reliance on animal exploitation precede the introduction of new herding strategies and larger-scale milk consumption by several centuries (Hoeckmann-Sites & Giblin 2012). What does become apparent behind all this diversity, however, is that a shift towards a wider range of economic strategies was widespread at this time and that, in several cases, this involved a greater reliance on animal husbandry. For Riedling itself, given the high incidence of dairy lipids, our results suggest a fully-fledged dairying economy was in place. This marks a significant change in the scale of dairy production compared to, for example, the Early Neolithic Linearbandkeramik (eg, Matlova *et al.* 2017) and is in line with the circumstantial evidence for at least partly mobile groups sketched out above.

Vessel use: cups that cheered?

The Riedling cups containing lipid residues (Fig. 5) are all of small, open, form, with estimated rim diameters rarely exceeding 200 mm. These are likely made for individual use and are presumably too small to have functioned as cooking vessels. The high lipid concentrations in three of these vessels (RIE065, RIE068, and RIE105: the two conical cups and the cup with wavy rim) suggest they underwent sustained use, presumably as individual serving dishes, with one (RIE065) holding ruminant carcass fats and the other two (RIE068 and RIE105) containing some form of dairy product. The deep cup with low dairy lipid concentrations (RIE066) was possibly only used infrequently or, bearing in mind that it is hot-processing that aids in the absorption of lipids into ceramic walls, was used to store or serve cold foods, possibly raw milk. Cups of this kind are often hypothesised to be used for consuming beer or other alcoholic drinks (eg, Sherratt 1987 – from whom the title for this section has been taken; Turek 2020). Our somewhat surprising results for the contents of these cups hence raise significant questions on the use and cultural significance of this vessel form at this time.

Whilst defining vessel function is complex, a strong correlation between form and function is often assumed (Rice 1987, 211–12; Santacreu *et al.* 2017). Yet ceramic use is a matter of deliberate cultural choice, possibly relating to specific customs or prohibitions, rather than necessarily to technological choice or specific performance characteristics (Dunne *et al.* 2018). Furthermore, the intended and the actual function can differ and use, re-use, and multi-functionality can make determinations of vessel function difficult (Skibo 2013, 4–5). Obvious shapes, such as handled cups, are often associated with drinking, while morphological and technological characteristics such as fine fabrics, size, and an opened or necked form, as well as lavish decoration, are frequently taken to imply use for 'special' occasions, such as communal consumption (see, for instance, Urem-Kotsou *et al.* 2002; Füzesi & Raczky 2018, 72–9).

Vessel shapes that suggest drinking (cups) do not appear in the Bavarian Early and Middle Neolithic (Pechtl 2015, fig. 29.4; Riedhammer 2017, Abb. 149). However, from the Münchshöfen culture onwards, we see the first vessel type associated with individual (or small group) drinking – the beaker. These are small conical decorated vessels, normally with two pairs of holes on one side where organic handles were fixed (Süss 1976, 32). One-handled cups are seen in later Münchshöfen phases (Bürger 2004) and are also frequent in the contemporary Jordanów-Jordansmühl culture of Bohemia (Zápotocky 2016, 10–11). Such handled vessels (cups and jugs) have also been documented in the following Altheim period, where they were always of fine quality (Driehaus 1960, 72, Taf. 3).

In the next phase, immediately preceding the Cham culture, one-handled cups become very frequent in Central Europe. The cups or dippers of the Baden complex match all criteria of individual drinking vessels and occur in large numbers. There are also indications that the social role of these vessels had changed and that in the second half of the 4th millennium they were an object whose significance was recognised across a vast area from the Carpathian Basin to Bavaria and other parts of central Europe.

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In the Carpathian Basin, cups often occur as grave goods in Baden cemeteries. Small or medium-sized cups, dippers, mugs, pitchers, beakers, jugs, and scooping vessels were abundant in the cemetery of 436 graves in Budakalász, Hungary; 133 such vessels were found in the 153 graves that contained pottery (Bondár 2009, 246–85). The same situation can be observed in another cemetery along the Danube, Pilismarót, where approximately two-thirds of the 116 graves contained such drinking vessels (Bondár 2015, 160–91). According to Horváth (2013, 467–516), dippers, cups, and mugs could contain at most 0.3 litres of liquid, whereas most jugs and pitchers could contain 0.5–1 litre.

Sets of vessels are also frequently deposited in ritual contexts, for example, at Donnerskirchen in Austria, where a collection of 15 complete and elaborately decorated Baden culture vessels had been buried together, including five small cups. The Baden culture area also sees many smaller deposits of 3–5 pots, generally exclusively consisting of drinking vessels (Kaus 1984, 14–9). The most frequent interpretation therefore is that cups, beakers, and associated items are the material expression of a new style of beverage consumption, most likely in the context of communal feasting and therefore linked in some way to socio-economic status (Turek 2020, 410–1). Although few such vessels have hitherto been analysed, this would imply that an appropriately special beverage, probably alcoholic, was being served.

The Riedling cups match the criteria of other vessels defined as being used for individual consumption and/or drinking vessels. Most of the cups with large handles are made of fine fabric and have an appropriate size and form. Moreover, they comprise the few decorated pieces of Cham pottery at the site. At this time, such vessel types are well-known outside of the area in which Cham assemblages occur. Similar types are, for instance, frequent in the Middle Elbe-Saale area in central Germany from Bernburg-type assemblages (eg, Torres-Blanco 1994). These vessels therefore fit into a pan-central European concern with new ways of liquid consumption and illustrate the far-flung connections that people using Cham material culture maintained.

The presence of milk or milk products in three of the four cups analysed is clearly noteworthy. How then to explain their use? At first glance, the consumption of milk-based drinks in these (socially valued) vessels is certainly hard to reconcile with long-held notions of alcohol-fuelled (possibly élite) feasts, where a cup of hot milk seems unlikely to have been the beverage of choice. Three possibilities can be suggested. First, the presence of dairy lipids in the cups indicates a milk-based product rather than beer, either 'raw' or heated milk. Bearing in mind that, in the absence of cooling, lactic acid bacteria would quickly turn milk sour (Rosenstock *et al.* 2021), a fermented milk drink is a possibility, although the identification of fermentation biomarkers is notoriously difficult (Whelton *et al.* 2021). If this was the case, some kind of feasting function for some of the Cham vessels can still be suggested. The analysed Řivnáč-type jug (RIE109) of very good quality and special form (Fig. 5: 8) could also fit this pattern. This large vessel containing ruminant carcass lipids may have been used as a central container to serve meat stews or soups, perhaps in communal dining. Good parallels for similar large one-handled jugs can be found throughout Bohemia in Řivnáč-type finds (eg, Zápotocký & Zápotocká 2008, 174).

Secondly, both the cups and the jug could alternatively (also) have been used for day-to-day consumption. Regular use would explain the high lipid concentrations observed in two of the three cups and in the jug. In this case, Cham culture cup users were clearly consuming significant amounts of milk in their daily lives, as also indicated by the high incidence of dairy lipids in other pot shapes. The fact that these vessels are aesthetically pleasing would then not equate with a special role in public status display, although it could still have been linked to particular kinds of persons, perhaps those of higher status. Thirdly, and partly connected to this point, we could also consider a general broadening out of who these 'particular kinds of persons' may have been. In analogy with Balkan Neolithic bone spoons, long thought to be a prestigious ritual artefact but recently revealed to have been used in feeding infants (Stefanović *et al.* 2019), the artefacts perceived as high status or special by archaeologists could, in practice, have been used by a wide range of social actors. While the Cham culture cups have no particular characteristics that would make them especially suitable for use by small children themselves (in contrast to the Bronze Age vessels with spouts discussed in Dunne *et al.* 2019, for instance), they could easily have been used in supplementary feeding practices and by slightly older children, as well as adults. In either case, we have demonstrated that the perceived health

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benefits of a dairy-rich diet, cited by Wilkin *et al.* (2021, 4) as crucial for population expansion from the steppe, were in fact already attainable in central Europe before the arrival of new populations.

CONCLUSION: CULTURAL CHANGE IN THE EARLY 3RD MILLENNIUM

Our study has revealed that a high proportion of Cham culture vessels contained milk fats. This includes drinking cups, some of them inspired by non-local styles, and therefore raises further questions regarding the role of these objects, previously associated with elite male alcohol consumption. For our material, this link is only one of several possible ones, dependent on the (entirely hypothetical) fermentation of milk. Thus, perhaps we need to rethink the role of cups in conveying high social status and instead associate them with the realm of everyday practices? This would fit with use-wear evidence on Corded Ware stone battle axes from the Netherlands, also generally associated with male warrior status but, in fact, used for rather more mundane activities, such as field clearance (Wentink 2020, 115–26). Alternatively, if we retain the idea of cups as highly symbolic artefacts, we need to rethink the role of milk, which may, for example, have been seen as particularly health-giving. However, a strict division between the functional and everyday, the value-laden and the special, may, in any case, be not appropriate. Breaking down this division could open up our interpretations to consider the role of cup users other than adult warrior males – for example women or children – and the ways they may have been involved in the production of symbolic and social value in the Late and Final Neolithic.

The results and comparanda we have compiled here, although based on a small sample, also fit into a growing body of archaeological work (eg, Furholt 2021) suggesting that a fundamental rethink of the transition to the Corded Ware horizon might be in order. For our Bavarian case study, this is, amongst others, indicated by the potential overlap of Cham pottery-using and Corded Ware pottery-using communities. Although the sample of ^{14}C dates remains small, it appears that Cham culture activity continues into a time when Corded Ware pottery is already in use in southern Bavaria, as also evidenced by the similarly late dates for the Cham-related Burgerroth group in Franconia (Link 2016, 122) and by the presence of Corded Ware beakers in the upper layers of Cham sites (eg, Gohlisch 2005, 186). In addition, our lipid data show that the shift towards a greater reliance on dairy products and a greater role for mobility in economic strategies, classically associated with the Corded Ware culture, evidently has deeper roots.

All this points to a scenario that differs quite substantially from the 'massive migration' postulated by Haak and colleagues (2015). Indeed, as more aDNA evidence becomes available the appearance of 'steppe' signatures can now be dated to as far back as the mid-5th millennium in south-eastern Europe (Gaydarska *et al.* 2022; Preda-Bălănică and Dieckmann 2023) and, in some regions such as Switzerland (Furtwängler *et al.* 2020), there was evidently long-term coexistence and admixture of people with 'Neolithic farmer' and 'steppe' ancestries. Thus, although the Corded Ware culture was largely spread by migrating individuals, by the early 3rd millennium their way of life may actually have been rather similar to that of their host societies in central Europe. In addition, these Corded Ware settlers hardly destroyed every society in their path, as Kristiansen *et al.* (2017) seem to imply. Rather, for a few generations at least, there may have been a patchwork situation, calling for new and more nuanced models of interaction.

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SUPPLEMENTARY MATERIAL

To view the supplementary material for this article please visit https://doi.org/10.1017/ppr.2023.3

NOTE

[1]A full report of the Riedling excavations is currently in progress and will be completed in 2024 (provisional title D. Hofmann, M. Szilágyi & L. Husty (eds), *Coming Together, Keeping Apart. Neolithic Networks and Society at the Münchshöfen Enclosure and Cham Site at Riedling, Lower Bavaria*). It will contain a fuller synthesis of the Bavarian Cham culture, as well as further results of lipid analysis by Julie Dunne *et al.*, the animal bone report by Jörg Ewersen, and pottery sourcing data generated by Britta Ramminger and Markus Helfert.

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RÉSUMÉ

La voie lactée: mobilité et économie au début du 3ème millénaire bc en Europe centrale méridionale, de Julie Dunne, Márton Szilágyi, Emmanuelle Casanova, Seren Griffiths, Richard P. Evershed et Daniela Hofmann

À la suite de discussions sur les changements sociaux attribués à l'arrivée de la culture de la Céramique cordée en Europe centrale, nous examinons ici les stratégies économiques d'un des complexes culturels qui précèdent immédiatement le Néolithique final. La culture Cham du sud de la Bavière se caractérise par une variété de choix économiques, mais des problèmes subsistent quant à la synthèse et la combinaison des preuves archéozoologiques et archéobotaniques. L'analyse des résidus lipidiques de la poterie de la culture Cham trouvée au site d'habitation de Riedling, en Basse-Bavière, nous permet d'identifier une économie basée sur les produits laitiers à cette époque. Les dates radiocarbone obtenues sur composés lipidiques spécifiques sont ensuite combinées avec celles d'autres échantillons pour fournir une estimation formelle de la durée d'activité à Riedling et le premier modèle chronologique bayésien de la culture Cham dans son ensemble. Bien que les données ne soient actuellement pas suffisamment précises pour faire la distinction entre les modèles en concurrence pour la période d'occupation du site, nous suggérons que le modèle de culture Cham fait partie d'une tendance plus générale en l'Europe centrale, d'une plus grande mobilité et d'une plus grande flexibilité économique chez les groupes précédant la Céramique cordée. Nous concluons que les principales stratégies économiques autrefois associées aux 'invasions des steppes' étaient déjà présentes dans les siècles antérieurs. Enfin, l'utilisation démontrée de gobelets pour des produits à base de lait, par opposition aux boissons alcoolisées comme suggéré précédemment, nous amène à proposer des alternatives possibles pour l'utilisation de ces objets et ceux qui s'en servaient.

ZUSAMMENFASSUNG

Die Milch macht's: Mobilität und Wirtschaft an der Wende zum 3. Jahrtausend im südlichen Mitteleuropa, von Julie Dunne, Márton Szilágyi, Emmanuelle Casanova, Seren Griffiths, Richard P. Evershed und Daniela Hofmann

Vor dem Hintergrund der Diskussionen über die sozialen Veränderungen, die mit der Ankunft der Schnurkeramischen Kultur in Mitteleuropa verbunden werden, untersuchen wir hier die wirtschaftlichen Strategien eines der Kulturkomplexe des unmittelbar vorangehenden Spätneolithikums. Die Chamer Kultur in Südbayern zeichnet sich durch eine Vielzahl von ökonomischen Präferenzen aus, aber die Synthese und Zusammenführung archäozoologischer und archäobotanischer Daten bereitet nach wie vor Probleme. Anhand der Analyse von Lipidresten aus Keramik der Chamer Kultur aus der unbefestigten Siedlung von Riedling, Niederbayern, die vollständig ergraben wurde, gelang es uns, eine Milchwirtschaft in dieser Zeit zu identifizieren. Verbindungsspezifische Lipid-Radiokarbondaten werden dann mit anderen Daten kombiniert, um eine formale Schätzung der Dauer der Aktivität in Riedling zu erlangen und das erste Bayes'sche chronologische Modell für die Chamer Kultur als Ganzes zu erstellen. Obwohl die Daten derzeit nicht feinauflösend genug sind, um zwischen konkurrierenden Modellen für die Dauerhaftigkeit des Ortes zu differenzieren, schlagen wir vor, dass das Muster der Chamer Kultur in einen breiteren mitteleuropäischen Trend zu größerer Mobilität und wirtschaftlicher Flexibilität im prä-schnurkeramischen Horizont passt, und kommen zu dem Schluss, dass wichtige wirtschaftliche Strategien, die bisher mit „Steppeninvasionen" in Verbindung gebracht werden, bereits in den vorangegangenen Jahrhunderten vorhanden waren. Schließlich führt die nachgewiesene Verwendung von Trinkgefäßen für Milchprodukte – im Gegensatz zu alkoholischen Getränken, wie zuvor angenommen – dazu, dass wir mögliche alternative Nutzungen und Nutzende für diese Gefäße vorschlagen.

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RESUMEN

El camino de la leche: movilidad y economía en la transición al III milenio en el sur y centro de Europa, por Julie Dunne, Márton Szilágyi, Emmanuelle Casanova, Seren Griffiths, Richard P. Evershed y Daniela Hofmann

A la luz de las discusiones ocasionadas en torno a los cambios sociales atribuidos a la llegada de la cultura de la cerámica cordada en Europa central, se plantea la investigación de las estrategias económicas de uno de los complejos culturales que inmediatamente les precede en el Neolítico final. La cultura Cham del sur de Bavaria está caracterizada por una gran variedad de elecciones económicas, pero persisten problemas para sintetizar y combinar la evidencia arqueozoológica y arqueobotánica. A través del análisis de lípidos de la cerámica de la cultura Cham excavada en el asentamiento de Riedling, Bajo Bavaria, hemos sido capaces de identificar una economía basada en los productos lácteos en estos momentos. Las dataciones radiocarbónicas de los componentes específicos de los lípidos se han combinado con otras muestras para aportar una estimación formal para la duración de esta actividad en Riedling aportando el primer modelo cronológico Bayesiano para la cultura Cham. Aunque los datos actualmente no están lo suficientemente depurados para distinguir entre modelos convincentes sobre la ocupación del sitio, sugerimos que el patrón de la cultura Cham se integra en una tendencia de mayor movilidad y flexibilidad económica en el horizonte pre-cordado en Europa central, concluyendo que estas estrategias económicas clave asociadas con "invasiones de la estepa" estaban ya presentes en las centurias previas. Finalmente, el uso de las copas para productos lácteos, a diferencia de las bebidas alcohólicas como se sugirió

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