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In Memoriam
Professor Tatjana Bregant (1932–2002)

Many of you knew and worked with the respected Professor Tatjana Bregant years before me. You were her colleagues and co-workers in the research at Ljubljansko barje and Celje Castle, and in Lupljanica and Obre in Bosnia. You saw and knew the aspirations she had, and the energy she put into establishing the chair of "Neolithic Archaeology" and the study and research programmes at the Department of Archaeology and the Science Institute of Filozofska Fakulteta in Ljubljana.

As we say our goodbyes, let us remember some of her work, which will always be an important part of Slovenian archaeology: her teaching of generations of graduates and post-graduates; her systematic research work and protective excavations at Ljubljansko barje and then at Celje Castle; her pioneering work in establishing interdisciplinary research, and the research foundations she laid in studies of castle compounds and medieval pottery; and last, but not least, her many years as the editor of the *Reports on researching the Palaeolithic, Neolithic and Eneolithic in Slovenia*.

Professor Tatjana Bregant died one day before her seventieth birthday. The Department of Archaeology at Filozofska Fakulteta in Ljubljana saw her graduate, receive her Ph.D., and then head the Neolithic teaching and research programmes until her retirement. She headed the research project *The Neolithic and Eneolithic of Slovenia*. She chaired the Prehistory Section of the Yugoslav Association of Archaeological Societies and the Prehistory Section of the Slovenian Archaeological Society. For twenty years she was the successful editor of the journal *Poročilo o raziskovanju paleolita, neolita in eneolita v Sloveniji III–XXI*, known as *Documenta Praehistorica* recently. She will not be forgotten.

Introductory remarks

Volume *XXIX* of *Documenta Praehistorica* – the *9th Neolithic Studies* anthology, comprises papers originally presented at the eighth international *Neolithic Seminar – The Neolithization of Eurasia – Perspectives from Pottery* at the Department of Archaeology, in November 2001. All the papers given by the invited speakers are included in revised form in this volume.

The authors shared expertise on and considered three analytical and interpretative complexes:

- the Mesolithic-Neolithic transition in Scotland and the rapid spread of farming across the British Isles and southern Scandinavia, which coincided with a shift to a more continental-type climate; the transition to farming on the Japanese archipelago, and economic and social stability in the Jomon period; the earliest pottery appearance in China (Miaoyan in Guangxi Province, Xianrendong, and Diaotonghuan in Jiangxi Province) and the Russian Far East (the Osipovka and Gromatukha complexes); the principles of direct pottery dating;
- the possibility of major innovations in food-processing in the millennia following the introduction of farming; the residue analysis of ceramic and the development of dairying in Europe; lipid extracts of archaeological pottery vessels and the identification of animal fats via compound specific $\delta^{13}C$ values of individual fatty acids;
- the studies of pottery functions and problems in determining the use of the vessels from archaeological contexts and a discussion of Neolithic society in Greece in terms of the use, function, distribution and discarding of pottery: the Makriyalos case study in Northern Greece; the final stage of the life of most Neolithic vessels and their ultimate disposal: the Polgar case study in North East Hungary.

Radiocarbon dates in this volume use the convention bp and bc for uncalibrated radiocarbon years. BP and BC are used to indicate calibrated radiocarbon dates unless otherwise noted by the authors.

Ljubljana, November 2002

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Documenta Praehistorica XXIX

The Mesolithic-Neolithic transition in western Scotland and its European context[1]

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ABSTRACT – *The transition is considered in terms of four related questions: (i) HOW did the shift from foraging to farming happen? (ii) WHY did it happen? (iii) WHEN did it happen? (iv) WHY did it happen WHEN it did? The adoption of farming coincided with a shift to a more continental-type climate with lower winter precipitation, which improved the prospects for cereal cultivation. It is suggested that this was a key factor in the transition from Mesolithic to Neolithic across north-west Europe as a whole.*

IZVLEČEK – *Mezolitsko-neolitski prehod obravnavamo glede na štiri povezana vprašanja: (i) KAKO se je zgodil prehod iz lovstva-nabiralništva v kmetovanje? (ii) ZAKAJ se je zgodil? (iii) KDAJ se je zgodil? (iv) ZAKAJ se je zgodil, KO se je zgodil? Do prevzema kmetovanja je prišlo v času, ko so klimatske razmere postale bolj kontinentalne in zimske padavine manj obilne. To je izboljšalo pogoje za gojenje žit. Menimo, da je bil to ključni dejavnik za prehod iz mezolitika v neolitik v celotni severozahodni Evropi.*

KEY WORDS – *Mesolithic; Neolithic; transition to farming; Scotland; Northwest Europe*

INTRODUCTION

The Mesolithic and Neolithic have figured prominently in the literature on Scottish prehistory, but almost invariably have been treated separately. Comparatively little has been written about the actual *transition* from one to the other. This may seem surprising given that the Mesolithic-Neolithic transition was a time of fundamental economic, social and technological change.

The reason is not hard to identify. Archaeologists have tended to specialize in one period or the other, and in the process have developed very different approaches and theoretical frameworks. While Mesolithic specialists have concerned themselves largely with economic and technological issues, Neolithic specialists have placed much more emphasis on social questions. The result is a conceptual divide (*cf. Thomas 1988*) across which little interaction takes place and which, in effect, has acted as a barrier to research.

This paper is an attempt to bridge that divide and to provide a fresh perspective on the subject. It looks at the transition from Mesolithic to Neolithic in terms of four related questions: (i) *How* did the shift from foraging to farming happen? (ii) *Why* did it happen? (iii) *When* did it happen? (iv) *Why* did it happen *when* it did?

1. This paper was presented at an international conference in Edinburgh in November 1999 on the theme, Mesolithic Scotland: the Early Holocene Prehistory of Scotland and its European Context. Whilst the text has not been revised, the opportunity has been taken to update the bibliographic references.

HOW DID IT HAPPEN?

There are two competing (but not necessarily mutually exclusive) explanations of the spread of agriculture into the British Isles and, ultimately, western Scotland. One is that it occurred primarily through colonization by immigrant farmers (*e.g. Case 1969; Bradley 1984*). The alternative is that it came about through a process of 'neolithization' – the transfer of ideas, resources and technology to the indigenous Mesolithic population from Neolithic farming communities on the European mainland (*e.g. Dennell 1983; Kinnes 1985; Williams 1989; Thorpe 1996; Whittle 1999*).

The immigration model

The immigration model rests on three principal lines of evidence: (i) the apparently abrupt disappearance of Mesolithic culture and its replacement by new forms of artefacts, burial customs and monumental architecture with clear parallels on the continent, (ii) the strong temporal coincidence between changes in economy and material culture, and (iii) the lack of settlement continuity across the Mesolithic-Neolithic transition.

The strongest argument for colonization from mainland Europe lies in the broad similarity of the Neolithic between the two regions. Though there are precedents on the Continent for the monument types and some of the portable artefacts that characterize the Early Neolithic of Britain and Ireland, it has always proved difficult to identify the specific region, or regions, from which colonists would have entered the British Isles.

Other key elements of the immigration model are also open to question. Abrupt culture change and settlement relocation are not *proof* of the arrival of a new people. Rather, it can be argued that they were a predictable outcome of the economic transformation that characterized the Mesolithic-Neolithic transition, regardless of the demographic context. Hunter-gatherers taking up agriculture can hardly be expected to have done so equipped only with their existing Mesolithic toolkit, which was not designed for the purpose. There would be a need to invent or adopt new technology. Moreover, if agriculture were the primary means of food production from the beginning of the Neolithic – as appears to have been the case in western Scotland, if not throughout the British Isles – then people are likely to have invested heavily in the new technology from the outset, and much less in forms of technology related exclusively to hunting, fishing and gathering which were of lesser economic significance. In general, people will invest more in those aspects of their technology that they regard as critical for survival. For example, the disappearance of the 'T-shaped' axes of red deer antler (Fig. 1A) that characterized the later Mesolithic of Scotland, and their replacement in the Early Neolithic by ground stone axes (Fig. 1B), probably reflects an increased investment in technology for clearing woodland and constructing fences around field plots. A stone axe may have been more expensive in terms of material and labour 'costs', but was probably more efficient and more durable. Conversely, the abandonment of microlithic technology and the introduction of the leaf-shaped arrowhead may be seen as a response to the decline in the economic importance of hunting in the Early Neolithic. An arrow tipped with a single leaf-shaped point was probably easier and quicker to make and maintain than one fitted with numerous microlithic armatures.

The apparent lack of settlement continuity is also inadequate evidence for the immigration model. Just as subsistence activities affect technology, they also influence settlement location. Use of the same sites is likely to have occurred only where conditions for Mesolithic and Neolithic settlement coincided. This point is well illustrated by the situation in the Iron Gates gorge on the River Danube (*Bonsall et al. 1997a*). In the Iron Gates fish and other riverine resources were of considerable economic importance in both the Late Mesolithic and Early Neolithic, while land suitable for habitation was restricted to narrow terraces bordering the river. It is not surprising, therefore, to find frequent examples of sites on these terraces that were occupied during both periods. In western Scotland, on the other hand, although 'settlement space' was often constrained by the hilly terrain, there were substantial differences in subsistence practices between Late Mesolithic and Early Neolithic. Mesolithic communities relied on the sea and the littoral zone for most of their food supplies, and their settlements show a strong preference for near-shore locations in sheltered marine inlets (*Johnson and Bonsall 1999*). These conditions were probably less important in the Early Neolithic when, in the context of an economy dominated by agriculture, proximity to land suitable for cultivation and livestock raising would have been a greater priority than direct access to the coast. There are, however, instances in western Scotland where favourable conditions for Mesolithic and Neolithic settlement did coincide and where archaeological remains of both

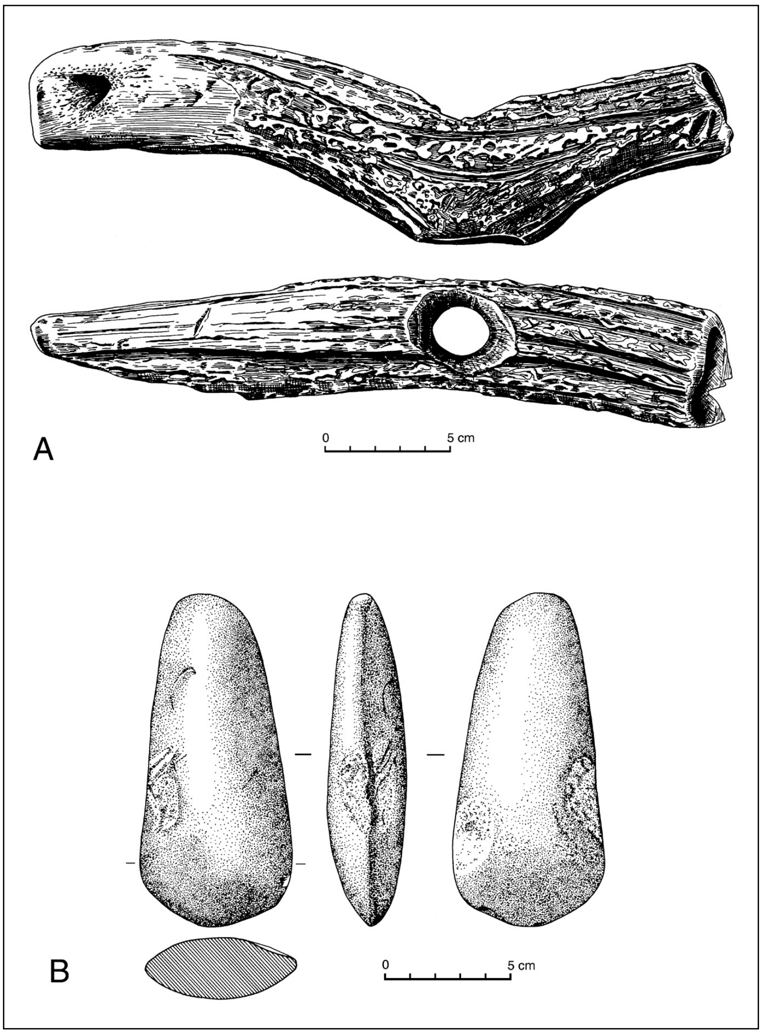

Fig. 1. A – Late Mesolithic T-shaped axe of red deer antler from Meiklewood, near Stirling (*after Bonsall and Smith 1990*) – a functional analysis of similar antler axes from Denmark (*Jensen 2001*) has shown convincingly that they were tree-felling and/or woodworking implements. B – Neolithic ground stone axe from the Isle of Ulva, Argyll. Drawn by Gordon Thomas.

periods occur. The Kinloch site, on the island of Rhum, occupied a sheltered position, near to fresh water, at the head of a narrow inlet where reasonably well-drained soils suitable for cultivation are also found (*Wickham-Jones 1990*). In major coastal valleys of the mainland and larger islands, with more extensive areas suitable for early agriculture, Mesolithic settlements tend to occur at the coast, while later farming settlements are located further inland. These relationships are well demonstrated in the Oban area, Argyll (*Bonsall et al. 1997b; Macklin et al. 2000*).

The neolithization model

Among the arguments advanced in support of the 'neolithization' model are that there is no obvious area of origin for British Neolithic culture on the European mainland, that at least some elements of British Early Neolithic technology (e.g. the leaf-shaped arrowhead) were developed locally, and that the spread of farming across the British Isles was too rapid to be explained simply in terms of immigration followed by population expansion (*Kinnes 1985*). These are all valid points. However, other arguments used to support the neolithization model are less persuasive.

For example, it has been suggested that the Early Neolithic of the British Isles was characterized by residential mobility and a continued reliance on wild food resources, indicating a substantial degree of economic and social continuity with the Late Mesolithic (*e.g. Thomas 1991; Armit and Finlayson 1992; Whittle 1999*). This argument is unconvincing because, although hunting and gathering were practised – in fact, they were almost universal among the early agricultural societies of Europe – there is no evidence that they were the dominant component of the Early Neolithic economy in any part of the British Isles. Similarly, the case for residential mobility rests not on actual data but on the *lack* of evidence for 'large' dwelling structures that are considered to be indicators of sedentism. How Early Neolithic sites such as Balbridie in Aberdeenshire (*Fairweather and Ralston 1993*) and Lismore Fields in Derbyshire (*Garton 1987*) and Late Mesolithic sites such as Williamson's Moss in Cumbria (*Bonsall et al. 1989*) can be accommodated within the residential mobility hypothesis is not adequately explained!

Likewise, the so-called 'Obanian' shell middens of the west coast of Scotland are sometimes claimed to show evidence of 'settlement' continuity across the Mesolithic-Neolithic transition (*e.g. Armit and Finlayson 1992; Thorpe 1996*). This evidence needs to be put into perspective. The middens are refuse heaps resulting mainly from food processing activities, but were probably not directly attached to settlements. Most likely, they represent places some distance from a settlement where small groups of mainly women and children came to collect shellfish from the littoral zone, sometimes combined with line fishing from the shore. The shellfish and fish collected were processed at the sites, with the meat being taken back to the settlement for consumption or storage (*Bonsall 1996*). Individual 'processing sites' may have been used regularly, possibly annually, each visit lasting perhaps less than a day. This would represent a logical strategy for shellfish gathering along the central-west coast of Scotland. Remains of shellfish that inhabit rocky shores, such as limpets, periwinkles and dog-whelks, dominate the middens. Such shellfish constitute a highly dispersed resource that is exploited most efficiently at different points along the shoreline. Attempts to gather shellfish frequently from only one location (adjacent to a settlement, for example) would rapidly deplete the local shellfish population. Thus, it is likely that an individual settlement would have had a number of outlying shellfish gathering-and-processing sites.

This pattern of shellfish exploitation appears to have been practised throughout the later Mesolithic of western Scotland; it may also have been practised during the Neolithic and in later periods. Equally, however, the same basic strategy was employed by archaeologically- and ethnographically-known shellfish gatherers in many parts of the world (*Meehan 1982; Waselkov 1987*) – evidence that different people will often arrive at similar solutions to the same basic problem. Thus, the existence of shell middens in both the Late Mesolithic and Early Neolithic of western Scotland cannot be used as evidence of demographic continuity from one period to the next.

In any event, although some 'Obanian' shell middens were added to over hundreds of years (*Bonsall 1996*) there are very few sites that show evidence of Late Mesolithic *and* Early Neolithic activity. Only two examples come to mind – Ulva Cave near Mull (*Bonsall et al. 1994; Russell et al. 1995*) and An Corran rockshelter on Skye (*Saville and Miket 1994*) – but in neither case is it possible to demonstrate continuity of use across the Mesolithic-Neolithic transition. Caves are more or less fixed points in the landscape that were convenient natural shelters for various kinds of past human activity (*cf. Bonsall and Tolan-Smith 1998*). Therefore, the presence of Mesolithic and Early Neolithic remains may owe more to the existence of the cave than to any biological or cultural connection between successive groups of occupants. Much the same argument applies in those instances where caves containing Mesolithic shell middens were later used as burial chambers (*Bonsall et al., n.d.; Saville and Hallén 1994*).

Shell middens do, however, provide a possible example of technological continuity between Late Mesolithic and Early Neolithic in the form of the *bevel-ended tools* of bone, antler and stone that occur in many sites (Fig. 2). These artefacts were almost certainly used for harvesting limpets (*Griffitts and Bonsall 2001*), rather than skin-working tools as suggested by Finlayson (*1993; 1995*). Direct dating of examples from a number of sites in Scotland has shown that their use was not confined to the Mesolithic, but continued through the Neolithic and into the Bronze Age (*Bonsall and Smith 1990; Bonsall et al. 1995; Saville, in press*). However, the bevel-ended tool is a very simple, expedient device that may have had a wide distribution around the coasts of Britain. It may also have been used by Mesolithic people elsewhere in Europe, and very similar tools are known from prehistoric shell middens in various parts of North America (*Johnson and Bonsall 1999*). Therefore, it is debatable how much reliance can be placed on this artefact form as an indicator of cultural or technological continuity.

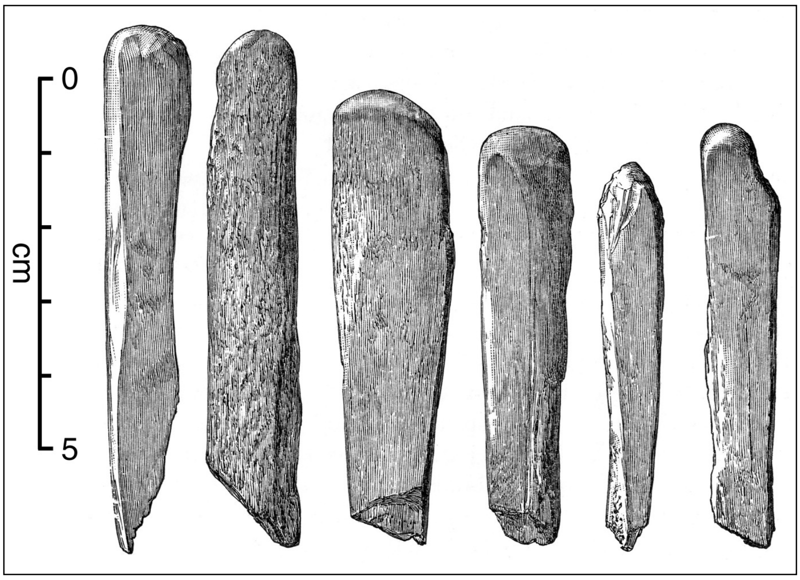

Fig. 2. Examples of bone bevel-ended tools from a Mesolithic shell midden in Druimvargie Rockshelter, Oban, western Scotland (**reproduced from Anderson 1898.figs. 10–15*****).***

To summarize, at present archaeological data are insufficient to establish which of the two main competing hypotheses of the origins of agriculture in western Scotland is correct. On balance, the evidence appears to favour the 'neolithization' model, although this needs to be tested against new and better data. Potentially, analysis of ancient human DNA could show whether there was a significant degree of biological continuity between the Late Mesolithic and Early Neolithic populations of the region. Currently, however, this line of enquiry is severely constrained by the scarcity of human skeletal material from Mesolithic sites.

WHY DID IT HAPPEN?

If indigenous Mesolithic people *were* largely responsible for the introduction of agriculture into the British Isles, including western Scotland, *why* did they choose to adopt agriculture? What were the conditions that persuaded hunter-gatherers to become farmers? This question applies equally to other areas along the Atlantic façade of Europe where hunter-gatherers are believed to have played a dominant role in the transition to agriculture (*Dennell 1983; 1985; Zvelebil and Rowley-Conwy 1986*).

It is often assumed that hunter-gatherers turned to agriculture simply in order to increase or improve their food supply. Williams (*1989.518*) argued that Mesolithic people in the British Isles adopted cereal cultivation out of a desire to increase the level of carbohydrate in their diet. Others have seen the need for a 'forcing' mechanism. A popular scenario is that an imbalance between population and food supply caused by an increase in the number of people, a decline in the availability of wild resources, or both, forced the adoption of farming (*Binford 1968; 1983; Cohen 1977; 1989; Cohen and Armelagos 1984; Rowley-Conwy 1984; Harris 1990*).

Implicit in such models is the presumption that early agriculture offered significant advantages over hunting and gathering as a mode of food production. Farming is considered to be more productive, more reliable and less arduous. These assumptions may all be questioned. *Intensive* farming may be more productive than hunting and gathering but from the time agriculture was first attempted by a Mesolithic population it could have taken years, if not generations, for the system to become securely established. Agriculture also requires considerable investment of time and effort, whereas ethnographic studies have shown that hunter-gatherers, even in marginal environments, usually do not need to work more than two or three days a week in order to feed themselves (*Lee 1968; Woodburn 1968*). Moreover, agricultural societies are just as likely as hunter-gatherers to face food shortages, especially in areas where the weather was unpredictable. Severe storms can badly damage crops, and prolonged drought can destroy the entire food supply. Equally, by virtue of being concentrated into relatively small areas, crops and livestock are more vulnerable to disease than are wild animals and plants.

Over much of Europe there is no evidence for long periods of co-existence between hunter-gatherers and farmers. In those areas where environmental conditions were conducive to cereal cultivation and stockraising, it seems that Mesolithic people took up farming soon after it became available to them. In some other regions of the world, however, there is evidence that hunter-gatherers lived in proximity to farmers for thousands of years without themselves becoming farmers. According to Ames and Maschner (*1999*) the native people of southern California lived near to the ancient farmers of southern Arizona for almost two millennia, engaged in trade for agricultural products, yet *never* adopted farming.

It is interesting to consider how conditions in Europe may have differed from those in California. An obvious difference is that in North America early farming economies were based primarily on domesticated plants.[2] Turkeys (derived from Mexico) and dogs were the only domesticated animals, but appear to have made little contribution to diet. In contrast, animals (cattle, pigs, sheep and goats) were much more important in early European agriculture. Not only did they contribute significantly to diet; they were also a potential source of wealth – an asset that could be 'owned' and controlled by households or individuals, rather than whole communities, and in ways that wild resources could not. It would seem likely that the new domesticated animal species were the main attraction of the west Eurasian mixed farming 'package' for Mesolithic hunter-gatherers. They represented not just additional sources of food and raw materials, but afforded new opportunities for the acquisition of wealth and power with all its social consequences. In this respect,

2. The major cultivated plants (maize, beans and squash) were originally domesticated in Mesoamerica, but one species of squash (*C. pepo*), several grasses, and the Jerusalem artichoke were domesticated independently in eastern North America.

if no other, the Mesolithic-Neolithic transition can be viewed as a 'social' as much as an economic event.
In order to keep livestock, people must have the means to sustain them. This involves the provision of adequate supplies of water and food. In particular, considerable effort has to be put into the production and storage of fodder for winter. Leaf gathering was a probable component of the Early Neolithic farming system and may have been an important source of winter fodder, especially in areas that were marginal for agriculture. But additional supplies would need to be *grown* in the form of grass or cereals. Cereals are particularly valuable. The grain is an important storable food source for humans as well as animals, while the straw can be used for animal feed and bedding. Thus the prospects for livestock husbandry (and human subsistence) are significantly enhanced if cereals can also be grown. Therefore, the importance of adopting the entire mixed farming 'package' is clear, even if the main motivation for the Mesolithic-Neolithic transition was the desire to procure domestic animal herds.

Recalling Kinnes's (*1985*) comments on the rapidity with which agriculture appears to have spread throughout the British Isles, there is an important corollary of the model presented above. That is, if indigenous hunter-gatherers rather than immigrant farmers were the agents of economic change, then an important control on the expansion of agriculture was the rate at which livestock could be bred (a matter of years) and traded. On the other hand, if immigrant farmers were the agents of change, then the rate of agricultural expansion would be more dependent on human population growth and ability to colonize new areas (decades to centuries). Under the latter scenario, the spread of agriculture across the British Isles is likely to have been more uneven and gradual than is suggested by the archaeological record, especially if indigenous peoples resisted the advance of immigrant farmers in certain areas. Of course, other factors such as climate and soils also would have been strong controls on agricultural expansion.

WHEN DID IT HAPPEN?

From the preceding discussion, it follows that an understanding of the timing of the Mesolithic-Neolithic transition is essential in evaluating the arguments for both 'how' and 'why' the transition occurred. In this section three sources of evidence for identifying the adoption of agriculture are considered: (i) ^{14}C dates for archaeological finds; (ii) dietary tracing of human bone; and (iii) palynological data.

Radiocarbon evidence

When researching this paper, the authors collated all available *(c.* 400) published or archived ^{14}C determinations for purportedly Late Mesolithic and Early Neolithic archaeological contexts in Scotland with mean ages between 6000 and 4500 BP. Radiocarbon ages have been converted into approximate calendar dates using the CALIB (rev. 4) calibration program developed at the University of Washington, Seattle (*Stuiver and Reimer 1993*). The conversion is summarized in Table 1.[3]

^{14}C age BP	cal BC age
4500	3200
4600	3350
4700	3450
4800	3550
4900	3650
5000	3800
5100	3950
5200	4000
5300	4100
5400	4300
5500	4350
5600	4400
5700	4500
5800	4650
5900	4750
6000	4900

Tab. 1. Radiocarbon date calibration table for the period 6000–4500 BP (cal BC ages rounded to 50 years).

Taking a very critical view of the radiocarbon evidence, ^{14}C dates falling into the following categories may be regarded as suspect:
❶ isolated dates
❷ dates with very large errors (>±2%)
❸ dates that are 'outliers' in an otherwise coherent series
❹ dates on charcoal samples where there is a distinct possibility of inclusion of 'old wood' or residual material
❺ dates on material of uncertain cultural affinity
❻ dates that are inconsistent with *either* the stratigraphic context *or* archaeological associations.

3. Dates quoted in 'cal BP' years in this paper are taken from publications where the original ^{14}C age estimates were not given.

Treating only the remaining dates as reliable permits the following general observations:

❶ Evidence from the Oban area (*Bonsall et al. 1997b*) suggests that Mesolithic technology in the form of narrow blade microliths was still in use on the west Scottish mainland *c.* 5300 BP (4100 cal BC)

❷ There are no secure dates for field monuments or for contexts with pottery or other distinctively Neolithic artefacts from any part of Scotland significantly older than *c.* 5000 BP (3800 cal BC)

❸ The earliest *direct* evidence for agriculture in Scotland is provided by AMS dates on charred cereal grains from Balbridie, Aberdeenshire (*Fairweather and Ralston 1993*) and Balfarg Riding School, Fife (*Barclay and Russell-White 1993*) of between *c.* 4940–4830 BP (3730–3600 cal BC) (Fig. 3A).

❹ On this evidence, the transition from Mesolithic to Neolithic in Scotland occurred sometime between 5300 and 4900 BP (4100 and 3650 cal BC).

A critical appraisal of the available radiocarbon dates for Late Mesolithic and Early Neolithic sites in England and Wales shows a broadly similar pattern. There is good evidence for the continuation of microlithic technology until *c.* 5300 BP (4100 cal BC), while there is no convincing evidence for Neolithic monuments, technology or agriculture before *c.* 5200 BP (4000 cal BC). In fact, the earliest direct ^{14}C age measurements on cultivated cereal remains are very similar to those from Scotland.

Dietary tracing of human bone

The measurement of stable isotope ratios in human skeletons is a useful tool for reconstructing ancient diets. Stable carbon isotope ($\delta^{13}C$) ratios, in particular, have been used to study the importance of marine foods in the economies of Mesolithic peoples inhabiting maritime regions of Europe and the changes associated with the spread of agriculture into those regions (*Tauber 1981; Price 1989; Lubell et al. 1994*). This is possible because (where C_4 plants are absent from the food chain) the $\delta^{13}C$ ratio of collagen extracted from human bone closely reflects the ratio of marine to terrestrial protein consumed by the individual (*Arneborg et al. 1999*).

Figure 3B summarizes the results of paired ^{14}C and $\delta^{13}C$ measurements on human bones from 10 sites in coastal areas of northern and western Scotland. These sites include caves, chambered cairns and shell middens, and the human remains range in age from *c.* 5400–4400 BP (4300–3000 cal BC).

A clear distinction is evident between the $\delta^{13}C$ profiles of individuals belonging to the periods before and after 5000 BP (3800 cal BC). Those individuals dated before 5000 BP (3800 cal BC) (represented by four samples from two sites on the island of Oronsay with (reservoir corrected) mean ^{14}C ages between 5335 BP and 5075 BP) have $\delta^{13}C$ ratios in the range –12‰ to –16‰ (*Richards and Mellars 1998; Richards and Sheridan 2000*). Assuming $\delta^{13}C$ values of –12.5‰ for a 100% marine diet and –21‰ for a 100% terrestrial diet (*cf. Arneborg et al. 1999*) the Oronsay data suggest a population that relied heavily on marine foods as the main source of protein. In contrast, those individuals dated after 5000 BP (3800 cal BC) (represented by 30 samples from 8 sites with mean ^{14}C ages between 4990 BP and 4410 BP) exhibit much lower $\delta^{13}C$ ratios ranging between –19.5‰ and –22.6‰, indicating diets in which virtually all of the protein was of terrestrial origin.

Since there is no reason to suppose that the people whose remains were found in the Oronsay middens placed more emphasis on marine resources than their contemporaries elsewhere in western Scotland, the results from dietary tracing may be used to infer that a major shift in regional subsistence practices occurred between *c.* 5100–5000 BP (3950–3800 cal BC). Given that diagnostic elements of Neolithic material culture also appear in the archaeological record around that time, the simplest explanation of the change in dietary patterns is that it reflects the shift from an economy based on hunting and gathering to one based on farming.[4]

If this interpretation is correct, then it also contradicts the view expressed by several authors (*Thomas 1991; Armit and Finlayson 1992; Whittle 1999*) that 'wild' foods played a major role in the Early Neolithic economy. Otherwise, it would be necessary to argue that wild land mammals and plants assumed much greater economic importance in the Neolithic than they did during the Mesolithic.

4. Since the text of this paper was finalized, the authors have become aware of an article by Richards and Hedges (*1999*) which draws similar conclusions regarding changes in subsistence patterns across the Mesolithic-Neolithic transition in England and Wales based on C-isotope data. No alterations have been made to the present paper in light of the data or interpretations published by Richards and Hedges.

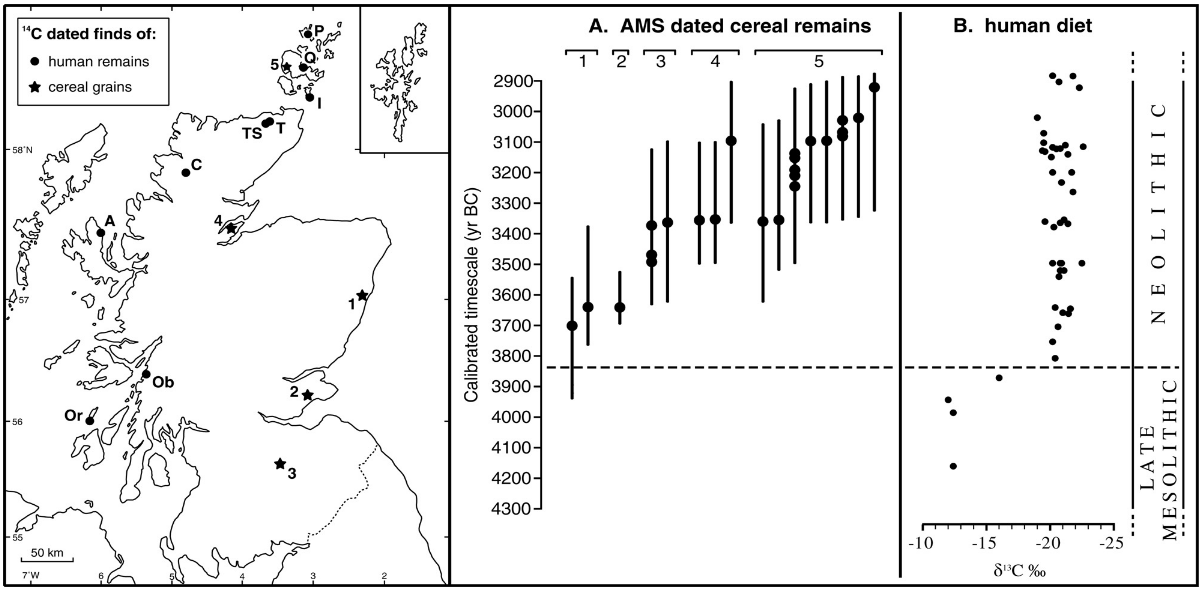

Fig. 3. Key indicators of economic change across the Mesolithic–Neolithic transition in Scotland. A – earliest radiocarbon dates (2-sigma age-ranges) for cultivated cereals: 1 – Balbridie (Aberdeenshire), 2 – Balfarg Riding School (Fife), 3 – Biggar Common (South Lanarkshire), 4 – Kinbeachie (Highland), 5 – Burnhouse (Stenness, Orkney). B – carbon stable isotope results from human skeletons dating between 4300 and 2900 cal BC: A – An Corran (Skye), C – Creag nan Uamh (Assynt), I – Isbister (Orkney), Ob – Oban (Argyll), Or – Oronsay (Argyll – 2 sites), P – Point of Cott (Orkney), Q – Quanterness (Orkney), T – Tulloch of Assery A (Highland), TS – Tulach an t'Sionnaich (Highland). The abrupt change in the $\delta^{13}C$ values c. 3850 cal BC indicates a shift in diet/subsistence patterns from mainly marine to mainly terrestrial. Data from various sources, including Bonsall (1999, unpublished), Bonsall and Murray (1998), Dalland (1999), Fairweather and Ralston (1993), Richards C. (1994), Richards M. and Sheridan (2000), Saville (1999) and Ward (1997).

The lack of marine protein in the diets of Early Neolithic peoples in western and northern Scotland is surprising, given the proximity of the sites to the sea. However, it is not without parallel elsewhere on the Atlantic seaboard of Britain. Similar evidence was reported from the Neolithic chambered cairn of Parc le Breos Cwm on the Gower peninsula of south Wales (*Richards 1998*). Richards (*1998.166*) speculated that the people buried in the tomb might have been high status individuals who had preferential access to terrestrial animal protein, such that their stable isotope profiles were unrepresentative of the local Early Neolithic population as a whole. This hypothesis would be more difficult to sustain for the Scottish sites since the human remains come not just from chambered cairns, but also from caves and shell middens – and in the case of the shell middens there is no certainty that the bones represent formal burials.

Palynological data

There has been much discussion in the archaeological and palynological literature of the significance of occasional finds of cereal-type pollen in peat sequences from Scotland and other parts of the British Isles spanning the period from the 'elm decline' of *c.* 5100/5000 BP (3950/3800 cal BC) (at one time accepted as the definitive palynological marker of the beginning of the Neolithic) back to *c.* 5800 BP (4650 cal BC) (*Edwards and Hirons 1984; Edwards 1989; Edwards and Whittington 1997*).

Some workers have interpreted these 'early' cereal-type pollen occurrences as evidence for small-scale agriculture prior to the development of a 'full' Neolithic economy and culture. This in turn has helped to sustain the concept of a centuries-long 'pioneer phase' preceding the main (monument building) phase of the Neolithic during which it is envisaged that hunting and gathering was the main form of subsistence technology but with agriculture, practised initially by small, dispersed groups of indigenous hunter-gatherers or immigrant farmers, gradually increasing in importance.

This argument is unconvincing for three main reasons. First, cereal-type pollen can emanate from wild as well as cultivated grasses (*cf. Edwards and Whittington 1997.72*). Secondly, pre-elm decline cereal-type pollen is by no means confined to the period between 5800 and 5000 BP (4650 and 3800 cal BC).

It has been recorded from much earlier contexts, most notably in the Oban region of western Scotland where it was found in early Holocene deposits at several sites back as far as *c.* 9700 BP (9200 cal BC) (*Macklin et al. 2000*). Thirdly, although a number of sites in Scotland have produced cereal-type pollen grains from pre-elm decline deposits, there is no securely dated *macrofossil* evidence of cereal cultivation earlier than *c.* 5000 BP (3800 cal BC).

Although the mere presence of cereal-type pollen is inadequate evidence of agriculture, a change in the pattern of occurrence of cereal-type pollen grains supported by other palynological indicators may convincingly indicate the time when farming took over from hunting and gathering as the main economic system. This is well illustrated by the work of Macklin *et al.* in the Oban area (*Macklin et al. 2000*). In order to document the history of environmental change during the Holocene at both local and regional scales, a comparison was made of the pollen, micro-charcoal and geochemical records from five radiocarbon dated peat sequences along an altitudinal transect from *c.* 3 m O.D. near the present coast to *c.* 300 m O.D. 9 km inland. The results are summarized on Figure 4. Although there are very early occurrences of cereal-type pollen in several sites, there is no supporting evidence for agriculture or major human impact on the landscape prior to *c.* 5000 BP (3800 cal BC). The first convincing evidence for land clearance related to agriculture occurs around that time. For example, pollen analyses from Gallanach Beg and Lochan a'Builgh Bhith both show the first substantial increases in *Plantago* spp. (indicative of land clearance) at about 5000 BP (3800 cal BC). There is also evidence for reduction in arboreal pollen, increased charcoal deposition, and a marked rise in the frequency and quantity of cereal-type pollen. At Gallanach Beg these coincide with a significant increase in erosion rates probably in response to soils being tilled for the first time.

The Elm Decline

The first palynological evidence for agriculture in the Oban region also coincides with the well-known elm decline, which is found in pollen sequences throughout the British Isles and Scandinavia at *c.* 5000 BP (3800 cal BC).

At one time climate change was invoked as the primary cause (*Iversen 1941; 1944*). Then, following the work of Troels-Smith (*1960*) it was interpreted as a consequence of Early Neolithic people attempting to keep livestock in a landscape with (initially) very little grass vegetation, so that they resorted to the use of elm leaves as fodder. More recently, this idea has fallen out of favour and disease (associated with the elm bark beetle *Scolytus scolytus*) is now regarded as the most likely explanation of the elm decline (*Girling and Greig 1985; Perry and Moore 1987; Girling 1988; Peglar 1993; Peglar and Birks 1993*).

While at first sight the disease hypothesis appears to offer a satisfactory mechanism, closer inspection suggests that disease is unlikely to have acted in isolation. Although a large number of pollen diagrams show an elm decline at about 5000 BP (3800 cal BC) across north-west Europe, there has been little attempt to define the geographical range of this event in relation to the geographical range of elm at that time. Indeed, elm trees were an important component of mid-Holocene woodlands across much of France, Germany and northern Italy (*Huntley 1988*) – areas with little evidence for an elm decline *c.* 5000 BP (3800 cal BC). If disease were the primary cause, why should evidence for the elm decline be restricted to north-west Europe? More specifically, why should an outbreak of disease leave such strong evidence in the pollen record of southern England (*e.g. Scaife 1988*) while being virtually absent just across the channel in northern France? A more likely explanation is that evidence for the elm decline *c.* 5000 BP (3800 cal BC) is strongest in north-west Europe *because* this area was undergoing the Mesolithic-Neolithic transition while areas to the south and east had already gone through this transition around a thousand or more years earlier. In fact, a detailed palynological study in the Paris Basin (*van Zeist and van der Spoel-Walvius 1980*) shows no clear evidence of an elm decline *c.* 5000 BP (3800 cal BC). Instead, it shows strong evidence from two sites (Silly-la-Poterie and Chivres) for an elm decline at about 6000 BP (4900 cal BC), around the time of the adoption of agriculture in this region. A similar date for an early elm decline is also reported from a site in the central Netherlands (*Hofstede et al. 1989*) and attributed to Neolithic activity.

It is difficult to see the spatial and temporal similarities between the mid-Holocene elm decline and the Mesolithic-Neolithic transition in north-west Europe as merely coincidental, and it is highly plausible that human activity and disease worked together. It is known that *S. scolytus* is not favoured by dense forests, but thrives in more open habitats with isolated copses and single trees (*Girling and Greig 1985*),

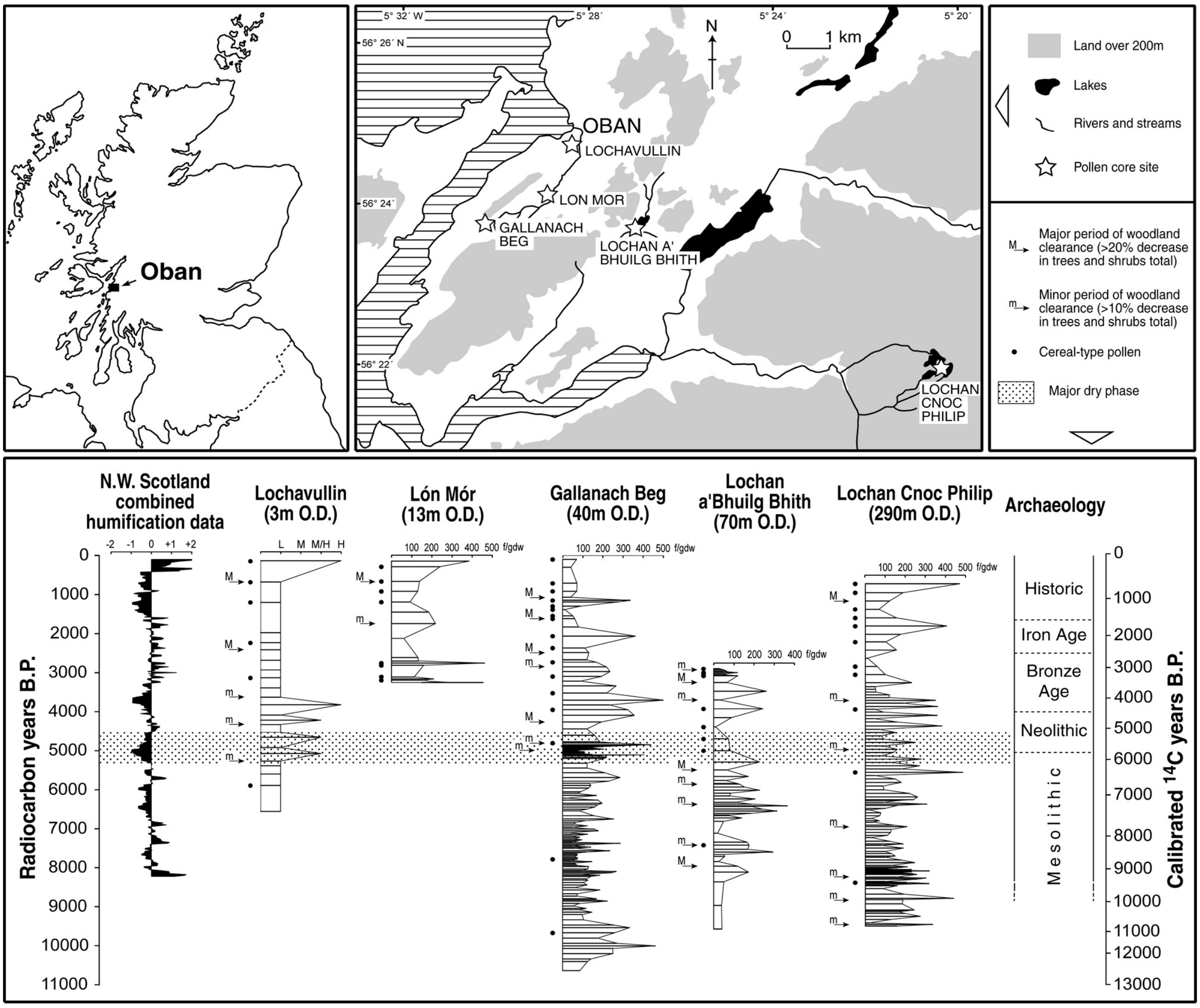

*Fig. 4. Holocene climatic changes inferred from peat bogs in north-west Scotland (*Anderson et al. 1998*) plotted against the micro-charcoal, cereal-type pollen and woodland decline records from five sites in the Oban area along an altitudinal transect from coast to upland (*adapted from Macklin et al. 2000*). Time-ranges of Mesolithic and later settlement in the region, established from archaeological research, are also shown. The stippled zone marks the prolonged phase of relatively dry climate between c. 4100 cal BC and 3200 cal BC.*

and hence early land clearance may have promoted the spread of the disease into new areas.

The main point that emerges from the foregoing discussion is that consideration of three separate lines of evidence – radiocarbon dating of archaeological finds, dietary tracing of human bone, and palynology – leads to the same broad conclusion. The transition from Mesolithic to Neolithic in western Scotland was a relatively short-lived and discrete event, occurring between 5300 and 5000 BP (4100–3800 cal BC) rather than a protracted process of gradual economic and cultural change beginning as early as 5800 BP (4650 cal BC) as envisaged by some researchers. The same was probably true of areas outside Scotland, since there is no firm evidence for Neolithic culture and economy anywhere in the British Isles before 5300 BP (4100 cal BC).

WHY DID IT HAPPEN *WHEN* IT DID?[5]

It has long been recognized that there was a 'delay' of 800–1300 years in the adoption of agriculture in the British Isles and southern Scandinavia compared to neighbouring regions of continental Europe (*Rowley-Conwy 1981; Kinnes 1984*). Zvelebil and Rowley-Conwy (*1986*) argued for a similar delay in many areas on the Atlantic seaboard of Europe. They attributed this to the maritime focus of indigenous

5. Some of the ideas and interpretations presented in this section of the paper have since been refined and published elsewhere (*Bonsall et al. 2002*).

Mesolithic economies that provided the basis for productive and stable settlement-subsistence systems, allowing hunter-gatherers to 'resist' agriculture for a considerable time.

There are two problems with this hypothesis. First, as research has progressed, the date of the earliest Neolithic in many coastal areas of Europe (e.g. Portugal and north-west France) has been pushed back in time, so that it appears no longer valid to argue for a delay in the uptake of farming compared to areas inland. The only part of Europe where a marked delay is still evident is the British Isles and Scandinavia (Fig. 5). Secondly, it fails to explain *why* the Mesolithic inhabitants of this part of Europe (with their seemingly productive maritime economy) ultimately adopted farming. Rowley-Conwy (*1984*) attributed the eventual 'collapse' of the Mesolithic maritime system in southern Scandinavian and its replacement by farming at *c.* 5200/5000 BP (4000/3800 cal BC) to environmental stress. He argued that a shift to cooler, drier climatic conditions coincident with a sea-level related decrease in the salinity of the Baltic resulted in a sharp reduction in wild food resources, especially oysters which he believed had acted as a seasonal buffer against starvation.

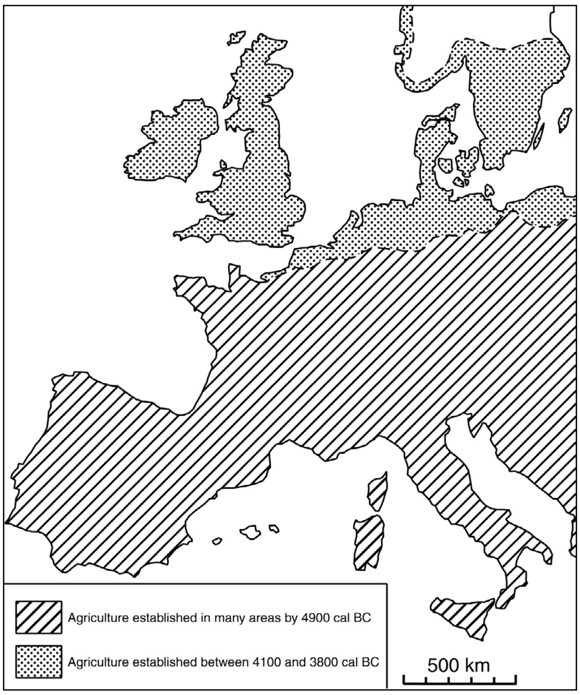

Fig. 5. Agricultural 'frontiers' in north-west Europe. Farming spread rapidly across the British Isles and southern Scandinavia between 4100 and 3800 cal BC, following a long period when the geographical limit of successful agriculture had remained more-or-less static on the North European Plain between northern France and northern Poland.

Rowley-Conwy's hypothesis has never gained wide acceptance among Scandinavian archaeologists, and cannot be applied outside the Baltic region. Nevertheless, despite the apparent deficiencies in Rowley-Conwy's hypothesis, it is still worth exploring the idea that climatic change was somehow a key factor in the transition from Mesolithic to Neolithic in north-west Europe. Until recently, it would have been almost impossible to do this in any detail because of a paucity of well-dated palaeoclimatic records spanning the mid-Holocene. However, recent advances in palaeoclimatology, especially in the analysis of peat stratigraphy, are helping to overcome this problem by providing regionally-based, continuous records of climate changes of sufficient temporal resolution.

Climate change in the mid-Holocene

Analyses of peat sequences from the Wester Ross area, north-west Scotland, have provided a detailed record of past changes in wetness and dryness back to *c.* 8250 BP (7250 cal BC) (*Anderson 1996; 1998; Anderson et al. 1998*). This reconstruction has involved humification, palaeoecological and radiocarbon analyses of peat cores from three different bogs (in Glen Torridon, Glen Carron and on Eilean Subhainn – an island in Loch Maree), each representing the palaeohydrology of a different drainage basin. The combined humification curve from these three peat bogs is shown on Figure 4.

The curve features several palaeohydrological shifts from 8000 BP (6950 cal BC) to the present. One of the major dry phases found in the record began *c.* 5300 BP (4100 cal BC) and culminated *c.* 5000 BP (3800 cal BC). This marked phase of relatively dry climate inferred from Wester Ross coincides with the first evidence for land clearance and agriculture further south along the west coast of Scotland in the Oban area (see above). The shift to drier conditions at *c.* 5300 BP (4100 cal BC) recorded in the Wester Ross peats may explain the timing of the adoption of agriculture along the west coast of Scotland.

Other peat-based studies in Scotland also indicate a phase of drier climate around this time. The combined humification curve from blanket peats on the slopes of Beinn Dearg, in northern Wester Ross (*Binney 1997*) shows a shift to drier conditions beginning *c.* 6250 cal BP and culminating *c.* 6000 cal BP (*Anderson et al. 1998*). Tipping (*1995*) also reports evidence for relatively dry conditions around 6000 cal BP from Burnfoothill Moss at Kirkpatrick Fleming, in southern Scotland.

Studies of lake sediments can also be used for inferring changes in climatic wetness or dryness. Of 28 lakes in Britain and Ireland evaluated by Yu and Harrison (*1995a*), a large proportion show relatively low lake levels between 7000 and 4500 BP (5850–3200 cal BC). More precise data are available from Achany Glen (northern Scotland), where the start of a prolonged hiatus in lake sediment accumulation (suggesting a phase of lower lake level) is dated to 5650±80 BP (GU-3951) (4690–4340 cal BC) (*Smith 1996; Anderson et al. 1998*).

The frequency of wood macrofossils preserved within peat can also be used as proxy evidence of climate change. Bridge *et al.* (*1990*) compiled radiocarbon dates for Scots pine stumps found in peats on Rannoch Moor (Scotland). They found distinct clusters of dates, especially at *c.* 6000 BP (4900 cal BC) and at *c.* 4500 BP (3200 cal BC), with an abundance of pine stumps indicating periods when conditions were good for wood preservation. Likewise, there are other periods of time that are under represented by pinewood, and Bridge *et al.* argued that these periods relate to phases of drier climate when preservation was poor due to more rapid decomposition. The most prominent trough in the frequency histogram of dated pine stumps is found at *c.* 5300 BP (4100 cal BC), closely matching the shift to drier conditions inferred from the Wester Ross peat sequences. Furthermore, Baillie (*1992*) reported a paucity of preserved oak wood in Irish peats between 4023 and 3916 cal BC. The lack of oak wood during this period may also relate to drier peat forming conditions associated with higher rates of decomposition. This phase of reduced oak is also matched by reduced frequencies of Irish pinewood (*Baillie and Brown 1999*).

Temperature reconstructions have been attempted from Holocene deposits using insect remains (*Osborne 1982; Dinnin 1997*). For instance, analysis of the beetle fauna from peat surrounding the Early Neolithic Sweet Track (Somerset Levels) suggests that climatic conditions were more continental than today at the time the structure was built *c.* 5000 BP (3800 cal BC) (*Girling 1979; 1984*).

Two beetle species associated with the Sweet Track are *Oodes gracilis* and *Chlaenius sulcicollis*. Today the northward limit of their distribution follows the 17°C mean July isotherm, and they are found in areas of Europe with a wide annual temperature range. For comparison, the winters in the Somerset Levels today are mild, averaging about 4 to 7°C, and mean summer temperatures rarely exceed 16°C. In contrast, during the Early Neolithic, the beetle evidence indicates that mean summer temperatures in the Somerset Levels may have been 1 to 2°C warmer with an annual temperature range similar to that currently found in eastern Denmark (*Girling 1984*).

Climatic change at around 5000 BP (3800 cal BC) was not restricted to the British Isles. Indeed, various lines of proxy evidence suggest that a change in climate at this time also affected much of northern Europe. Peat stratigraphic evidence from the Meerstalblok bog in the Netherlands shows a distinct shift to drier conditions estimated at *c.* 6000 cal BP (*Dupont 1986*). Furthermore, lake levels throughout north-west Europe were generally low at 5000 BP (3800 cal BC) (*Yu and Harrison 1995b*), and a detailed study from Lake Bysjön, southern Sweden, showed a lake level regression from *c.* 5300 BP (4100 cal BC) to *c.* 4700 BP (3450 cal BC) (*Digerfeldt 1988*). Evidence for temperature change can be gleaned from studies of Scots pine tree-ring widths, and one such temperature reconstruction by Briffa (*1994*) shows that mean July/August temperatures in northern Fennoscandia increased by about 1°C at 5200 BP (4000 cal BC). This is also consistent with evidence for an increase in the altitudinal limit of Scots pine in Scandinavia dated to 4000 cal BC (*Karlén and Kuylenstierna 1996*). A temperature reconstruction based on speleothem data from northern Norway places the temperature rise (of approximately 1°C) a little earlier, at *c.* 4400 cal BC (*Lauritzen and Lundberg 1999*).

Chemical analyses of the Greenland GISP2 ice core show several shifts in the amount of sea salt incorporated within the ice layers spanning the Holocene. O'Brien *et al.* (*1995*) argued that phases of higher sea salt concentration within the ice core indicate times when a more meridional atmospheric circulation pattern prevailed in the North Atlantic. One of the most prominent increases in sea salt concentration occurred at *c.* 6000 cal BP, closely matching the shift toward drier climatic conditions and warmer summers in north-west Europe. A shift to a more meridional circulation would have caused warmer summers *and* colder winters. When the upper westerly airflow is relatively zonal, moisture-laden air masses frequently track across northern Europe throughout the year, moderating seasonal swings. However, a more meridional air flow over the North Atlantic favours more frequent periods of blocking high pressure. In the summer this brings clear skies and higher temperatures whereas in the winter, more frequent high pressure is associated with colder and drier conditions.

Summing up climatic change c. 5000 BP (3800 cal BC)

The idea of significant climatic change in northern Europe at around 5000 BP (3800 cal BC) is not new. Indeed, 5000 BP (3800 cal BC) has traditionally been thought to mark the transition from Atlantic to Sub-Boreal conditions as originally envisioned in the Blytt-Sernander scheme of post-glacial climatic change (*Mangerud et al. 1974*). It also marks the transition between zones VIIa and VIIb of the Jessen-Godwin pollen zonation scheme (*Godwin 1975*). On the basis of descriptive peat stratigraphy in Scandinavia, Blytt, and later Sernander, argued that a relatively wet Atlantic was followed by a drier Sub-Boreal period (*Sernander 1908*). Later work by Iversen (*1941; 1944*) on the pollen of spectra from deposits in Denmark showed a decline in the pollen of thermophilous taxa, notably ivy, holly and mistletoe, associated with the European elm decline (*c.* 5100 BP) (3950 cal BC). Iversen inferred a temperature decline from his data, and ever since, climate change at 5000 BP (3800 cal BC) has often been seen as a climatic deterioration, with the onset of the Sub-Boreal bringing colder and more continental conditions. 'Climatic deterioration' has been supported by more recent studies, including some reconstructions of alpine glacier advances that show an expansion of glaciers in mountainous regions of Europe at, or shortly after, 5000 BP (3800 cal BC) (*e.g. Denton and Karlén 1973; Nesje et al. 1991; Nesje and Johannessen 1992*). In fact, O'Brien *et al.* (*1995*) also interpret their shift towards increased sea salt in the GISP2 core at 5200 BP (4000 cal BC) as representing a phase of climatic deterioration that correlates with glacial advances world-wide. However, pinning down the timing, and the causes, for alpine glacial advances is by no means straightforward, and some reconstructions actually show glacial retreat around 5000 BP (3800 cal BC), notably in Scandinavia (*Röthlisberger 1986*).

At first glance, it may seem that this older view of climatic change at around 5000 BP (3800 cal BC) is at odds with the more recent evidence for drier conditions, with warmer summers, presented above. However, if the change is seen primarily as an increase in continentality, then new evidence can be squared with old. For instance, increased continentality, involving colder winters and warmer summers, can explain the decline in frost-sensitive forest plants, as observed by Iversen, while also explaining the expansion of pine – a tree that would be less affected by severe winters and favoured by a warmer growing season. In the more mild, oceanic areas of north-west Europe, especially in north-west Scotland, temperature changes probably would have been less significant than changes in moisture, and hence the climatic change around 5000 BP (3800 cal BC) is most easily detected in palaeohydrological archives such as peat bogs.

Climatic change and the adoption of agriculture in north-west Europe: a working hypothesis

Climate is a critical factor affecting the viability of all agricultural systems, and the Early Neolithic system of mixed cereal cultivation and livestock husbandry would have been no exception. In fact, it may have been especially sensitive to relatively small changes in precipitation or temperature given the limitations of early farming technology and because pioneer farmers would not have had the benefit of hindsight when dealing with marginal conditions or periods of environmental stress. As discussed previously, cereals were a crucial component, vital as a storable source of winter food for both humans and livestock. Cereals can be grown under a wide range of environmental conditions, although the yield will vary with climate, soils and other factors. In north-west Europe, an important control of cereal yields would have been the length of time that soils were waterlogged during winter. The incidence of waterlogging depends not only on precipitation levels, but also on the structural properties of the soil. There is a much greater tendency to seasonal waterlogging in soils with slowly permeable clayey subsoils, as well as in low-lying situations where there is a high groundwater table (e.g. estuaries and inland basins). Waterlogging can adversely affect cereal yields in several ways. It will inhibit germination and retard growth in cereals and other crops. It also affects the 'workability' of the soil. When saturated the soil is unsuitable for cultivation because of stickiness and plasticity, and such conditions preclude autumn sowing of cereals or delay planting in spring thereby reducing the length of the growing season. A shift to a more continental-type climate at, or shortly after, 5300 BP (4100 cal BC) with lower winter precipitation and, less critically, higher summer temperatures would have enhanced the prospects for successful cereal cultivation. This effect would have been most pronounced in the more maritime areas where precipitation levels tend to be higher, as well as on fine-textured, poorly drained soils.

If the 'neolithization' model applies, and indigenous Mesolithic people were largely responsible for the spread of agriculture across the British Isles and southern Scandinavia, then it is reasonable to assume that farming would have developed first in areas they already occupied. There is strong evidence that in the final stages of the north-west European Mesolithic most people inhabited the coastal zone. Today, the coastal areas of north-west Europe have high winter precipitation and/or extensive tracts of slowly permeable poorly drained soils derived from glacial or raised estuarine/marine deposits. For cereal agriculture to be adopted widely in these areas such soils would have to be taken into cultivation.

Under these climatic and edaphic conditions, the shift to a more continental-type climate beginning *c.* 5300 BP (4100 cal BC) would have represented an 'improvement' with respect to cereal cultivation. It is possible, therefore, that the change in climatic conditions facilitated the uptake of agriculture by indigenous hunter-gatherers in the British Isles and southern Scandinavia by increasing cereal yields and thereby improving the agricultural potential of large areas especially at the coastal margins. By extension this hypothesis provides an underlying mechanism to account for the relatively sudden appearance of the Neolithic throughout this region between 5200 and 5000 BP (4000 and 3800 cal BC).

The corollary of this model is that very probably climatic conditions were both the cause of the 800–1300 year 'delay' in the spread of agriculture from the North European Plain and northern France into southern Scandinavia and the British Isles, as well as the major stimulus of its eventual adoption in those regions. When agriculture became established on the North European Plain and along the Channel coast in the centuries around 6000 BP (4900 cal BC) (Fig. 5), prevailing climatic and technological conditions may have been such that the Neolithic farming system had reached the geographical limit of its viability, with areas to the north and west at that time being marginal for agriculture. It was not until the climatic 'improvement' of *c.* 5300–4500 BP (4100–3200 cal BC) that further expansion was possible, allowing cereal cultivation and animal husbandry to become widely established in the British Isles and southern Scandinavia for the first time. However, once established and adjusted to local conditions, the Neolithic farming system was likely to cope with subsequent climatic reversals even if this necessitated the temporary abandonment of agriculturally marginal areas (*cf. Champion 1999*).

This hypothesis, however, does *not* rule out the possibility of earlier attempts at farming in the British Isles and southern Scandinavia prior to 5300 BP (4100 cal BC). Indeed, it is possible to envisage situations in which there *were* experiments with agriculture, but on a scale and duration that would be difficult to detect in the archaeological and palynological records.

The explanatory model of the Mesolithic-Neolithic transition in north-west Europe presented above may have relevance for other regions, especially upland areas such as the Alps, Carpathians and Cantabrian mountains, where climate change during the early Holocene could have created similar windows of opportunity allowing the adoption or expansion of farming into formerly marginal environments.

CONCLUSIONS

This study of the Mesolithic-Neolithic transition in Scotland within the wider north-west European context has reached four principal conclusions:

❶ The transition from Mesolithic to Neolithic in Scotland (and throughout the British Isles) was a relatively short-lived and discrete event, occurring sometime between 5300–5000 BP (4100–3800 cal BC) – and not the protracted process of gradual economic and cultural change beginning over half a millennium earlier that some researchers have envisaged.

❷ Native Mesolithic peoples probably played a significant if not dominant role in the development of Neolithic culture and economy in the British Isles, although on present evidence the possibility that immigrant farmers were also involved cannot be excluded.

❸ The rapidity with which agriculture, once adopted, was able to spread across the British Isles and other maritime areas of Europe was due in part to the availability of animal domesticates that would have provided native hunter-gatherers with new opportunities for the acquisition of wealth and power, as well as alternative sources of food and raw materials.

❹ The widespread adoption of farming across the British Isles and southern Scandinavia between 5300–5000 BP (4100–3800 cal BC) following a long interval when the agricultural frontier lay further south in continental Europe, coincided with a shift to a more continental-type climate with lower winter precipitation and, perhaps, higher summer temperatures. By improving the prospects for cereal cultivation on land that previously was marginal for agriculture, this climatic event may have been a key factor in the transition from Mesolithic to Neolithic in north-west Europe.

Some of the arguments advanced in support of these conclusions reinforce views expressed by previous authors, by bringing new evidence to bear. Others are original and for that reason may be regarded as contentious, not least the suggestion of a causal link between climate change and the expansion of the Neolithic across north-west Europe. Much remains to be learned about climatic conditions during the mid-Holocene at local, regional and sub-continental scales, as well as the effects of relatively minor changes in precipitation and temperature on prehistoric land use patterns. This is an obvious priority area for future research. If this paper helps in some small way to stimulate that research, it will have served its purpose.

ACKNOWLEDGEMENTS

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Documenta Praehistorica XXIX

Another Neolithic in Holocene Japan

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ABSTRACT – *In the Japanese Islands, small sedentary villages sustained by hunting, gathering, fishing and cultivation emerged around 10 000 years ago. This life style of the Jomon people continued for around 7000 years without any drastic changes in material culture, subsistence strategy and village size until the diffusion of continental civilization into Japan approximately 2500 years ago. This indicates that the incipient sedentary society of the Jomon Period was very stable, a state which is not indicative of civilized society after that time. After the prehistoric situation in Japan, we are able to classify sedentary society into two phases; sedentism with stability and sedentism with instability (civilized society). Therefore it is possible to say that the emergence of sedentism and cultivation are not direct factors which promote the emergence of civilization.*

IZVLEČEK – *Na japonskem otočju so se pred okoli 10 000 leti pojavile majhne, stano naseljene vasi, ki so se preživljale z lovom, nabiralništvom, ribolovom in obdelovanjem zemlje. Ta življenjski stil ljudstva Jomon se je nadaljeval okoli 7000 let brez večjih sprememb v materialni kulturi, načinu preživljanja in velikosti vasi, dokler ni prišlo do difuzije kontinentalne civilizacije na Japonsko pred okoli 2500 leti. To kaže, da je bila prvotna stalno naseljena družba obdobja Jomon zelo stabilna, kar za civilizirano družbo po tem času ni bilo značilno. V prazgodovini na Japonskem lahko stalno naseljeno družbo ločimo na dve fazi; stalna naseljenost s stabilnostjo in stalna naseljenost z nestabilnostjo (civilizirana družba). Zato je mogoče reči, da pojav stalne naseljenosti in obdelovanja zemlja nista neposredno povezana s pojavom civilizacije.*

KEY WORDS – *sedentism; Jomon period; Neolithic; stability; insatiability; civilization*

INTRODUCTION

The Neolithic in Europe, West Asia and China is characterized by farming, pottery and sedentism, with these aspects considered to be the basis of civilized society. Pottery first appeared in the Japanese Archipelago around 13 000 years ago, with sedentary villages appearing at around 10 000 years ago (Fig. 1). However, agricultural practices did not begin until 2500 years ago (*Imamura 1996*). The period immediately before agriculture began is called the Jomon period. There are some similarities in lifestyle patterns and time span between the Neolithic and Jomon periods; however, the Jomon people did not practice agriculture.

Many Japanese archaeologists believe that the presence of cereal agriculture is the most important element of the Neolithic culture of the Eurasian continent, and for this reason consider the Jomon period different from the Neolithic period. Consequently, comparative research of both periods is not well developed and research on the Jomon period has been isolated from prehistoric research in general.

If we analyse the artifacts of the Jomon period we can easily understand that the subsistence activities of the Jomon period are characterized by hunting, gathering and fishing. The presence of well constructed houses and refuse heaps indicates the sedentisation of this period. However, until recently there was little recognition by Japanese archaeologists that sedentism was an established characteristic of the Jomon period. The reason it took Japanese researchers so long to recognize this fact is that they were influenced by the theory of the Neolithic revolution and considered it difficult to believe that the people who subsisted by fishing, hunting and gathering during the Jomon period could also maintain a sedentary lifestyle.

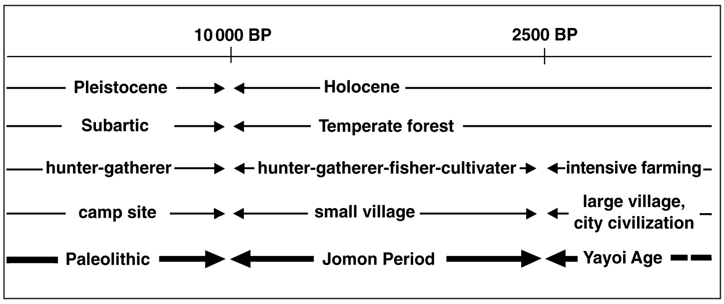

Fig. 1. Prehistory of Japanese Archipelago.

In addition, a strong traditional belief held within Japan is that Japanese culture is based on rice farming. For this reason, the Japanese people believe the roots of Japanese culture began in the Yayoi period, because the Jomon lifestyle, based on fishing, gathering and hunting is, considered unstable.

The image and historical interpretation of the Jomon period has changed dramatically in the last twenty years. This is partly due to the fact that the design and beauty of Jomon pottery has been recognized. The excavation of gourd and hemp remains, which were useful for daily living activities, have been found at Jomon sites even though these species are not indigenous to Japan. In addition, there is evidence that chestnuts, one of the major foods of the Jomon people were cultivated. The excavation of timber posts nearly one meter in diameter, and beautiful lacquer ware indicates highly advanced technology. These are some of the reasons the image and historical interpretation of the Jomon period changed.

Recently, the richness of the Jomon period has been exaggerated, in tandem with claims that the roots of Japanese culture extend back to the Jomon period. By incorporating the advanced nature of the Jomon period into Japanese history it is possible to extend further the roots of Japanese society by more than 10 000 years. This manipulation of historical perspective is necessary for the creation of civilized Japanese society. Civilized societies manipulate historical interpretations of the past to their own advantage. For this reason, it is very important to eliminate nationalism and the way of looking at history from the viewpoint of modern civilized societies in the study of the Jomon and Neolithic periods.

To remove this focus from Neolithic and Jomon studies it is necessary to do three things:

❶ Increase comparative research on the Jomon and Neolithic cultures.
❷ Eliminate the historical viewpoint of looking at past societies as the roots of specific nations or civilizations.
❸ Use an ecological perspective to understand past societies from their survival strategies.

In this paper I am going to give an overview of Jomon society and discuss new perspectives for a comparative study between the Jomon period in the Japanese Islands and the Neolithic on the continent of Eurasia.

The Jomon peoples lifestyle which incorporated hunting, gathering, fishing and cultivation did not change for 7500 years. The absence of constant population growth indicates that Jomon society was very stable (*Koyama 1987*). In spite of this fact, many Japanese archaeologists have tried to periodise Jomon society and give meaning to the differences instead of understanding that the Jomon period was a stable society that did not undergo big and drastic changes.

This interpretation is based on historical research methods and looks at social and cultural change processes. Change in civilized societies can cause instability, in contrast with simple societies, which do not undergo drastic changes. Therefore, it is not helpful to do research on simple societies using historical viewpoints or perspectives. If we wish to understand the unchanged nature of Jomon society, we have to focus on how this stability was established. We have to focus on the socio-ecological mechanisms which enabled the stability of the Jomon period to continue for such a long time.

If we focus on the reasons for the stability of Jomon society, we can re-evaluate the Neolithic period of Europe, China and West Asia. If the Neolithic period is considered the starting point of civilized societies, then this also marks the point at which these societies began to lose their stability. Therefore, the main task of my research is to clarify why Neolithic societies lost their stability and developed into civilized societies. This question contributes to a better understanding of the instability of civilized societies.

LIFE DURING THE JOMON PERIOD

Many houses during the Jomon period were of pit house construction and used thick wooden posts as support structures. From Jomon village sites many pottery sherds and heavy stone cooking implements have been excavated. In those sites where preservation conditions are good, the remains of food have been recovered. In addition, the presence of refuse heaps indicates that cleanliness was important. These characteristics are not found in Palaeolithic sites and are major indicators of the sedentisation of villages during this period.

Sedentised villages appeared in the southern part of the Japanese Archipelago at around 10 000 years ago. This lifestyle did not appear in the north of Japan until thousands of years later. This time lag represents the period when sedentisation followed the spread of the temperate forest environment from the south to the north of the Japanese archipelago. This indicates that the sedentary lifestyle of the Jomon period emerged as an adaptive process to the temperate forest environment.

The Japanese Archipelago was covered with sub-arctic tundra during the ice age, and many stone tools used for hunting have been excavated. However, during the Holocene the archipelago was covered with temperate dense forest. Flora and fauna changed, as did the environmental conditions under which hunting could be practiced. The existence of dense forest meant that animals were no longer clearly visible, making hunting more difficult. Under such conditions the techniques and lifestyle of the Jomon period was formed.

Jomon subsistence and technology

I will explain Jomon subsistence and technology with reference to those sites at which I assisted in the excavation process. The Torihama site is located next to a shallow lake, therefore refuse and debris which were excavated from the bottom of the lake were well preserved. I analysed the kitchen refuse, seeds and charcoal from this site.

Hunting

Deer and wild boar were the most important animals hunted during the Jomon period (*Nishida 1980*). They comprise 95% of the faunal remains at the Torihama site. The analysis of teeth recovered from the site indicates that wild pigs were hunted in winter and deer were hunted all year round. Other faunal remains include bear, monkey, hare, fox, otter, wolf, and lynx in smaller quantities. The presence of animal hides from the above species at the site suggests that the hunting season for these types of animals was limited to winter. Small quantities of geese bones were also excavated. These birds were also hunted in winter, as geese typically migrate during the winter months.

Gathering

Walnuts, acorns, chestnuts and water chestnuts were excavated in large quantities from the Torihama site. These nuts are gathered in autumn and may be preserved to use during other seasons. Therefore, these nuts constituted an important food source for the Jomon people. The collection of nuts is an activity that anyone can do. Wild fruit seeds were also excavated, but their nutritioned importance is not clear. In addition, the use of wild vegetables, mushrooms and wild yams is assumed; however there, are few records from Jomon sites.

Fishing

Fishing was an important subsistence activity of the Jomon period. Various species of fish bones were excavated from the Torihama site. It is more than 10 kilometers from the Torihama site to the ocean. In winter a strong wind blows from the north, increasing wave height and making fishing from a boat very dangerous. Therefore, lake and ocean fishing would have been considered a summer activity.

Shell collection

Around 30 species of freshwater and marine shells were excavated from the Torihama site. Using growth line analysis it is estimated that these shells were collected in spring, summer and autumn. Shells constituted the most prolific and visible food debris found in the Torihama sediment; however, calculations suggest that the caloric value rate of shellfish was not so high.

Farming

An explanation is necessary to understand the farming practiced during the Jomon period, as no direct evidence, such as domesticated plant remains, traces of farmland or farming implements, have been recovered from Jomon sites.

During the Jomon period several species of useful plants were introduced to the Japanese Islands and utilized in daily life. They are: gourd (*Lagenaria sicenraria*): liquid container, edible seed. Hemp (*Cannabis sativa*): fibre, narcotic drug, and edible seed. Perilla frutescens Britten (*Perilla frutescene*): cooking oil, solvent used for urushi lacquer, edible seed. Urushi (*Rhus verinicifiua*): lacquer. Kajinoki (*Broussonetia kazinoki*): fibre, bark cloth, sweet berry.

These plants are not indigenous to Japan and could not grow successfully in the natural Japanese forest environment. We estimate that these species were planted and nurtured by Jomon people in disturbed artificial vegetation areas near villages.

There is clear evidence from seed and charcoal analysis that suggests Jomon villages were surrounded by disturbed secondary vegetation areas (*Nishida 1983*). Firstly, many kinds of seeds of sun loving plants, which cannot flourish in shady areas, were excavated from the Torihama site. Secondly, charcoal from chestnut trees is the most common component at many Jomon sites. This indicates that chestnuts were used as firewood. Chestnut trees are also sun-loving plants which cannot grow in dense forest.

Artificial secondary vegetation areas of forest and grass fields were formed around Jomon villages because people cut down trees for building houses, making tools, and firewood. Even if the chestnuts were originally wild species, and in spite of primitive planting methods, these chestnuts were the products of a artificial vegetation. The Jomon people consumed large quantities of chestnuts, which were a product of this artificial field.

It is estimated that the cost of planting, collecting and transporting these kinds of chestnuts was minimal because the procurement area was close to the village. This close proximity was advantageous in terms of restricting potential competition with bears, deer, wild pig and monkeys, as these animals would have been wary of foraging close to human occupation areas.

The cutting down of trees for firewood and house building influenced the kinds of plants found around the sedentised villages. This disturbance of the natural vegetation ensured that an artificial environment automatically emerged around Jomon villages. The humidity of the Japanese archipelago ensured that chestnuts and other sun-loving plants increased in these disturbed areas. The nurturing of these areas of sun-loving plants by human beings necessitated the selective procurement of firewood so as not to cut down those trees used for subsistence purposes.

From the Yayoi period onwards paddy planting required people to cultivate, seedlings and weeding, as well as pipes and irrigation to control the water flow. Compared to such advanced planting methods the primitive planting methods of the Jomon period were not labour intensive. In contrast, the cost performance of labour during the Yayoi period must have been very high.

Village and houses

In many village sites a cemetery was found close to the village. In some cases it was located at the centre of the settlement. From some sites tomb stones were excavated in an upright position indicating the importance of marking these burial places to the people.

Jomon people created sedentary villages and collected most of their food and other resources in close proximity to these areas. To maintain specific areas surrounding the villages was a most important survival strategy. The people of the villages must have succeeded or inherited these areas from their ancestors, and the tombs of their ancestors built near the villages may have been symbols of rights to land. The existence of visible tombs from the Jomon period indicates that lineal descent and land transfer were practiced during this time.

Sedentisation

The people of the Jomon period practiced fishing, gathering, hunting, produced pottery and polished ground axes, stored food and lived in small sedentary villages. In contrast, Palaeolithic societies specialized in hunting, with the ability for high mobilization. The sedentary society of the Jomon period was a generalist one where people utilized many different kinds of resources. This is the same for Western Asia during the initial period of sedentisation when subsistence was diversified and focused on broad-spectrum subsistence activities (*Flannary 1965*). There are several reasons for utilizing broad-spectrum subsistence strategies during the initial period of sedentisation:

❶ Utilizing a broad spectrum of food resources, villagers could collect enough food within a relatively short distance village, which reduces the labor costs of subsistence activities.

❷ Utilizing this type of subsistence strategy meant that sedentary villages were able to maintain a much higher population rate than Palaeolithic societies.

3. Sedentary villagers started eating certain types of food which had not been consumed previously, indicating that they had moved on to less desirable or secondary food sources.

These three points show the correlation between the increase in population rate and sedentisation. In West Asia, China and Japan, the most important food that human beings started eating as sedentisation began was small seeds, like cereals, rice, chestnuts and acorns, which contain a lot of starch. And there is no recorded usage prior to this time. The reason for this is simple. These seeds are small and covered with a hard shell, and the edible parts are so hard that they cannot be eaten without being cooked. Some acorns, which contain tannin, cannot be eaten without leaching. To remove the hard shell from small seeds, and leaching then cooking them requires much time and energy. Up until this time the kinds of animals and root vegetables which had been consumed by human beings did not require such thorough cooking or processing. It was very easy to cook these foods over a small campfire.

It is easy to process small starchy seeds effectively using implements such as millstones, grindstones, pottery or ovens. However, preparation and usage of heavy implements or tools and also the preservation of large quantities of food at harvest time does not fit with a nomadic lifestyle. For the nomads of the Palaeolithic cereals and acorns were a food for animals and birds,not for human beings.

The ancestors of human beings carried out a nomadic lifestyle for millions of years. Frequent movement or migration was a beneficial adaptation for apes and other larger mammals. Constant movement of camps must have been the normal pattern of life for people in the Palaeolithic, with the decision to sedentise being a second choice.

Sedentisation and eating small starchy seeds were secondary choices for the people of the Palaeolithic, compared to an established nomadic lifestyle. The crisis situation which forced this change needs to be investigated.

The Holocene crisis

Like wolves and tigers, people of the mid latitude environments during the Palaeolithic specialized in hunting and food selection. In order to use their environment like wolves and tigers, they had to maintain a low population density so as not to over extend the carrying capacity of their territory. However, by 15 000 years ago human beings had extended their living territory up to the northern end of the Eurasian continent. The human penetration of such a harsh environment suggests a higher population density than that of prior nomadic hunting and gathering societies. Under these conditions human beings experienced a big climatic change.

Even if human penetration of the north occurred as a result of rising global temperatures, such a move may not have been problematic. By the end of the last ice age, human population already extended to the north of the Eurasian continent, which meant that there was no more space to go north. Europe, Western Asia, China and Japan where sedentisation occurred, were areas which experienced a climatic change from the sub arctic environment of tundra and coniferous forest to a warm temperate forest environment. The change from a open-end to a dense forested environment meant that the hunting techniques of the Palaeolithic were no longer effective. Under such conditions survival strategies needed to be re-assessed.

In warm temperate forest environments different types of starchy seeds in large quantities flourished. They were easy to collect and had a high caloric value. These are hard to process but if processed with heavy tools and stored in large quantities, they can be eaten at any time. This response to the crisis made migration difficult and led to sedentisation.

Chestnuts or cereals

In Eastern Asia, cereal cultivation developed, and in the Japanese archipelago, chestnuts were cultivated. The differences derive from the early stages of these two areas. During the Holocene, the Japanese archipelago was surrounded by ocean, experienced a high degree of rainfall throughout the year, and was deeply forested, with the exception of high mountainous areas. This type of environment is not suitable for cereal cultivation. Even if the villagers cut down trees for building or firewood the disturbed areas were not invaded by gramineous plants, but became secondary forest environment.

In West Asia and China the warm temperate forest area was next to the dry grassland area of the interior region. In such marginal forest areas, much more gramineous plant flourished, and when the trees were cut down the vegetation easily reverted to gramineous grassland. Domestication of gramineous plans might start under such conditions.

The ecological process for the emergence of cultivation might be almost same forrice, wheat and chestnut, but the process for the emergence of cultigens is quite different. Firstly, domesticated gramineous plants are annual grasses, whereas chestnuts are not, which means that the rate of genetic change is quite different. Secondly, most of the gramineous plats are self-fertilizing, whereas chestnuts require cross-fertilization. Thus even if the initial cultivator selected fine cultigens, it is hard to keep it to the next generation without grafting techniques.

Cereal plants tend to become cultigens; however, chestnut cultivation encompasses techniques for nutritious growth. Once the cultivation of gramineous plants began, new types of cultivation emerged. Chestnut cultivation encompassed managing wild types only. Due to these factors, cultivation during the Jomon period has not been understood well until recently.

Civilized society emerged in Western Asia and China where gramineous plants were cultivated. For this reason, the cultivation of gramineous plants is considered to be the basic factor for the emergence of civilizations. This is the biased idea of ancient legend. For example, according to the legends of ancient Japan, human beings received rice seeds from God, began rice cultivation and created a nation. Rice was considered to have the mysterious power to form a nation.

At the same time, people argue that an increase in the production of crops and creation of a surplus leads to civilized society. In this argument, mystical power was correlated with the power of production of a surplus. This idea is a mere transformation of legends. Rice as a crop itself does not change the rate of increase in production, nor produce surplus food.

Intensification of production

In Western Asia and China during the Neolithic, intensive cultivation and specialized practices were developed, and these elements are considered important stages for the development of civilized societies (Fig. 2). On the other hand, during the Jomon period cultivation occurred, but was not specialized, and at the same time fishing, hunting and gathering were actively pursued. To carry out such subsistence activities there are costs and benefits.

The fact that hunting, gathering and fishing were practiced during the Jomon period is attributed to the rich natural resources of that time. Villages of the Jomon period were relatively small and were located near rivers, lakeside and ocean. Villages maintained a low population density, which was essential from an ecological viewpoint to maintain the level of subsistence activity carried out.

Hunting, gathering and fishing activities do not require the high labour costs associated with pastoralism, intensive cultivation and production or factories. These natural resources reproduce according to natural cycles, and people collected produce when needed. It is natural for hunter-gatherer societies to maintain a food supply with small labor costs.

We can assume that hunting, gathering and fishing activities were pleasurable for prehistoric people. Hunting, gathering and fishing activities in modern society are weekend hobbies because these activities are more pleasant than farming or office work. The patterns of subsistence activities in the Jomon period must have had benefits in terms of labor cost and quality.

In Jomon villages chestnuts were cultivated; however, people also collected large quantities of acorns and water chestnuts, which flourish in the primary vegetation. If people can collect sufficient to fulfil dietary needs, much more chestnut cultivation would not have been necessary. Labor costs associated with chestnut cultivation must have been the same or less than that of the gathering in the primary forest. In Jomon society there was no need for surplus production.

To maintain the rich natural resource balance it was necessary to control population growth and resource

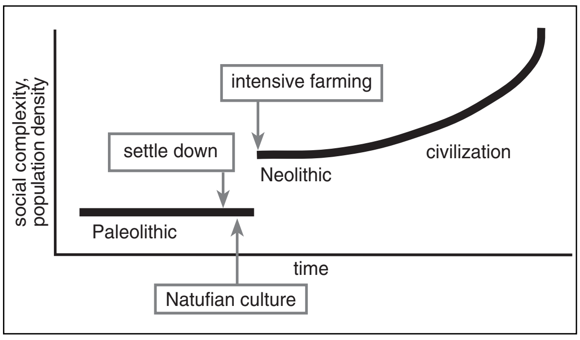

Fig. 2. Neolithic model.

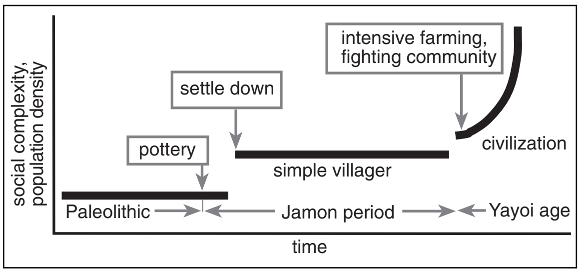

Fig. 3. Jomon model.

collection. It is natural for hunter-gatherer societies which depend on natural resources to be concerned about the consumption of such resources. Such attitudes of self-restriction enabled population control.

The fact that Jomon villages were small-scale indicates less conflict amongst villages. If larger villages tried to control smaller ones, all the villages would have tried to increase their power to influence other villages. This phenomenon was not found in the Jomon period. The low population density during the Jomon period was maintained so as to control social conflict over natural resources and space.

On the other hand, during the Neolithic age of West Asia and Europe the scale and density of villages increased, and intensive and specialized cultivation developed. The rich natural environment of the hunter gatherer period decreased and food production was intensified. The reason behind such changes must have been due to population increase and social conflict.

As population and social conflict increased, more armies, weapons and land were required, leading to further population increase and conflict. Once this cyclic process began, population and community size increased, and weapons and war technology became more developed. These are the characteristics of the historical era.

The beginning of civilization is identified archaeologically by an increase in the scale of villages, the intensification and specialization of cultivation, the emergence of military fortifications, and the development of military technology (Fig. 3). These elements are found within the Yayoi period in the Japanese archipelago, but not within the Jomon period.

Jomon societies were sedentary societies with a high degree of stability, whereas societies after the Yayoi were unstable. The difference between the two periods is quite marked. If we consider the aforementioned points we can look at West Asian prehistoric research and draw some conclusions. One is about the beginning of sedentary societies in the Mediterranean and the understanding of Natufian culture.

According to research on Natufian culture, the Natufians were hunters, gatherers and fishers, and lived in small-scale sedentary villages, and they collected wild cereals. Gramineous plants are sun-loving plants, and wild barley must have been growing in secondary vegetation near Natufian villages. If human beings created the artificial environment in which wild plants grew, then people consumed them, the reciprocal relationship between plants and humans was established. It is not gathering, but cultivation.

It is hard to understand why Natufian culture was regarded as an epi-palaeolithic culture. The survival strategies of sedentary and nomadic societies are different. In nomadic societies there is frequent changing of campsites in response to the carrying capacity of the land, environmental changes and dangerous social trouble. Nomadic societies are characterized by frequent migration in response to inconveniences, whereas sedentary societies adapt to inconveniences within their villages.

Frequent migration is a long historical tradition, which lasted for millions of years through the history of apes and human beings. When the tradition of a nomadic way of life was abandoned, sedentary society, which is different from the living patterns of the great apes, emerged. This change is the most significant event in the evolutionary history of apes and human beings. It is wrong to conclude that the Natufian culture is epi-palaeolithic.

Natufian culture did not last longer than the Jomon period. During the Natufian period there was no increase in village scale, the development of military fortifications or intensification of cultivation, so Natufian society must have been as stable as Jomon society, and thus can be distinguished from the unstable civilized societies of the Neolithic.

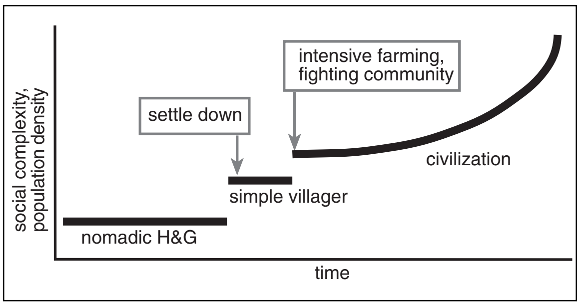

Fig. 4. General model.

Nomadic hunter-gatherer societies, Jomon or simple sedentary societies, including Natufian culture, and civilized societies all have their own characteristics and existed over large areas and long period. Nomadic hunter-gatherers societies existed in all parts of the world until 10 000 years ago. Simple sedentary societies emerged in temperate forested areas around 10 000 ago. This type of society existed in wide areas of humid tropical Asia and Africa just before the occupation of civilized society. Now, civilized societies exist all over the earth and have expanded globally; however, all types of societies are important. These three types of societies should be identified clearly in the history of humankind, as shown in Figure 4.

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The discovery of early pottery in China

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ABSTRACT – *During the transitional period from the Upper Pleistocene to the onset of the Holocene, there were two different cultural traditions in southern and northern China. The pottery appeared in both cultures. The earliest pottery in southern China might be dated back to 16 000 b.p. The early pottery found in the North is later than the earliest pottery in southern China, the Russian Far East, and Japan, but its character bears some similarity with the early pottery from other areas, especially from the Russian Far East and Japan.*

IZVLEČEK – *V prehodnem obdobju med poznim pleistocenom in začetkom holocena sta bili na južnem in severnem Kitajskem dve različni kulturni tradiciji. V obeh se je pojavila keramika. Najzgodnejšo keramiko z južne Kitajske lahko datiramo do 16 000 b.p. Najzgodnejša keramika s severa je kasnejša kot najzgodnejša keramika z južne Kitajske, ruskega Daljnega vzhoda in Japonske, toda po značilnostih je nekoliko podobna najzgodnejši keramiki s teh področij, posebno tisti z ruskega Daljnega vzhoda in Japonske.*

KEY WORDS – *Mesolithic; Neolithic; China; pottery*

INTRODUCTION

In the early 1960s, a series Mesolithic or Early Neolithic cave sites associated with early pottery were found in a limestone area of southern China. In 1962 and 1964, two seasons of excavations were conducted at one of these cave sites, Xianrendong, in northeastern Jiangxi Province (Fig. 1). More then 500 pieces of pottery sherds were uncovered from two layers within the excavated 69 square meters. Two radiocarbon dates were published afterwards in the mid-1970s; one bone sample from the lower layer was dated to 8575±235 b.p. (ZK-92-0), one shell sample from the upper layer was dated to 10 870±240 b.p. (Zk-39) (*Jiangxi Provincial Committee for Administration of Cultural Relics 1963; Jiangxi Provincial Museum 1976*). These dates do not fit the strata, and are considered unreliable. In 1973, Zengpiyan Cave in Guilin, Guangxi Province, was excavated, and the same kind of pottery as at Xianrendong was found from the lower layer at the site. Seven shell samples from Zengpiyan lower layer were dated to around 10 600 b.p., and the TL date of the pottery sample was 10 370±870 b.p. (*Hu Dapeng, et al. 1999*). In 1980, eight pottery sherds unearthed from the lower layer at Liyuzui Cave in Liuzhou, Guangxi Province, and two shell samples from the same layer dated to 18 555±300 b.p. (PV-0379-1), and 21 025±450 b.p. (PV-0379-2) were so much earlier that they are doubted by most researchers (*Liuzhou Museum et al. 1983*).

In late 1980s and 1990s, more cave sites were excavated in southern China. Within these sites, five pieces of early pottery sherds were found from layer 5 at Miaoyan, in Guilin, Guangxi Province; the pottery samples were dated to 15 660±260 b.p. (residue, BA94137b) and 15 560±500 b.p. (humic acid, BA94137a). Two pottery pots unearthed at Yuchanyan in Daoxian (*Yuan Jiarong 1996*), Hunan Province (Fig. 2), were dated to 14 810±230 b.p. (residue, BA95057b) and 12 320±120 b.p. (humic acid, 95057a) (*Yuan Sixun et al. 1997*). Further excavations conducted at Xianrendong (Fig. 3) and Diao-

Fig. 1. View of Xianrendong.

tonghuan (Fig. 4), only 800 meters away from Xianrendong, unearthed more than 300 pieces of pottery sherds from several stratified layers; more than 30 carbon and bone samples from these layers were dated to between 17 640±60 b.p. and 12 430±80 b.p. (*Zhang Chi et al. 1996*). It is claimed that the same kinds of pottery were also uncovered in the recent excavation at Dayan in Guilin, Guangxi Province. These discoveries indicate that the limestone area in southern China was among the sites where the earliest pottery was produced.

The earliest pottery found in northern China is not as rich as in the south, and 3 sites where early pottery has been unearthed are located in a limited area in the northern part of Hebei Province and Beijing. In 1987 and 1997, two seasons of excavations conducted at Nanzhuangtou site in Xushui uncovered 60 pieces of pottery sherds, and the carbon sample from the associated layer was dated to 10 510±110 b.p. (BK87075) (*Baoding City Institute for Administration of Cultural Relics 1992*). In 1995–1997, excavations at Yujiagou (Fig. 5) in Yangyuan unearthed several pieces of pottery sherds, and the TL date of one piece was 11 000 b.p. (*Xie Fei 1998*). Early pottery from the excavations at Zhuannian in Being in the 1995–1996 has not been published, although it is reported that the date of the associated sample is around 9800 b.p. (*Yu Jincheng 1998*).

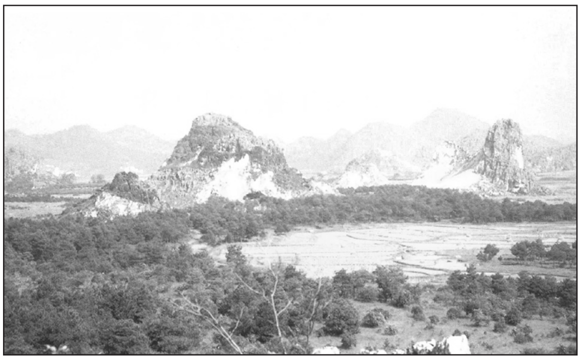

Fig. 2. View of Yuchanyan.

THE ARCHAEOLOGICAL CONTEXT OF THE EARLY POTTERY

According to the absolute dating, early pottery in China appeared during the transitional period from the Upper Pleistocene to the onset of the Holocene. In this period, there were two different archaeological cultural traditions in China: one was the so-called cave dwelling culture in the south, and its lithic industry was related to the pebble lithic industry of adjacent continental Southeast Asia of the same period (the Hoabinhian culture). The second was the so-called microlithic culture in the north, and its microlithic industry is associated with the lithic industry of Northeast Asia.

Fig. 3. Excavation at Xianrendong, 1993.

The cave dwelling culture in the South is characterized by cave dwelling sites. These cave dwelling sites are primarily found in the karst area, especially at the base of the southern slope or the northern slope of the Nanling Mountains in South China. In stratagraphy, the cultural deposit in these cave sites is in the transitional period from the Pleistocene to the Holocene. It contains large amounts of snail and mollusc shells and fossil vertebrates. Almost all the faunal remains are of modern species. The artifact assemblage includes substantial amounts of lithic, bone, antler, and mollusc shell implements. The manufacture of chipped pebble implements, which is characterized by using the direct percussion method and unifacial retouch, is a primary feature of the lithic industry. In typology, chopping implements predominate in the lithic assemblage. Some scrapers and points are also present. Flake implements are few in number. Perforated pebbles (so-called "weight stones") and cutting implements with polished blades are the most abundant polished implements. Some

Fig. 4. Excavation at Diaotonghuan, 1995.

localities yielded small flint implements. The major types of bone, antler, and shell artifacts include awls, needles, projectile points, spades, and knives (*Yuan Jiarong 1991*).

The 1990's excavations of cave dwelling sites such as Xianrendong, Diaotonghuan, and Yuchanyan have yielded more information on the subsistence strategy in this period. At Xianrendong and Diaotonghuan, over 1600 phytoliths from all types of plants were detected in more than 40 samples obtained from every layer. Researchers applied multivariate analysis to compare the double peak formed rice phytoliths statistically. With this method, a certain number of phytoliths morphologically indicative of wild rice (*Oryza nivara*) and cultivated rice (*Oryza sativa*) have been identified. This suggests that cultivated rice had become part of people's diet during this period. The results from the carbon isotope (^{12}C, ^{13}C) and nitrogen isotope (^{14}N, ^{15}N) analysis on the human bones excavated at Xianrendong and Diaotonghuan tend to confirm this observation. The discovery of rice phytoliths is widespread in the cultural deposit at Yuchanyan site. Over 40 species of plants were identified at the Yuchanyan site through the floatation method. More importantly, four rice husks were found at the site, two of which were found in layers close to the bottom of the deposit. Based on the microscopic analysis of the morphological feature of the double peak on the surface of the husks, researchers believe that these rice samples retain characteristics of *O. Sativa indica,* and *O. Sativa japonica,* as well as wild rice. They represent the archaic prototype of cultivated rice developed at the initial stage of the evolution from wild to cultivated rice.

A substantial amount of faunal remains have been excavated at Xianrendong and Diaotonghuan. After the initial classification of bone remains, the presence of deer, boar, rabbit, fox, turtle, and a variety of birds were identified. Bones from various species of deer predominate in the faunal remains, which is followed by boar and bird remains. Among the large amount of faunal remains at Yuchanyan, deer predominates, including water deer, red deer, and other kinds of deer, followed by boar, cattle, and the Chinese bamboo rat. There are also abundant bird bones, which account for 30 per cent of total animal remains. Substantial amounts of aquatic animal remains were uncovered at the site, including fishes, turtles, molluscs, and snails. The faunal remains have attributes similar to those of the Xianrendong site. This reflects the general pattern of the hunting activities during this period.

Since these remains have striking characteristics and similarities in distribution and chronology, the majority of scholars are inclined to classify them as the remains of one cultural horizon *(Yuan Jiarong 1996*). Based on the fact that this group of assemblages demonstrate similarities with the Hoabinhian Culture which was widespread in Southeast Asia in the contemporary period, and the Hoabinhian Culture was thought to be representative of a "Mesolithic" period, some scholars proposed that the remains of these cave dwelling sites represent the Mesolithic cultures in

Fig. 5. Profile at Yujiagou.

south China (*Tong Enzheng et al. 1989*) before 1990s. Contemporaneous with the southern finds, a microlithic assemblage dated to the transitional period from the Pleistocene to the Holocene has been identified in northern China. This microlithic assemblage is found to be widespread in North China and its adjacent areas. Over 100 sites containing this assemblage have been located in Hebei, Shandong, Henan, Shanxi, and Shaanxi. Among these localities, the Shayuan site in Dali, Shaanxi, the Lingjing site in Xuchang, Henan, the Hutouling site in Yangyuan, He-

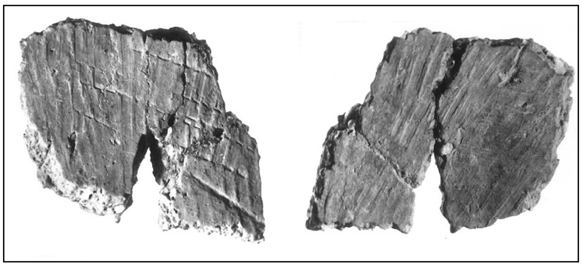

Fig. 6. Stripe-marked Pottery from Xianrendong.

bei, and the Fenghuangling site in Linyi, Shandong have been excavated or intensively surveyed. The cultural assemblages of these sites maintained the tradition of microlithics from the upper Paleolithic in northern China. Flint and quartzite were the main types of raw material. The lithic assemblage includes microblades and cores of wedge shape, keel shape, and conical shape. It also has microlithic implements made from retouched flakes, including projectile points, scrapers, engravers, and knives. This microlithic assemblage demonstrates minor variations in regional characteristics. Therefore, it is subdivided into the "Shayuan Culture," "Hutouliang Culture," and "Fenghuangling Culture".

Most of these sites were identified as lithic workshops after excavation, and the overall characteristics of the society are still inadequately known. The new discoveries of the 1990's from the Nihewan basin in Yangyuan yielded more information on other cultural aspects. Close to ten sites containing microlithic assemblages have been excavated or intensively surveyed, including Yujiagou, Ma'anshan, Qijiawan, Gongdiliang, and Bashibutan. The dates of these sites fall into a range between 14 000 and 9000 BP. Fire hearth and ash pits have been located at the Ma'anshan site, which has lithic cores, flakes, microblades, and blanks for lithic implements scattered around the site. The cultural deposit at the Yujiagou site consists of three layers. Its lithic assemblage includes microblades, scrapers, projectile points, burins, and adzes. There are also decorative items made of mollusc shells, snail shells, and ostrich eggs. The animal remains uncovered from the cultural deposit

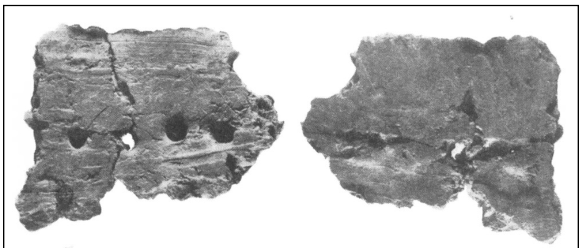

Fig. 7. Stripe-marked Pottery from Xianrendong.

include frogs, ostriches, mice, wild horses, wild donkeys, deer, bison, and antelope. Antelope predominate in the fauna.

Like the cave dwelling culture in the south, many scholars have regarded this microlithic assemblage as the representation of the Mesolithic cultures in northern China (*CASS 1984; Yan Wenming 1987*). Nevertheless, these two cultural traditions are the sources of the succeeding Neolithc cultures after 9000 b.p. in the mid and lower Yellow River basin and the mid and lower Yangtze River basin, which were both heartlands of the cultural development in China.

TYPES OF EARLY POTTERY

Since the early pottery in China appeared in different places and lasted for a long period, different characters can be observed from the unearthed pottery specimens. The stratified Xianrendong pottery provides leads for further study of early pottery in southern China.

The hundreds of potsherds at Xianrendong came from 8 stratified layers. These are primarily body sherds as well as a small quantity of rim sherds. Most of these potsherds have a similar paste, which was tempered with coarse grain quartzite grit. The diameter of grain size ranges from 1 to 5 mm. Some are over 5 mm in diameter. The sorting is poor for the temper, which indicates that no attempt at intensive selection was made.

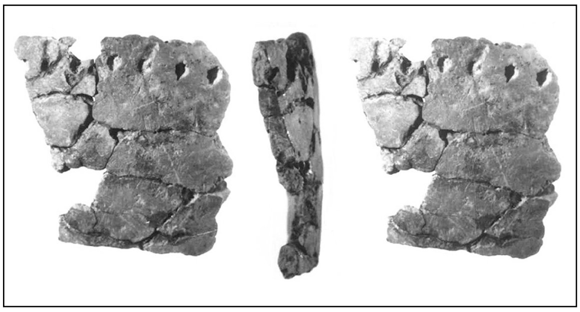

Fig. 8. Plain Pottry from Xianrendong.

Since many quartzite implements have been excavated from the local sites of this period, it follows that the raw material for the temper might have come from the adjacent area and the pottery might be of local production. Brown is the basic color tone of the potsherd, which derives into many colors, including brown, dark brown, reddish brown, and grayish brown. Some potsherds have a black core, indi-

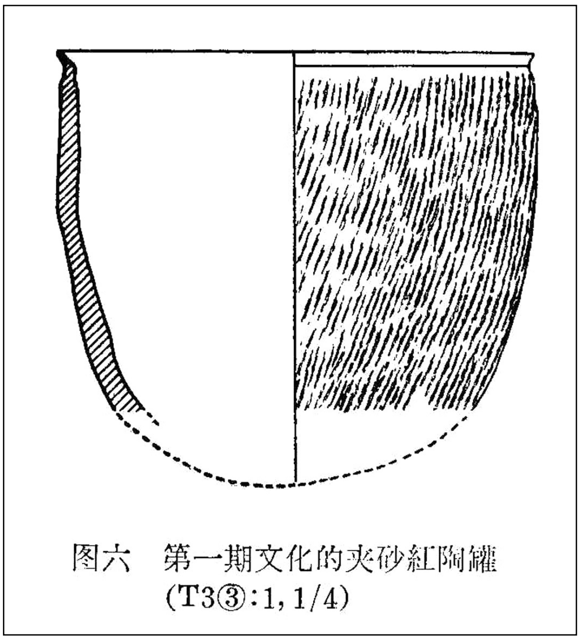

Fig. 9. Cord-marked Pottery from Xianrendong.

cating that the paste was not fully oxidized and the pottery ware might not have been fired in a kiln.

The piece building method and the coiling method were both applied in pottery production. Pottery made by the former method is classified into two types. The first type has stripe-marks which were wiped or scored with some sort of blunt object with teeth like a fork on both the interior and the exterior of the vessel as a result of surface retouching (Figs. 6, 7). The second type has a plain surface, created by hand smoothening (Fig. 8). The decoration on the stripe-marked pottery and the plain pottery is primarily the same, which is characterized by V-shaped or U-shaped denticulations at 1 cm intervals on the vessel rim. In the area under the rim, the exterior surface is decorated with a single row of puncture dots created by using a small stick to punch the interior of the vessel. The walls of both types of vessel are thick, generally measuring 0.7 cm. Some vessels are as thick as 1.2 cm. Although no intact specimen survives, the vessel shape as suggested by the fragments was probably that of a round-based jar with a straight rim.

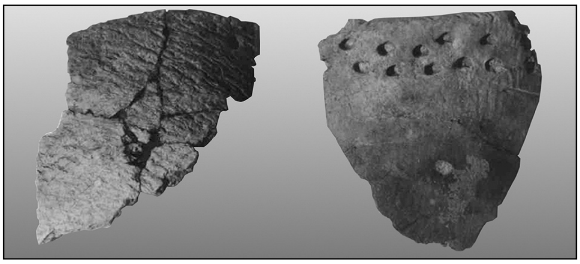

Fig. 10. Woven Pattern Pottery from Xianrendong (exterior).

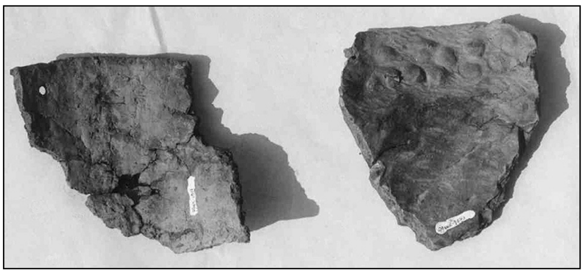

Fig. 11. Woven Pattern Pottery from Xianrendong (interior).

Vessels manufactured by the coiling method were stamped with a potter's paddle to reinforce the wall. The paddle was wrapped with cord or fiber of various strands. The vessel surface was left with an impression similar to the cord-mark paddle stamping, which could be classified as cord-mark pottery (Fig. 9). The vessel type should be a round-based jar (or urn), with a slightly flared round rim and a straight mouth. The pottery vessels manufactured by the coiling method were tempered primarily with coarse grain quartzite grit. A small quantity of vessels was tempered with crushed cord-mark potsherd. The manufacturing process was the same for pottery tempered with both materials. A few pieces of potsherd from pottery produced by the coiling method have a straw mat or cord-woven mat impression stamped on the exterior surface, which could be referred to as woven pattern pottery (Figs. 10, 11), and some of these kinds of pottery might have been paddled by deer horn.

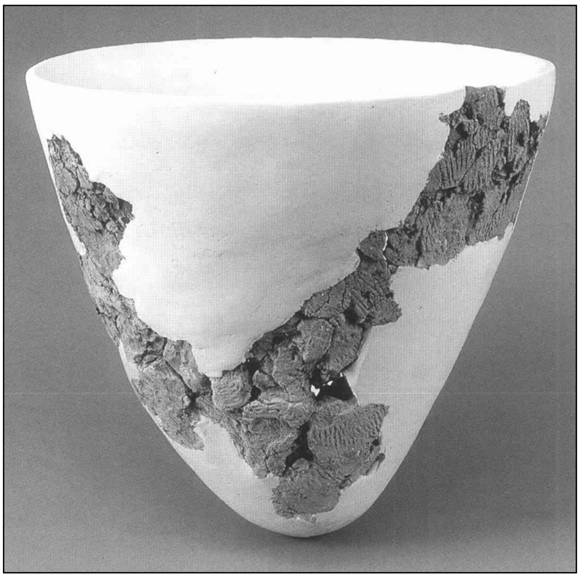

Fig. 12. Pottery from Yuchanyan.

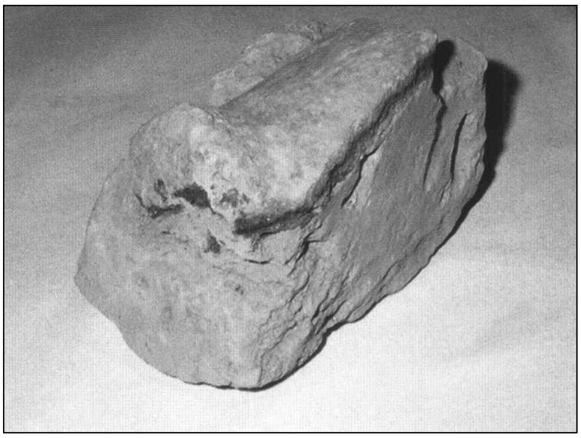

Fig. 13. Pottery from Yujiagou.

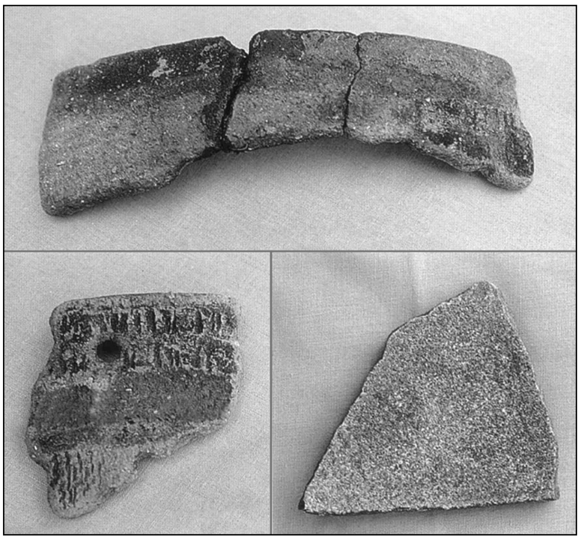

Fig. 15. Pottery from Nanzhuangtou.

According to the stratification at Xianrendong, the stripe-marked pottery is the earliest pottery type. The plain pottery and the cord-marked pottery are represented as the following type in the pottery sequence. The woven pattern pottery is the latest.

Two piles of potsherds situated near the bottom of the deposit are the only pottery remains encountered at the Yuchanyan site. The thickness of the body sherds is heterogeneous. Some specimens reach 2 cm in thickness. The ware is dark brown. Its paste is tempered with quartzite grit of various grain sizes. The majority of the grain size falls into a range between 5 and 10 mm. A round-based urn with slightly pointed bottom, flared rim, rounded rim and slanted body is the only vessel that can be restored (Fig. 12). Pottery from this site also has a paddled cord mark on both exterior and interior surfaces, which was manufactured by a method similar to that of the cord-marked pottery from the Xianrendong site.

The 5 pieces of pottery sherds from Miaoyan site bear the same character as the plain pottery from Xianrendong. Its paste is tempered with large quartzite grit, and its surfaces were smoothed by hand. And the pottery from Zengpiyan site and Dayan site are all cord-marked types similar to that from Xianrendong.

The date of early pottery in northern China is later than that in the south, and there are more differences between them. The pottery found in Yujiagou, Nanzhuangtou, and Zhuannian are all jars with flat bases. The potsherd from Yujiagou site was tempered with sand, reddish brown and yellowish brown in color, and formed by slabs joined together. Its exterior was cord-marked, and was incised with parallel arcs like fingernail marks (Fig. 13). The potsherds from Nanzhuangtou were tempered with quartz and mica or shell, made by coiling, and paddled by cord paddle (Figs. 14, 15).

CONCLUSION

During the transitional period from the Upper Pleistocene to the onset of the Holocene, there were two distinct and separate cultural traditions in southern and northern China, and the early pottery appeared in both these two cultures. In southern China, the earliest pottery might date to 16 000 b.p.

The early pottery found from the cave dwelling culture in the South can be divided into different types: the earliest type, strip-marked pottery uncovered at Xianrendong site, bears a great similarity to the early pottery from Sagamino No. 149 in the Kanagawa (Fig. 16), Miyagase in Yokahama, Japan, and from the Ust'novka 3 site on the Amur River in Siberia. So

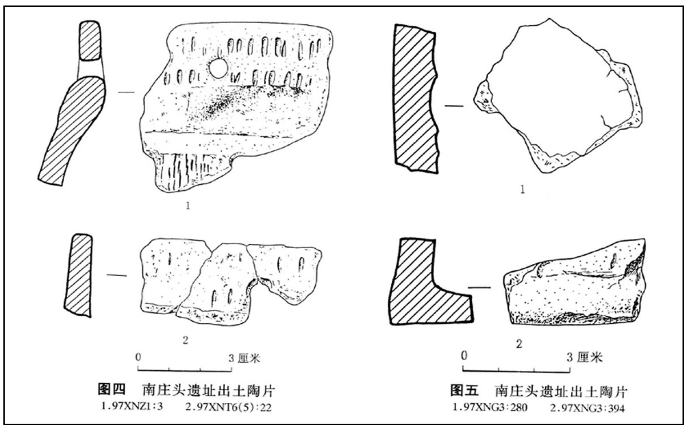

Fig. 14. Pottery from Nanzhuangtou.

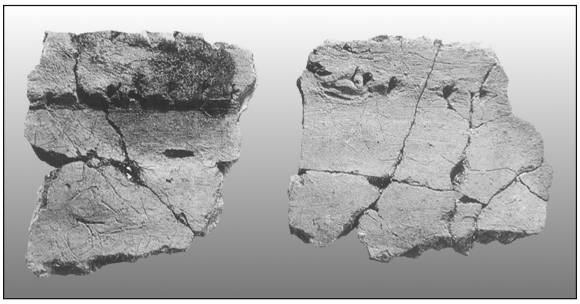

Fig. 16. Pottery from Sagamino No. 149.

that we have no evidence to say that the earliest pottery technique was created separately in different areas of Eastern Asia, although we cannot point out the specific place where it was created. The cord-marked pottery is the most popular pottery type in the South, and eventually became the dominant pottery technique in the succeeding period. The microlithic complex in the North related much more closely to the contemporaneous lithic industry in northeast Asia. The early pottery found in the North is later than the earliest pottery in southern China, the Russian Far East, and Japan, but its character bears some similarity with the early pottery from other areas, especially from the Russian Far East and Japan.

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The earliest centres of pottery origin in the Russian Far East and Siberia: review of chronology for the oldest Neolithic cultures

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ABSTRACT – *The earliest pottery from the Russian Far East, Osipovka and Gromatukha cultural complexes, was radiocarbon-dated to c. 13 300–12 300 BP. In Siberia, the earliest pottery is known from the Ust-Karenga complex, dated to c. 11 200–10 800 BP. The Osipovka and Gromatukha complexes belong to the Initial Neolithic, and they are contemporaneous with the earliest Neolithic cultures in southern China and Japan. In spite of the very early emergence of pottery in the Russian Far East, there is no evidence of agriculture at the beginning of the Neolithic, and subsistence remains based on hunting and fishing, including anadromous salmonids in the Amur River and its tributaries.*

IZVLEČEK – *Najzgodnejša keramika z ruskega Daljnega vzhoda, iz kulturnih kompleksov Osipovka in Gromatukha, je radiokarbonsko datirana okoli 13 300 do 12 300 BP. Najzgodnejša znana keramika iz Sibirije je iz kompleksa Ust-Karenga, datirana pa je okoli 11 200 do 10 800 BP. Kompleksa Osipovka in Gromatukha pripadata začetnemu neolitiku in sta sočasna z neolitskimi kulturami na južnem Kitajskem in Japonskem. Kljub zelo zgodnjemu pojavu keramike na ruskem Daljnem vzhodu pa ni dokazaov o kmetovanju na začetku neolitika. Način preživljanja še vedno temelji na lovu in ribolovu vključno lososov (anadromous salmonids) v reki Amur in njenih pritokih.*

KEY WORDS – *pottery; initial Neolithic; radiocarbon dating; Russian Far East; Siberia*

INTRODUCTION

The aim of this review is to present an updated chronology of the oldest Neolithic cultural complexes in the Russian Far East and Siberia, along with a brief description of the earliest pottery and some suggestions on the palaeoeconomy. The prehistory of the Russian Far East covers the Amur River basin, Primorye (Maritime) Province, and Sakhalin Island (*Suslov 1961*). The term "Neolithic" as elsewhere in Northeast Asia means the presence of pottery (*e.g. Chard 1974.63–64; Barnes 1999.69*). The archaeological study of the earliest Neolithic sites in the Russian Far East was initiated in the late 1920s by Gerasimov (*1928*) and was continued in 1935 by Okladnikov (*1936; 1980*). However, until the mid-1970s the oldest Neolithic complex in the lower stream of the Amur River, Osipovka, was thought to be associated with the Mesolithic (*e.g. Okladnikov and Derevianko 1973*). Since the mid-1970s, the stratigraphic association of microblades, bifaces, and pottery has been recognized at Gasya, the key site of the Osipovka complex (*Derevianko and Medvedev 1992a. 13; 1993.24–25*). Pottery-associated charcoal from Gasya was radiocarbon (below – ^{14}C) dated to c. 13 000 BP (*Okladnikov and Medvedev 1983*).

The second earliest Neolithic complex of the Russian Far East, Gromatukha in the middle reaches of the Amur River basin, was excavated in the 1960s (*Okladnikov and Derevianko 1977*), but was ^{14}C-dated only in the late 1990s and in 2000. The ^{14}C age of the Gromatukha culture at c. 12 300 BP and possibly up to c. 13 200 BP, is quite close to the age of the Osipovka complex. The third earliest Neolithic complex, Ust-Karenga, was identified in the 1970s in the middle reaches of the Vitim River in Eastern Siberia; excavations are on-going (*Vetrov 1985; 2000*). The earliest pottery derives from cultural layer 7 and was ^{14}C-dated to c. 11 200–10 800 BP (*Vetrov 1995*). This is the earliest pottery outside of the Russian Far East; Ust-Karenga represents the earliest Neolithic complex in Siberia (*Kuzmin and Orlova 2000*).

MATERIALS AND METHODS

For the purposes of this review, published archaeological and palaeogeographical data are used, including geoarchaeological and geochronological data obtained by the author (*Kuzmin 1995; 1997; 1998a; 1998b; Kuzmin and Jull 1997; Kuzmin et al. 1997; 1998a; O'Malley et al. 1999; Jull et al. 2001*). ^{14}C dating is a particular focus of this study. Different kinds of carbon compounds were ^{14}C-dated: a) charcoal from hearths; b) dispersed charcoal from cultural layers; and c) plant fibre from temper in pottery. ^{14}C dates were calibrated using the most recent software CALIB rev. 4.3 (Quaternary Isotope Lab, University of Washington, Seattle, WA, USA) (*Stuiver and Reimer 1993; Stuiver et al. 1998*). When calibrated, all possible intervals for 2 sigma ($\pm 2\sigma$) were combined up and rounded up to the next 10 years. When ^{14}C dates determined in Russia, the USA, and Japan, are compared with dates from China, the Chinese dates have been recalculated for Libby's ^{14}C half-life value (5568 years). For independent control of directly ^{14}C-dated pottery, a few thermoluminescence (TL) dates of the pottery were generated (*Kuzmin et al. 2001*).

The ^{14}C dating of charcoal was conducted using the standard procedure (*e.g. Taylor 1987*). As for direct ^{14}C dating of pottery temper by the accelerator mass spectrometry (AMS) technique, a special protocol was developed (*O'Malley et al. 1999*). First of all, pottery samples were subdivided into exterior and interior parts. The pottery was then powdered using pestle and mortar, and pre-treated using the standard acid- alkali-acid procedure. The next step was pottery combustion on a vacuum line employing two different substances: a) with copper oxide, and b) with oxygen. Two temperature combustion regimes, 400°C for one hour and 800°C for 30 minutes, were used to extract carbon. Additionally, bulk pottery, i.e. without separation into exterior and interior parts, was combusted at c. 1000°C for 10 minutes with copper oxide. The evaluation of different ways of carbon extraction for AMS dating, made by comparison of temper dates with charcoal dates from the same cultural layer, leads to the conclusion that the low temperature fraction (400°C) of the internal carbon-rich portion of plant fibre-tempered pottery, combusted with oxygen, provides the best estimate of the age of ceramics (*O'Malley et al. 1999.23*). It seems that in this way we were able to release carbon mostly from temper and to reduce the release of carbon from clay. The carbon dioxide, obtained after combustion, was converted to graphite for AMS ^{14}C dating.

THE EARLIEST POTTERY IN THE RUSSIAN FAR EAST AND EASTERN SIBERIA

At the present stage of research, three principal earliest Neolithic cultural complexes (in Russian archaeological terminology – cultures), Osipovka, Gromatukha, and Ust-Karenga, have been distinguished in the Russian Far East and Siberia (Fig. 1). The Osipovka site itself was discovered and partially excavated in the late 1920s (*Gerasimov 1928*), and at the time of intensification of the excavations in the early

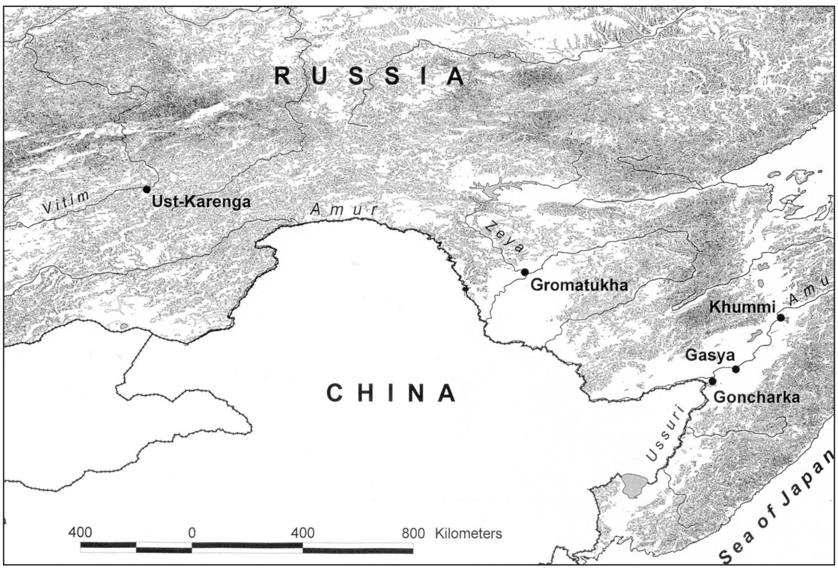

Fig. 1. Location of the earliest Neolithic cultural complexes in the Russian Far East and Siberia.

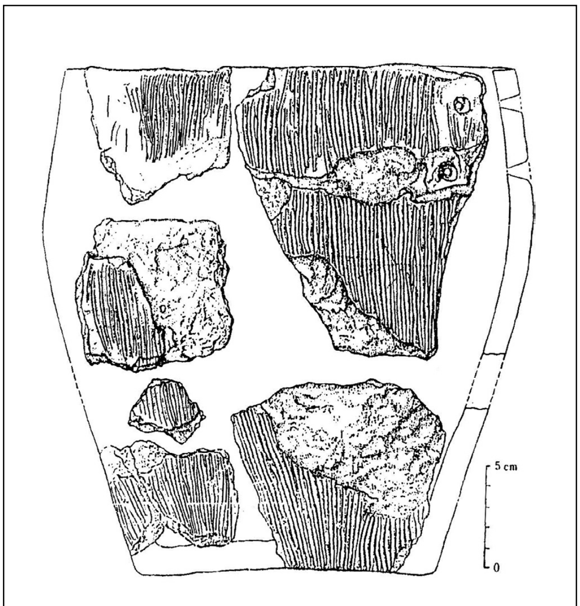

Fig. 2. The Osipovka complex pottery from the Gasya site (**after Derevianko and Medvedev 1995*****).***

1950s by Okladnikov and his students (*e.g. Okladnikov 1958*), the site had been severely damaged by modern agricultural and building construction activities. Today, it is completely destroyed, and further excavations are impossible. We now have three main sites belong to the Osipovka complex, Gasya, Khummi, and Goncharka, all located in the lower reaches of the Amur River basin. The sites of the Gromatukha complex occur in the central part of the Amur River basin, and the Ust-Karenga cultural complex sites are located in the Vitim River area.

The Osipovka complex

The Gasya site was excavated from the 1960s to the 1980s, but only preliminary results of the excavations have been published (*Derevianko and Medvedev 1992a; 1992b; 1993; 1994; 1995a; 1995b*). The earliest pottery, represented by a few fragments, was first discovered in 1975 near the bottom of the cultural layer, in association with a Mesolithic-like laurel-leaf point (*Derevianko and Medvedev 1992a. 13–14*). In 1980, larger pieces of pottery (about 20 fragments) were found in association with charcoal (*Derevianko and Medvedev 1993.24*), later ^{14}C-dated to c. 13 000 BP. The reconstruction of a pot allows us to reveal the general features of the earliest ceramics (Fig. 2). The pot is of conoidal shape with a flat base, and 25–27 cm high. The thickness of the walls is 1.2–1.7 cm, and the thickness of the base is 1.5–1.7 cm. The estimated volume of the pot is approximately 5.5–6 litres. The design is quite simple, and is represented by vertical grooves on the external surface. The colour of the pot is black, and traces of soot were recognized on both sides of the pot. The pottery is plant fibre-tempered (*Zhushchikhovskaya 1997a; 1997b*).

At the Khummi site, about 20 pottery fragments were found in 1992 and 1993 (*Lapshina 1998; 1999*) (Fig. 3). It has not been possible to make reconstructions of the pottery because of both the small number and small size of the fragments. The thickness of the fragments is 0.7–1.0 cm. There are grooves on both sides of the pottery sherds; however, there is no real design. The colour of the pot is blackish-grey. Similar to the Gasya site, the pottery is plant fibre-tempered; some grog inclusions were considered to be accidental (*Lapshina 1998.195*).

At the Goncharka site, several hundred fragments of pottery have been found, and this has allowed us to reconstruct four flat based vessels (*Shevkamud 1997*). The pottery was subdivided into two groups.

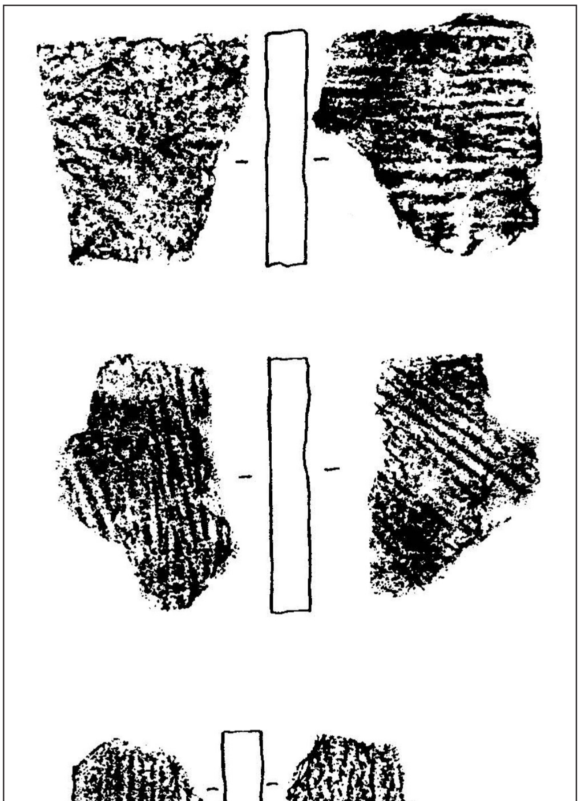

Fig. 3. The Osipovka complex pottery from the Khummi site (**after Lapshina 1999*****).***

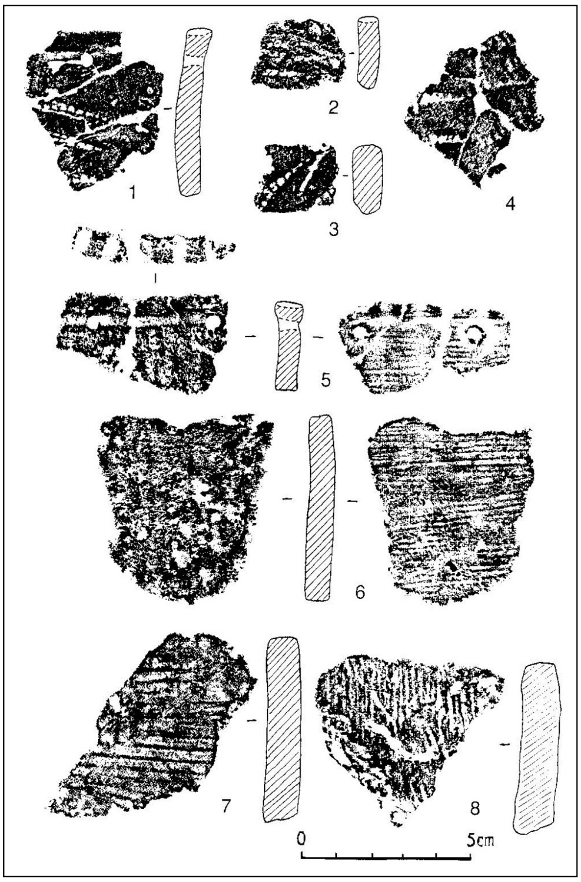

Fig. 4. The Osipovka complex pottery from the Goncharka site (*after Shevkamud 1997*).

For the first group (Fig. 4: 5–6), the thickness of wall fragments is 0.7–0.8 cm. There are horizontal internal scratches made by either bundles of grass or a comb. Wave-like indentations, made by pressing sticks or cords on to the surface, occur on the rims. Some sherds are decorated with comb-like vertical zigzag impressions (Fig. 4: 1–2). The second group (Fig. 4: 1–4, 7–8) has external traces of a comb-like instrument or cord impressions. The wall fragments are 0.7–1.0 cm thick. The design is well-developed, and is represented by a vertical zigzag made with a comb (Fig. 4: 3–4). For both groups, there is no evidence of organic temper in the ceramic paste. This is in contrast to the other Osipovka complex sites, Gasya and Khummi.

The Gromatukha complex

Okladnikov and Derevianko (*1977*) described the Gromatukha cultural complex after excavations in the 1960s. At the key site of this complex, Gromatukha, several dozen plant fibre-tempered pottery fragments were recovered from the lower part of the cultural layer. The reconstructed vessel has a flat base (*Okladnikov and Derevianko 1977.97*); the walls are 0.7–0.8 cm thick. The pottery has grooves on its internal and external sides (Figs. 5, 6). The temper in the form of plant fibre blades is visible on the surface of the sherds.

The Ust-Karenga complex

The Ust-Karenga cultural complex is represented by more than 30 sites (*Vetrov 1997*). The pottery from the earliest Neolithic component of the key site, Ust-Karenga (layer 7), is very different from the earliest pottery in adjacent Eastern Siberia and the Amur River basin (*Vetrov 1985; 1995*). Several hundred fragments have been excavated, and about 20 pots have been reconstructed (Fig. 7). There are sharp based parabolic vessels of two sizes, one 12–14 cm in diameter and 16–18 cm high, and the other 20 cm in diameter and 35–38 cm high. The walls are 0.4–0.5 cm thick. The design is quite elaborate, and represented by comb decorations, zigzag, herringbone, and cogged stamps (Fig. 8). The pottery is plant fibre tempered.

CHRONOLOGY OF THE EARLIEST NEOLITHIC COMPLEXES

The results of ^{14}C dating of charcoal from hearths and concentrations of small charcoal particles in the cultural layers, as well as of pottery temper (*Kuz-*

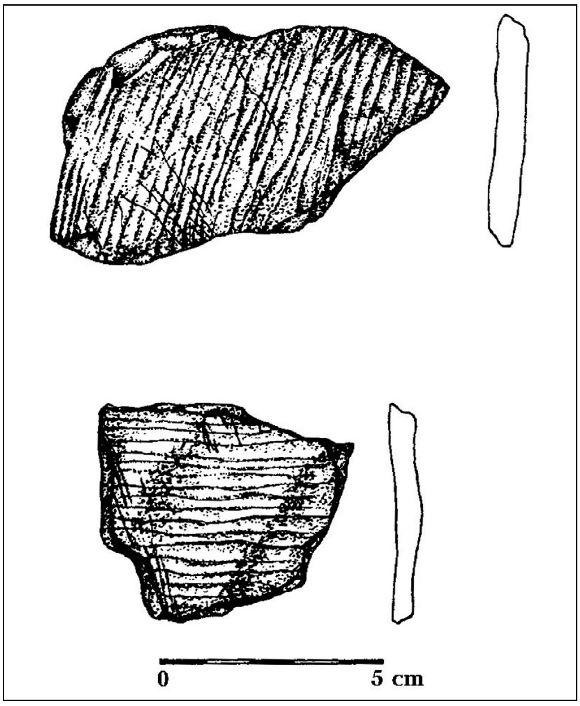

Fig. 5. The Gromatukha complex pottery from the Gromatukha site (*after Jull et al. 1998*).

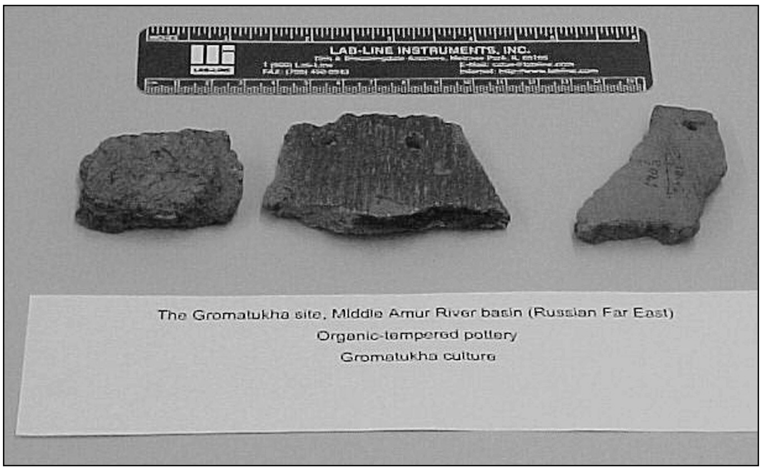

Fig. 6. The Gromatukha complex pottery from the Gromatukha site.

min and Jull 1997; Kuzmin 1998; Kuzmin et al. 1997; 1998a; O'Malley et al. 1999; Jull et al. 2001), are presented in Table 1. This dataset is state-of-the-art as of early 2002. At the Gasya site, the earliest pottery-associated charcoal is dated to c. 14 200–12 500 cal BC. At the Khummi site, the earliest charcoal date is c. 14 500–13 000 cal BC, and at the Goncharka site it is c. 13 600–12 200 cal BC. Unfortunately, for these sites we do not have ^{14}C dates run on pottery temper using combustion with oxygen at 400°C. There are other dates, obtained by using combustion of the internal part of sherds with copper oxide: at 400°C – 9020±65 BP (AA-20934) for the Gasya site, and at 800°C – 11 915±80 BP (AA-20932) for the Khummi site. Bulk temper dates are 11 905± 80 BP for Gasya and 12 010±100 BP for Khummi (*O'Malley et al. 1999*).

For the Gromatukha and Ust-Karenga sites, we have charcoal dates and pottery temper dates, run on temper using combustion with oxygen at 400°C (*O'Malley et al. 1999*) (Tab. 1). The earliest charcoal date for Gromatukha is c. 13 500–12 200 cal BC, and for Ust-Karenga c. 11 800–11 100 cal BC. The pottery temper date for the Gromatukha site is even older at c. 14 600–12 900 cal BC. For Ust-Karenga, the pottery temper dates are quite close to those run on charcoal.

Region, complex	Site	^{14}C date, yr BP	Lab No.	Calibrated age, cal BC	Reference
Russian Far East					
Osipovka	Gasya	12 960±120*	LE–1781	14 160–12 530	Kuzmin and Jull 1997
		11 340±60*	GEO–1413	11 830–11 080	Kuzmin 1998
		10 875±90*	AA–13391	11 190–10 690	Kuzmin and Jull 1997
	Khummi	13 260±100*	AA–13392	14 500–12 950	Kuzmin and Jull 1997
		12 425±850*	SOAN–3583	15 040–10 740	Kuzmin 1998
		10 345±110*	AA–13391	10 880–9740	Kuzmin and Jull 1997
	Goncharka	12 500±60*	LLNL–102169	13 600–12 210	Jull et al. 2001
		12 055±75*	AA–25437	13 400–11 720	Jull et al. 2001
		10 590±60*	LLNL–102168	10 990–10 240	Jull et al. 2001
		10 280±70*	AA–25438	10 790–9750	Jull et al. 2001
		10 280±70*	AA–25439	10 790–9750	Jull et al. 2001
		9890±230*	GaK–18981	10 380–8650	Jull et al. 2001
Gromatukha	Gromatukha	12 340±60*	AA–36079	13 530–12 160	Jull et al. 2001
		9895±50*	AA–36447	9600–9250	Jull et al. 2001
		13 310±100**	AA–20940	14 560–13 070	O'Malley et al. 1999
		13 240±85**	AA–20939	14 460–12 920	O'Malley et al. 1999
Eastern Siberia					
Ust-Karenga	Ust-Karenga	11 240±80*	GIN–8066	11 820–11 050	Vetrov 1995
		10 750±60*	GIN–8067	11 030–10 490	Vetrov 1995
		11 065±70**	AA–38101	11 240–10 720	This paper
		10 600±100**	AA–21378	11 000–10 210	Jull et al. 2000

* Charcoal dates

** Pottery temper dates (internal part, oxygen, 400°C)

Tab. 1. Radiocarbon dates of the earliest Neolithic complexes of the Russian Far East and Siberia.

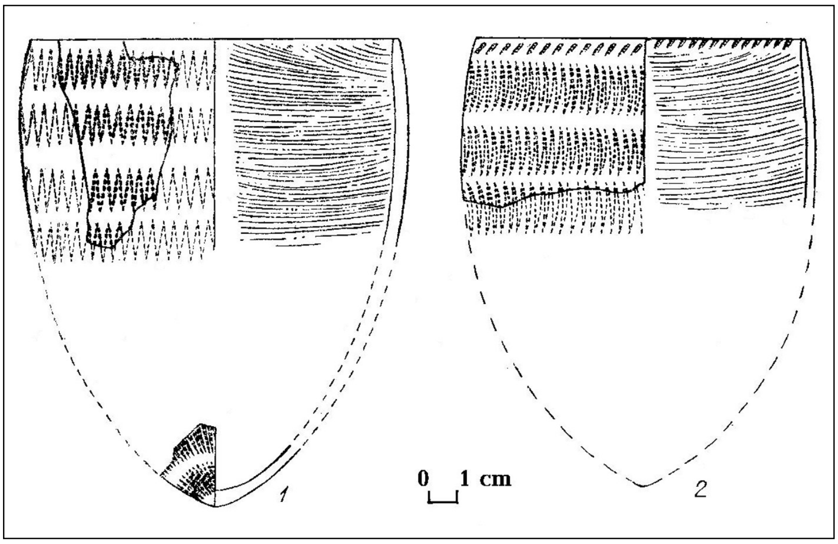

*Fig. 7. The Ust-Karenga complex pots from the Ust-Karenga site (*after Vetrov 1985*).*

nal or plant remains have been recovered from the cultural layers of the Osipovka and Ust-Karenga complexes.

In this situation, it is possible to use archaeological data to evaluate how natural resources were utilized. At the Gasya site, several net-sinkers were found in the earliest Neolithic layer (*Derevianko and Medvedev 1993.99–100; 1994. 92–93*). The data available show that hunting and fishing were the primary economic activities at all of the three complexes. In this case, pottery may have been used for the cooking of meat and fish, as well as for fat extraction from anadromous salmonids in the Amur River basin, as was suggested by Medvedev (*1995. 236*). The earliest solid evidence of dryland agriculture in the Russian Far East is known only from the

The tentative determinations of the TL age of the Gasya site pottery are between 13 460 and 8580 calendar years BP (cal BP) (*Kuzmin et al. 2001*). The TL dates span an overall age range of some 5000 years. The errors of the TL dates are up to about 1500 years. ^{14}C dates from the Gasya pottery range from c. 11 900 BP to c. 9020 BP. In order to compare the ^{14}C and TL dates, the former need to be calibrated. Generally, it was found that the calibrated ^{14}C and TL dates overlap (*Kuzmin et al. 2001.947*).

Thus, the ^{14}C dating of the earliest Neolithic cultural complexes of the Russian Far East and Siberia has allowed us to establish that pottery appeared in the Amur River basin at c. 13 000 BP, or c. 14 000–13 600 cal BC. In Siberia, the earliest pottery is dated to about 11 000 BP, or 11 200– 10 900 cal BC. First results of an independent check by TL dating of the Osipovka complex pottery from the Gasya site support these age determinations.

DISCUSSION

One of the most important questions in the study of the earliest pottery is: "What was the purpose of the use of ceramic vessels?". To answer this question, we need to know the main aspects of the palaeoeconomy. This is, however, quite difficult to determine due to the lack of direct evidence of human economic activities in the Russian Far East (*e.g. Kuzmin 1998b*). At the Gromatukha site, the bones of ungulates (*Cervus elaphus*, *Sus scrofa*, *Capreolus* sp., and *Equus* sp.) and unidentified fishes were found (*Okladnikov and Derevianko 1977*). No fau-

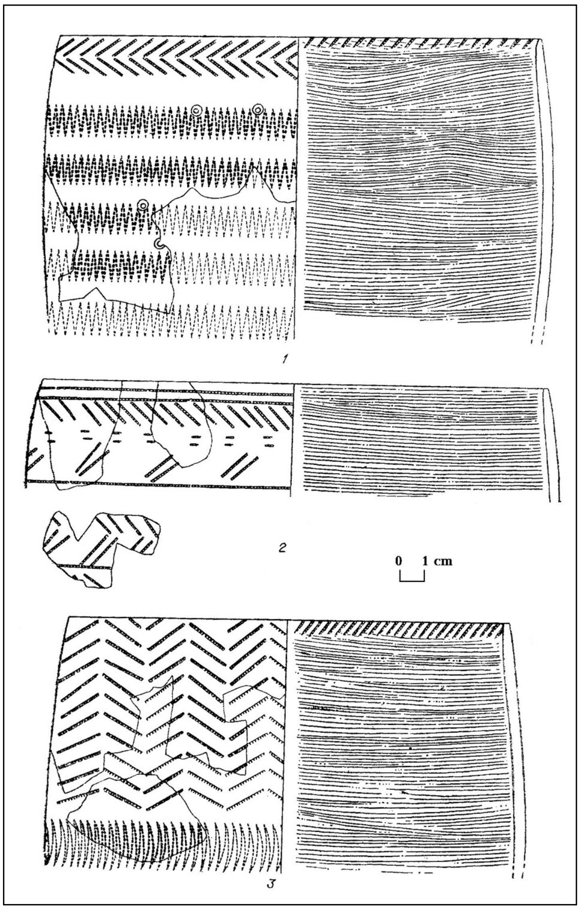

*Fig. 8. The Ust-Karenga complex pottery from the Ust-Karenga site (*after Vetrov 1985*).*

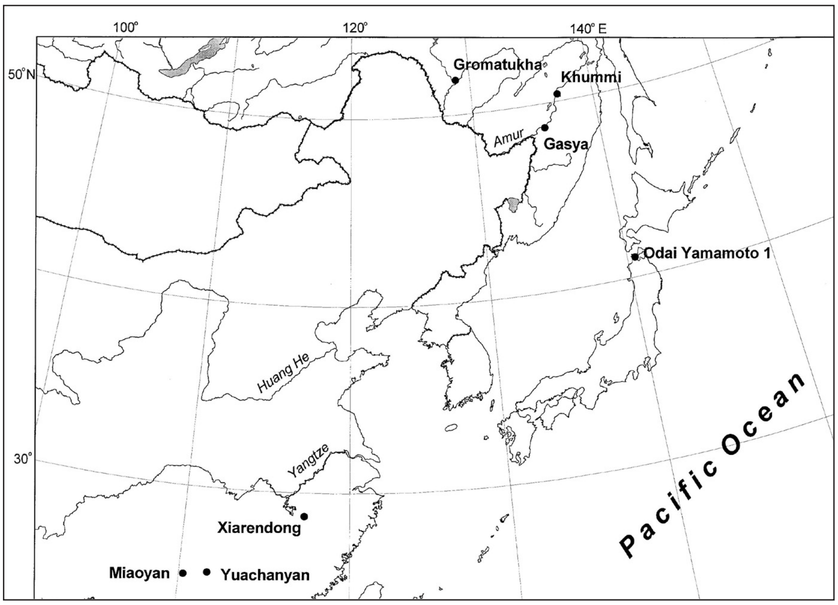

Fig. 9. The earliest Neolithic sites in East Asia.

Food adhesions on the pottery surface were dated to 13 780±170 BP (NUTA-6510) and 13 210±160 BP (NUTA-6515) (*Taniguchi 1999*). However, after averaging all of the Odai Yamamoto site ^{14}C dates, using calculation proposed by Long and Rippeteau (*1974*), the ^{14}C age for layer 4 was estimated as 13 050±108 BP, and the ^{14}C age for layer 3 as 13 170±56 BP. This gives us essentially the same age as for the Gasya and Khummi sites.

Late Neolithic, at approximately 4200–3700 BP (*Kuzmin et al. 1998b*).

After the determination of the Late Glacial (i.e. pre-10 000 BP) age of the Osipovka, Gromatukha, and Ust-Karenga complexes, it is necessary to compare it with adjacent East Asia. There are two regions outside the Russian Far East with pre-12 000 BP pottery: southern China and Japan (Fig. 9). In southern China, the earliest published Neolithic ^{14}C dates, run on organic remains in pottery, are known from the Miaoyan site in Guangxi Province, layer 5: 15 220±260 BP (BA94137b) and 15120±500 BP (BA94137a) (*Zhao and Wu 2000*). At the Yuchanyan site in Hunan Province, the earliest pottery-associated charcoal ^{14}C date is 13 680±270 BP (BA95058), and the organic remains in the pottery date to 14 390±230 BP (BA95057b) and 11 970± 120 BP (BA95057a) (*Zhao and Wu 2000*).

The early ^{14}C value for the Xianrendong site in Jiangxi Province (zone 2B1), 14 185±290 BP (BA93181) (*MacNeish and Libby 1995*), should be excluded from consideration due to possible mixture of cultural materials. As was emphasized by Zhang (*1999. 6–7*), the early ^{14}C dates from Xiarendong, which range from between 19 780±360 BP (BA95136) and 15 050±60 BP (UCR 3555), should be rejected, and the youngest ^{14}C value, 12 430±80 BP (UCR 3561) from zone 3B1, is the most reliable age estimate for the earliest Neolithic component from this site.

In Japan, the earliest site with pottery is Odai Yamamoto 1 in northern Honshu (Aomori Prefecture).

The lack of information on the stratigraphy does not allow us to accept the very early ^{14}C dates from the Miaoyan site, and critical evaluation of the dates is still necessary. Based on the solid data, it is possible to make a preliminary conclusion about the emergence of pottery at approximately the same time, c. 13 000 BP (c. 15 600 cal BP, or c. 13 700 cal BC), in several places within East Asia, such as Japan, southern China, and the Russian Far East (Fig. 9).

CONCLUSION

Both the Osipovka and Gromatukha cultures clearly represent ***the earliest Neolithic complexes*** in the Russian Far East, Siberia, and the adjacent territories of Korea and northeast China (or Manchuria). The calibrated ^{14}C age of the earliest charcoal dates falls within the time interval of c. 13 990–12 360 cal BC (c. 15 940–14 310 cal BP), shown as average values between the maximum and minimum calibrated ages for charcoal ^{14}C dates in Table 1. Thus, the Osipovka and Gromatukha complexes may be determined as ***Initial Neolithic*** (*Medvedev 1995.236*), and both complexes are most probably contemporaneous with the earliest Neolithic complexes in Japan and southern China. The Ust-Karenga culture, the oldest Neolithic complex in Siberia, dates to c. 11 800–10 500 cal BC (c. 13 800–12 500 cal BP).

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Documenta Praehistorica XXIX

Direct dating of Neolithic pottery: progress and prospects

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ABSTRACT – *Pottery sherds can be dated by four methods: (i) stylistic features; (ii) luminescence analysis of minerals within the sherd; (iii) ^{14}C assay of carbon on or within the sherd; and (iv) archaeomagnetic intensity of the sherd. Each method has its own sources of uncertainty. The results obtained by the various methods are reviewed, and the conclusion reached that a combination of at least two of the methods, where possible, is recommended in order to enhance confidence in the validity of the outcome.*

IZVLEČEK – *Fragmente keramike lahko datiramo na štiri načine: (i) stilne lastnosti; (ii) luminiscenčna analiza mineralov v fragmentu; (iii) analiza ^{14}C na ali v fragmentu; in (iv) arheomagnetna gostota fragmenta. Vsaka metoda je do neke mere nezanesljiva. V članku preverjamo rezultate vsake metode in ugotovimo, da je za zanesljivost in verodostojnost rezultata priporočljivo uporabiti, kadar je to mogoče, vsaj dve metodi.*

KEY WORDS – *Neolithic; pottery; dating; stylistic features; radiocarbon; luminescence; archaeomagnetism*

INTRODUCTION

A reliable method for the direct dating of pottery would be advantageous for two fundamental reasons: (1) Pottery is often the most abundant material found on archaeological sites and is the basis of many traditional chronological frameworks for the Neolithic, especially in southeast Europe. (2) With the advent of single entity dating, using AMS, the problems of dating by association using charcoal or animal bone samples have become more apparent. At Schela Cladovei in Romania, Bonsall *et al.* (unpublished) chose to ^{14}C date bone tools from a Starčevo pit on the assumption that the ^{14}C ages would 'date' the pit and the pottery contained in it. However, the one-sigma age ranges fell outside the 'expected' age-range of the pottery (Fig. 1). This could arise through inaccuracies of excavation (since the pit cuts earlier archaeological features) or through deliberate backfilling of the pit with soil material containing older artefacts derived from elsewhere on the site. This example highlights the potential taphonomic problems of dating by association. Equally, it focuses attention on the question of 'archaeologically expected ages'. In the above example from Schela Cladovei, the expected age is derived from stylistic analysis of the pottery (see below), which in turn relies on good stratigraphic sequencing and associated radiocarbon dating *at other sites* and, of course, this introduces circularity into the chain of reasoning.

There are four methods, each with its own sources of uncertainty, which have been used to date pot-

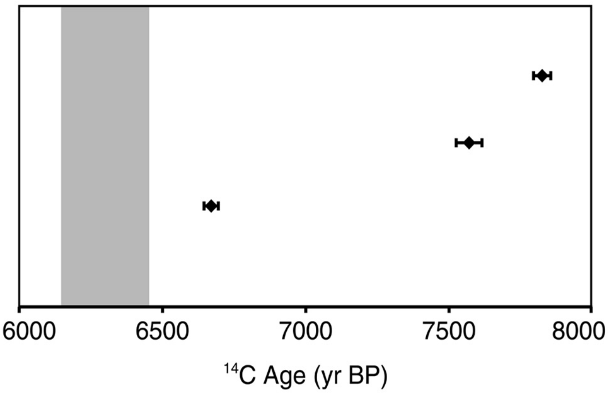

Fig. 1. ^{14}C dates for bone tools from a Starčevo pit at Schela Cladovei (Romania) plotted against the expected age range (stippled zone) based on stylistic dating of pottery from the pit (*Bonsall et al., unpublished data*).

tery. These are (i) stylistic features; (ii) ^{14}C assay of carbon on or within the sherd; (iii) luminescence analysis of minerals within the sherd; and (iv) archaeomagnetic intensity of the sherd.

STYLISTIC DATING

The oldest method of directly dating pottery involves the construction of pottery typologies and seriation techniques. The plasticity of clay allows potters to create vessels in a great variety of shapes, with a wide range of surface treatments and decorative elements, using a broad array of paste and temper combinations. For the past one hundred years, archaeologists have realized that this variability resulted in the production of ceramic styles that could be chronologically ordered (*e.g. Petrie 1904; Fewkes 1935; Milojčić 1950; Aranđelović-Garašanin 1954*). Ceramic styles followed a pattern of increasing popularity followed by progressively lessening popularity, which was reflected in artefact frequencies that could be graphed as the now familiar 'battleship curves'. Recognition of stylistic change through time gave archaeologists the ability to construct relative chronologies and temporal frameworks based on cross-dating (*Michels 1973*).

Pottery typologies are still useful chronological tools in archaeology, but their limitations have become clearer as their applications have become more widespread. Creating a pottery typology generally requires a thorough understanding of the stratigraphy of a site. The most widely used stylistic chronology for Starčevo pottery was developed by Draga Aranđelović-Garašanin (*1954*) from an analysis of some 50 000 sherds recovered during the early 1930s excavations at Starčevo-Grad, Serbia. Many of the sherds came from pit feature 5A, which Aranđelović-Garašanin considered a closed, well-stratified context. Others (*Korošec 1973; Ehrich 1977*) have cast doubts on the reliability of the stratigraphy of pit 5A and believe any typology based on material from the pit is questionable.

Stylistic dating can also be very subjective. Both Korošec and Ehrich criticized Aranđelović-Garašanin for basing much of her typology on the painted ceramics – which accounted for less than 5% of the total ceramic assemblage at Starčevo-Grad. Other researchers have devised slightly different pottery typologies for Starčevo ceramics (Fig. 2). Ideally, archaeologists should clearly describe the context of their artefact assemblage, the process by which they sorted the pottery into types, and their underlying assumptions. The specific goals and research questions of a project are likely to affect the variables that are chosen to construct a typology – see Whallon and Brown (*1982*) for a thorough discussion on this subject. Sinopoli (*1991*) has pointed out that only by stating explicitly the defining criteria of a typology can other researchers be expected to replicate the typology, using the same criteria at other sites, or to verify the typology, using statistical analyses.

It is not always clear what other variables may have affected the stylistic variation used to construct a pottery typology. Seriation and cross-dating between sites over a broad geographic range does not take

Milojčić 1950	Aranđelović-Garašanin 1954	Garašanin 1979	Garašanin 1979	Gimbutas 1974	Srejović 1972	Dimitrijević 1974, 1979		Brukner 1979
							Final	Late Körös
Starčevo IV	Starčevo III	Starčevo III	Veluška Tumba IV	Anzabegovo III	Classic Starčevo	LATE CLASSIC	Spiraloid B	
						LATE CLASSIC	Spiraloid A	
Starčevo III	Starčevo IIb	Starčevo IIb				CLASSIC	Garlandoid	Early Körös
Starčevo II	Starčevo IIa	Starčevo IIa	Veluška Tumba III	Anzabegovo II		CLASSIC	Dark Linear (Linear B)	
Starčevo I	Starčevo I	Starčevo I Gura Baciului	Veluška Tumba II	Anzabegovo I	Proto-Starčevo	PRECLASSIC	White Linear (Linear A)	
			Veluška Tumba I			PRECLASSIC	Monochrome	

Fig. 2. Starčevo ceramic sequences (*after Manson 1995*).

into account any lag time for a style to achieve peak popularity at a new location (*Michels 1973; see Plog 1980 or Rice 1987 for specific examples*). In the case of the typologies outlined in Figure 2, it is not clear which of the differences can be attributed to regional variation, to temporal disparity, or to cultural distinctions.

Perhaps the most important limitation on stylistic dating is that it can provide only a relative and not an absolute chronology. It must, therefore, rely on associations with other datable material in order to be assigned absolute ages. The problems of dating by association at Schela Cladovei were noted above. A thorough understanding of the site formation processes and stratigraphy are essential to identifying reliable artefact associations. Even under the best field conditions, however, verification of associations can be problematic.

In spite of the evident limitations of utilising typological approaches to chronology, which are at best indirect indicators of chronology, these methods have a central place in the history of prehistoric archaeology, and are likely to retain their place within archaeological practices. It is therefore highly desirable to obtain independent dating evidence to underpin these approaches, whenever possible. This requires both the application of absolute dating methods, and a proper understanding of the deposition processes and relationships between the time of a pot's manufacture, its use-life, and the events being dated by other means.

LUMINESCENCE

The applied timescale for luminescence dating is much wider than ^{14}C, but the former usually gives poorer precision. Therefore, many laboratories have concentrated their archaeological applications on the period beyond the limit of ^{14}C dating (about 40 000 yr BP), utilising burnt flints and stones, and also working on dating sediments (*Prescott & Robertson 1997; Roberts 1997*). However, it is worth pointing out that luminescence dating, in the form of thermoluminescence (TL), was developed primarily for dating pottery and other forms of baked clay, such as bricks and tiles (*Aitken et al. 1968*; *Aitken 1990*), and that applications to ceramics remain the most frequently reported case studies in prehistoric and later archaeology. Moreover, there have been a number of significant technical developments in recent years with potential for improving both the range of material and events that can be dated, and also leading to improved precision. It is worth noting in this respect that the opportunities for cross-validation of such techniques against other dating evidence are far greater in Neolithic and later periods, than on applications to Lower and Middle Palaeolithic archaeology. Therefore there are good reasons for dating laboratories to pursue such applications in refining the method.

Luminescence has two major advantages over radiocarbon: (1) It is an 'absolute technique', producing an age in calendar years, and (2) It directly dates the object of interest. Its limitations in respect of Neolithic pottery relate to the likely precision that can be obtained from material of this age, and the practicalities of applying the technique to a wide range of samples. Luminescence dating requires measurements of the stored radiation dose experienced by the sample since firing, and also a detailed analysis of the radiation dose-rates, or dosimetry. The stored dose is quantified using luminescence measurements of natural minerals, which are inherently variable systems, relative to calibrated laboratory radiation sources, which must be accurately and precisely calibrated. The radiation dose rates are determined by a combination of low-level radiometric methods and radiochemical techniques, which again require accurate calibration, usually based on reference materials, and also need to be able to cope with natural variations. Since part of the radiation dose rate is associated with the environment of the sample, there are significant practical advantages in making field measurements of the local gamma radiation of the burial context of the sample. The requirement for such measurements, plus the range of information needed for accurate dating, can impose significant constraints on archaeological work, as well as carrying higher costs than those associated with some other approaches.

The precision that can be achieved depends to a large extent on the sampling and sample credentials. Recent developments of newer optical readout methods have improved the precision of laboratory luminescence measurements, in some cases to better than ±2%. However, overall accuracy remains dependent on uncertainties in the radiation dosimetry and the influence of water content and its past variations. For these reasons the quoted uncertainties of luminescence dates are likely to remain in the 3–7% range, at least for the majority of applications. These uncertainties are proportional to the age of the sample. Thus, for a Neolithic sample of 8000 years, a ±5% uncertainty at one standard deviation corresponds to ±400 years, which may prove limiting for some applications. To improve on this precision, at present the only practical approach is to design projects that date groups of related objects, e.g. contemporary sherds within a well-constrained stratigraphic context. To resolve time intervals of 100–150 years during the Neolithic in this manner would typically require 6–10 dating determinations per unit, which again carries cost implications. To achieve this level of precision requires (1) the availability of relatively thick sherds (minimum 7–8 mm), (2) a detailed knowledge of the position of the sherds and the "geometry" of the burial context, (3) measurements of the external dose rates (gamma ray activity of the surrounding soil, (4) retention of the original water content of the sherd and some consideration of its past variations.

According to Aitken (*1990*), the best conditions are when the sherd is surrounded by a homogeneous soil to a distance of 30 cm. This is the approximate limit of penetration of gamma photons in soil. In practice, since the external components normally account for only some 30% of the total radiation dose rate, the majority of which originates from within 10 cm of the sample, some latitude can be allowed relative to this idealised situation. However, it is preferable that on-site measurements are taken of the gamma radiation from the surrounding soil/sediment, so that the effects of stratigraphic discontinuities can be assessed and taken into account. Otherwise laboratory measurements are made on soil and rock samples collected from the site, in addition to those from the sample.

It follows that sherds that are long removed from their original context (*i.e.* museum collections) present additional limitations, as the gamma background cannot normally be measured and has to be estimated. Under these circumstances, a precision of ±10–20% is probably the best that can be achieved using routine approaches.

There have been several studies of European prehistoric sites that have sought to compare luminescence dates on pottery sherds with radiocarbon dates on 'associated' organic materials. Varying levels of agreement were obtained between the luminescence and ^{14}C ages.

Sherds of 'Scored Ware' from Iron Age sites in southern Britain gave luminescence dates that were in reasonable agreement with the expected age-range based on ^{14}C dates for the contexts that produced the pottery (*Barnett 2000*). However, the range of 1060 years for the luminescence ages (760 BC– AD 300) is substantially greater than the expected archaeological range of 400 years (400–1 BC), and four of the 11 luminescence two-sigma age ranges lie outside the expected age range (Fig. 3).

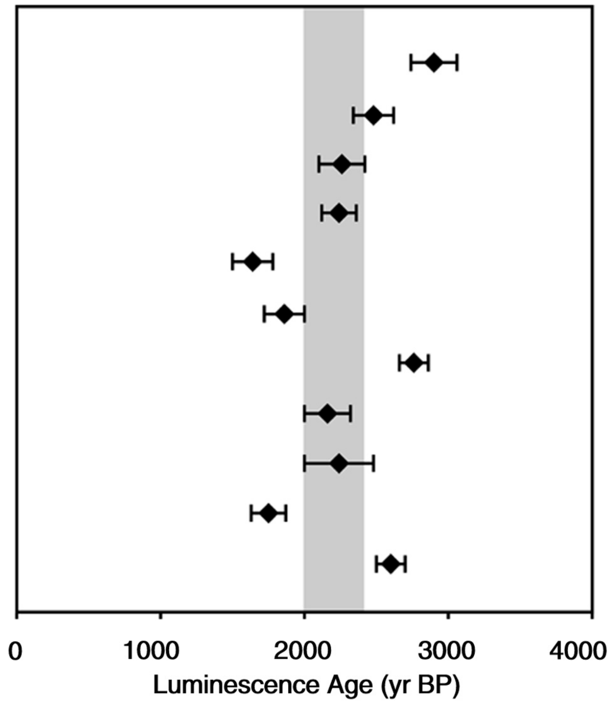

Fig. 3. Luminescence dates for Iron Age Scored Ware from southern Britain plotted against the expected age range (stippled zone) based on ^{14}C age measurements for the same contexts (*redrawn from Barnett 2000*).

Johnson *et al.* (*1986*) report TL ages for measurements on Neolithic and Iron Age sherds from Europe, which typically overlap (at one sigma) both a series of calibrated radiometric radiocarbon ages on associated charcoal and AMS measurements on carbon included in the sherds (Fig. 4).

At Anzabegovo in Macedonia four sherds from an early Neolithic layer (Ib) were dated by the Research Laboratory for Archaeology and the History of Art at Oxford University. Only the mean ages are quoted (*Gimbutas 1976*). These range between 6390 and 6830 BC, which is 400–800 years older than the calibrated ^{14}C ages of charcoal samples from the same layer (Fig. 5). It is not stated whether background measurements were made on soil samples associated with the sherds. If not, then the errors on the TL ages may be very large (±20%) and this may explain the apparent discrepancy between the TL and calibrated ^{14}C ages.

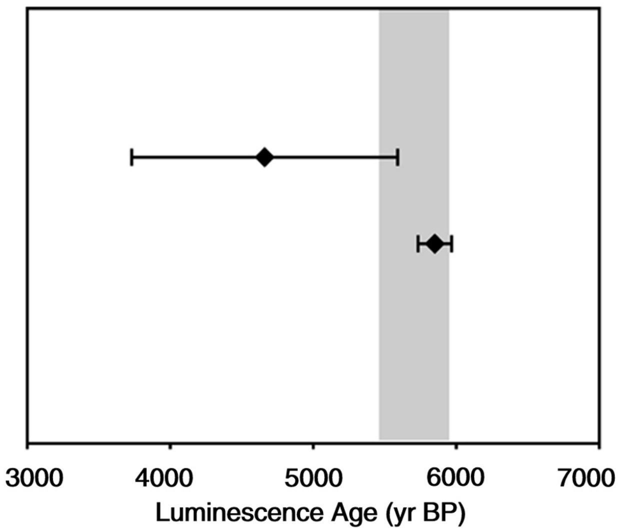

Fig. 4. Luminescence dates for Neolithic pottery from Egolzwil, Switzerland, plotted against the expected age range (stippled zone) based on ^{14}C age measurements for the same contexts (*after Johnson et al. 1988*).

Benkö *et al.* (1989) report 33 TL measurements on sherds from four sites in southeast Hungary and eastern Croatia – Gorsza, Tápé-Lebő, Tiszapolgár-Basatanya, and Vučedol – which span the period from Late Neolithic to Early Bronze Age (*c.* 5000–2000 cal BC). The largest series (24 measurements) relates to graves in the Copper Age cemetery of Tiszapolgár-Basatanya. In each case the TL dates overlap (at one-sigma) a series of calibrated ^{14}C ages on charcoal and/or bone, although the errors on the TL dates are large, ranging between ±8.7 and ±15.5% (Fig. 6). However, the fit between the TL /^{14}C ages and the internal 'phasing' of the sites is less good.

It is also worth mentioning the study by Whittle and Arnaud (*1975*) of Neolithic and Chalcolithic pottery from megalithic monuments and settlement sites in the Alentejo region of central Portugal. Forty-two sherds from 9 sites were dated by the quartz inclusion technique (*Fleming 1970*). The dates for Neolithic contexts in relation to 'expected ages' are shown in Figure 7. In this case, the expected ages are derived from radiocarbon-based regional chronologies constructed in the 1960s, rather than on ^{14}C dates from the sites under study, and may therefore require revision. The differences in the expected age ranges for the various sites are presumably based on typological considerations. Of the 35 measurements from Neolithic contexts, 20 (*c.* 57%) overlap the expected age ranges at one-sigma, while 6 dates, including the majority from Gateira, Gorginos and Carenque 2, are significantly older than the expected ages. A further 7 sherds (from Giraldo, Serra de Baútas 'C' and Farisoa anta 1) produced ages that are significantly younger than the expected age range. Whittle and Arnaud (*1975*) argue that these sherds were attributed to the wrong archaeological context.

At the Scottish Universities Environmental Research Centre between 1986 and 1989 a number of dating projects were conducted in support of Scottish archaeological excavations. Field gamma spectrometry was always carried out during the excavations for the dual purpose of determining environmental dose rates from a range of contexts, and also ensuring a proper understanding of the nature of the dating problems being considered. Feldspar inclusion TL dating methods were used in this programme, resulting in approximately 200 luminescence dates from burnt stones and ceramics. Where external age controls were available the results appeared to be generally consistent. In two sites in particular Neolithic sequences were studied. At the site of Pool, on Sanday (*Hunter & MacSween 1991*) more than 70 determinations were obtained from a sequence of vertically stratified midden deposits containing substantial quantities of Neolithic pottery. The majority of results were fully consistent with the original stratigraphic phasing of the site, although a small percentage appeared to indicate archaeological mixing processes or laboratory errors. The mean dates for successive phases produced approximately 100-year precision based on groups of 8–10 determina-

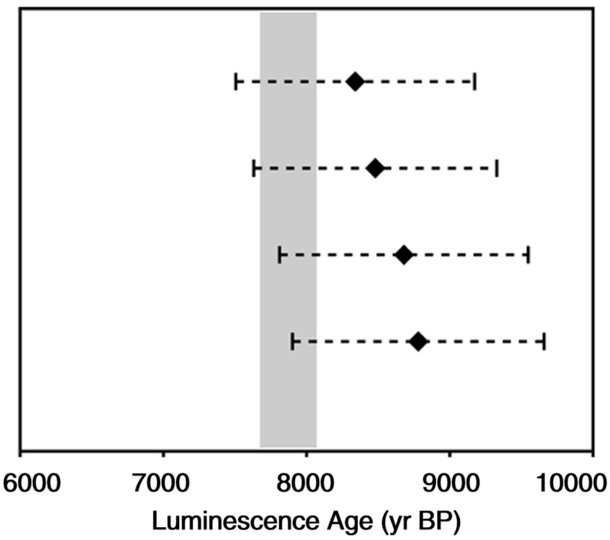

Fig. 5. Luminescence dates for Starčevo pottery from Anza 1b, Macedonia, plotted against the expected age range (stippled zone) based on ^{14}C age measurements on charcoal from the same layer (*after Gimbutas 1976*). The luminescence ages were obtained by the fine-grained TL technique (*Zimmerman 1971*). One-sigma errors of ±20% have been assumed.

tions per unit, with an overall chronology implying two major periods of activity at the site, in the late 5th/early 4th millennium BC, and the late 3rd/early 2nd millennium BC. The results are broadly consistent with both AMS and radiometric ^{14}C where available, but there are indications from the ^{14}C dates of mobility of small, carbonized plant fragments within the archaeological horizon. At the multi-phase site of Tofts Ness, also on Sanday (*Dockrill et al. 1994*), a series of ceramics and heated stones from the two earliest occupied structures were also dated, together with a series of hearthstones from a later prehistoric structure. On this site ^{14}C age measurements, based on carefully selected short-lived materials, were also available. The luminescence ages for the earliest two structures, based on the mean results from 4–5 samples per phase (Area A, 2600 ± 240 BC; Area B, 2250 ± 290 BC) are in the correct stratigraphic order and are consistent with the ^{14}C chronology within the precision of the calibration curve. These studies still await final archaeological publication, but are perhaps useful in indicating what can be achieved using multiple samples and close collaboration between dating laboratory and excavator.

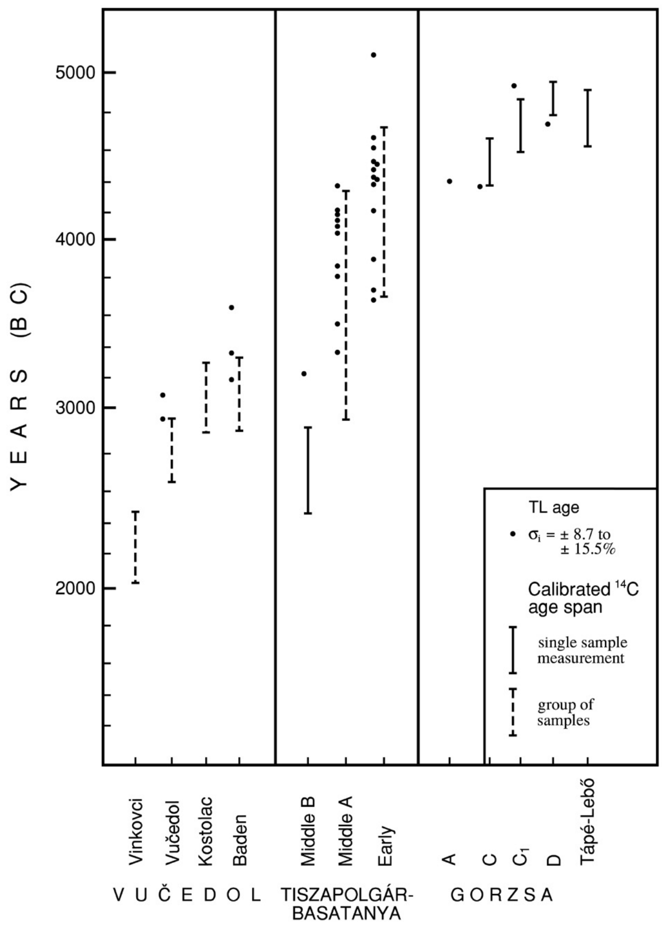

Fig. 6. Comparison of luminescence and calibrated ^{14}C dates for Late Neolithic to Early Bronze Age sites in south-east Hungary and eastern Croatia (after* Benkö et al. 1989*). The luminescence ages were obtained by the quartz inclusion TL technique (*Fleming 1970*).

Since this work was undertaken, there have been rapid advances in luminescence measurement methodology, which may have a constructive impact on the costs associated with such work, and the underlying reliability. However, some of the new procedures involve different luminescence signals, minerals and procedures, raising the need for careful validation to assess accuracy and reliability. Studies of this sort would benefit enormously from cross-validation relative to independent dating. In this respect the use of ^{14}C dating is critical, and the increasing potential of work on food residues from ceramics (see below) may offer important opportunities. Finally, it should be noted that the Neolithic, and its association with the introduction of ceramics, remains a vitally important period of prehistory, and therefore there are good reasons for undertaking work to enhance the absolute chronometric data sets which document this period, notwithstanding the practical challenges presented by material of this age.

RADIOCARBON

Direct ^{14}C dating of organic carbon derived from the matrix of archaeological ceramics was first attempted in the late 1950s and early 1960s (*Ralph 1959; Evans & Meggers 1962; Stuckenrath 1963; Taylor & Berger 1968*), however, the quantity of pottery required to provide sufficient carbon for radiometric ^{14}C analysis (of the order of 1 gram of elemental carbon) was often prohibitively large. With the advent of accelerator mass spectrometry (AMS) and the requirement for significantly less sample carbon (approximately 1 milligram), AMS ^{14}C analysis became a potentially very useful technique for direct dating of pottery (*e.g. Hedges et al. 1992; Delqué Kolić 1995; Gomes & Vega 1999*). However, AMS ^{14}C dating of potsherds is still a complex issue because of the potential number of possible sources of carbon to be found in sherds. These include:

❶ *Carbon that is derived from naturally occurring organic matter present in the clay matrix:* De Atley (*1980*) has observed that primitive potters used a wide range of clays, including many poor grade varieties with high carbon contents. These could potentially vary in age from recently formed surface deposits to some of a significant geological age. Where these clays are from surface deposits, the organic material may derive from recently deposited vegetation, roughly contemporary with the time of manufacture of the ceramics. Conversely, older deposits, particularly those of a sedimentary nature, would contain organic matter of a significant age relative to the time of ceramic manufacturing. Inclusion of this latter material would consequently reflect an age for the ceramic sample that is earlier than the time of manufacture, if this carbon survived the firing process. Indeed, de Atley (*1980*) presents a number of examples of pottery, dated by ^{14}C, which give radiocarbon ages that are significantly older than expected, while Johnson *et al.* (*1988*) present conclusive evidence that naturally occurring organic matter contained in clays can survive firing temperatures that are well in excess of those achieved by primitive techniques.

❷ *Carbon that is derived from temper:* The various forms of temper include grasses, straw, chaff, dung, calcite and ground shells (*Evin et al. 1989; Roosevelt et al. 1991; Hedges et al. 1992; Kuzmin & Keally 2001*). Those forms that are organic and terrestrial in nature would typically be contemporary with the manufacturing of the pottery and would represent the carbon component that would be most suitable for direct dating of the pottery. However, the use of shell material presents two problems:

a. *The initial ^{14}C activity*: For marine shells, there is a marine reservoir age to be taken into account (*e.g. Harkness 1981*). For freshwater snails, there is the potential for a hard water effect while for terrestrial species, the digestion of significant amounts of carbonate carbon has to be considered (*Evin et al. 1980*) and

b. There is the potential for the carbonate temper (mainly calcium carbonate) to be converted to calcium oxide. During cooling and subsequent time, the calcium oxide may combine with carbon dioxide to reform calcium carbonate. De Atley (*1980*) notes that tempers composed of shell may therefore contain carbon from three sources, namely, from the original shell, the ambient atmosphere during firing of the clay, and the depositional environment subsequent to firing.

❸ *From fuel in the kiln:* Reduced oxygen conditions in the kiln will result in incomplete combustion of the fuel, giving rise to soot and smoke production, both of which can become absorbed by the pot whilst being fired. Provided that the timber used as fuel is recently felled (with respect to the firing of the pot) and does not suffer from the 'old wood' effect, *i.e.* it is from comparatively short-lived species, then the carbon incorporated from this source will be suitable for dating the age of the potsherd. A similar effect to that of 'old wood' would apply where peat was used as fuel. Delqué Kolić (*1995*) demonstrated that low temperature combustion of surface material from experimentally prepared potsherds showed some promise in giving a CO_2 sample for AMS measurement that was predominantly derived from fuel smoke, however, the presence of carbon derived from the clay itself could not be discounted. Furthermore, when this type of sampling was used for archaeological sherds, the results were less conclusive because of external contaminants from the depositional environment.

❹ *From use of the pottery:* In this context, the carbon would be derived from adhering food residues

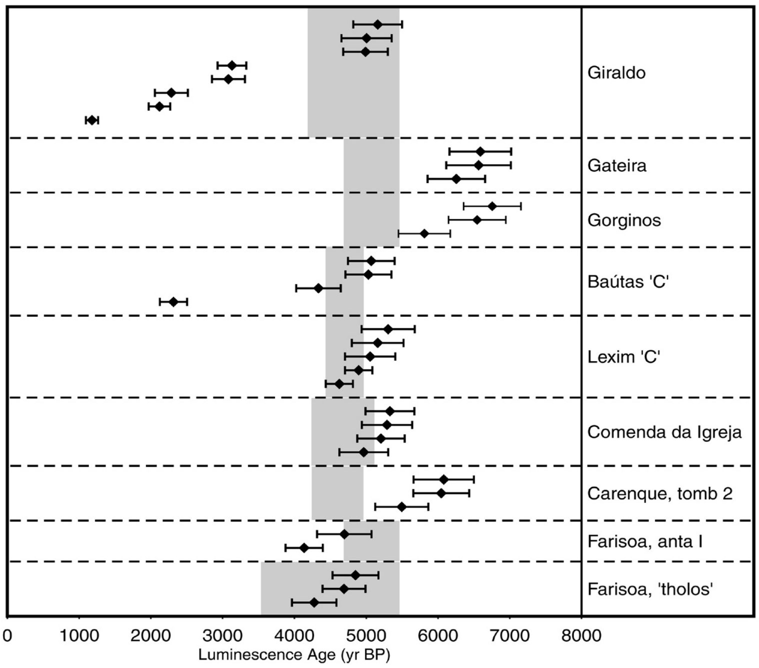

Fig. 7. Luminescence dates for Neolithic pottery from megalithic monuments (Carenque, Comenda da Igreja Farisoa, Gateira and Gorginos) and settlement sites (Baútas, Giraldo and Lexim) in central Portugal (*after Whittle & Arnaud 1975*). The luminescence ages were obtained by the quartz inclusion TL technique (*Fleming 1970*).

and/or soot and smoke absorbed during cooking. Again, there is the possibility that the soot/smoke may derive from old wood (or peat) being used as the fuel and this could result in a ^{14}C age that is hundreds of years older than the time of use of the pot. Food residues can also be problematic. They are firstly not all that common and are also highly susceptible to geochemical contamination, although this can probably be removed by chemical pre-treatment. In addition, there is also the question of what type of food source gave rise to the residue. If the residue was derived from a terrestrial plant/animal product then, in the absence of contamination, this material would yield a suitable age for the time of use, however, if the residue was derived from fish/shellfish (marine or fresh water), ^{14}C analysis is likely to give a radiocarbon age that is hundreds of years older than the date of the sherd. Work by Heron *et al.* (*1991*) has demonstrated that the migration of soil lipids into long-buried potsherds was negligible and did not affect the residue composition of the vessel. In addition, they also observed that the effects of microbial reworking of the organic residues absorbed in sherds were negligible and that preservation of lipids in the porous microstructure of the vessel was excellent. The nature and variation of the extracts from sherds was indicative of residues consistent with vessel usage rather than being derived from other sources. The authors conclude that sherds found to have a high yield of well-preserved organic constituents absorbed during usage could potentially be used for ^{14}C dating.

❺ *Secondary contamination from carbon containing components in the surrounding soil:* Once in its depositional environment, the potsherd is subject to the same potential contaminants from the surrounding soil as any other sample that may be radiocarbon dated. These would include humic substances, lipids, rootlets, *etc*. Gabasio *et al.* (*1986*) suggest that all of these organic elements, the mean age of which is a function of the rate of turnover of organic carbon in the context under consideration, are younger than the potsherd. However, this would only be true if the depositional environment were the surface soil. Instances where the potsherds are part of an infill could mean that their placement is in a context where the surrounding organic matter is, on average, older than the date of manufacture of the pot. Gabasio *et al.* (*1986*) propose that treatment of the potsherd with sodium hydroxide or pyrophosphate would probably eliminate most of the secondary carbon although they do not present direct evidence of this occurring in potsherds.

Of the five potential sources discussed above, those most likely to produce reliable ^{14}C ages would be: (1) Temper derived from terrestrial plant material (straw, chaff, dung, etc), and (2) Food residues that are identifiably of a terrestrial origin.

Stäuble (*1995*) has demonstrated that in sherds from the earliest LBK contexts in central Europe, the organic temper-derived ages were significantly older than expected. This was thought to be due to the combustion of a proportion of the organic matter originally associated with the clay. In contrast, organic food residues gave rise to ^{14}C ages that were both consistent and expected.

Hedges *et al.* (*1992*) undertook direct dating of pottery from a number of sites in Serbia, China, Thailand, Brazil and the USA. In the case of the Starčevo pottery from Serbia (expected age of *c.* 7000 BP), they observed that the temper, which consisted of chaff or dung, had not been completely burned out because of low firing temperature. Radiocarbon dating of a humic acid fraction and a residual fraction (which appears to be a combination of temper and carbon from the clay) generally produced what the authors considered to be unreliable ages. Typically, the residue samples were older than they expected because of incorporation of geological carbon from the clay, and the humic samples were younger than expected. Where humic acid and residue ages were in agreement, the combined age was consistent with the archaeologically expected age (Fig. 8).

With respect to the Asian material, the separated temper fraction, which could be expected to be the most reliable, generally fell between the humic acid and residue ages. Lipid-derived ages were generally considered to be unreliable, although identification of the components of this fraction was not undertaken. Nevertheless, Heron *et al.* (*1991*) maintain that migration of soil lipids into long-buried potsherds was negligible and did not affect the residue composition of the vessel, implying that the analyses undertaken by Hedges *et al.* (*1992*) should produce reliable ages without resorting to identifying the lipid components. Hedges *et al.* (*1992*) concluded from their studies that organic rich coatings such as food or soot gave fairly reliable ages and further that the validity of the age was strengthened if a second fraction (e.g. humic substances) gave a similar age. Temper samples that could be physically removed from sherds were also generally reliable but the authors again concluded that validity was strengthened by similar ages from other frac-

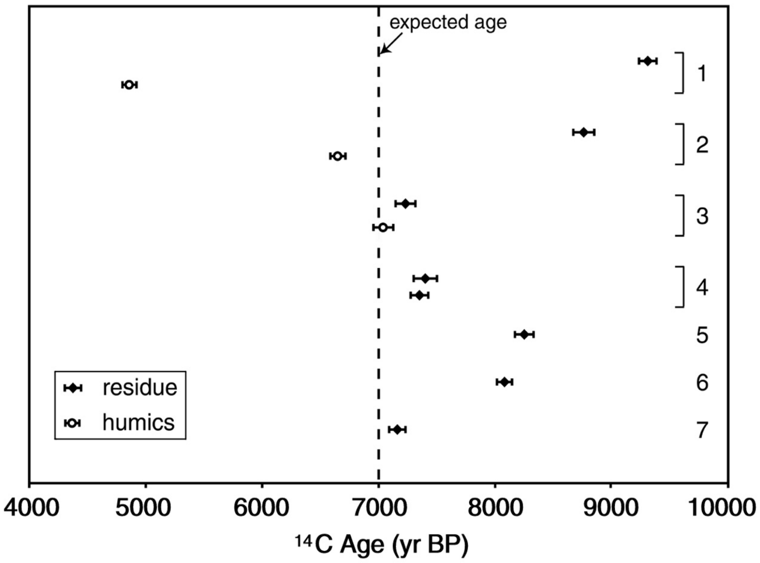

Fig. 8. ^{14}C dates for Starčevo pottery from Serbia: 1 = Banja; 2 = Grivac; 3 = Vinča; 4 = Divostin; 5 = Dobrovodica; 6 = Starčevo-Grad; 7 = Rudnik (*based on data from Gowlett et al. 1987; Manson 1990; Hedges et al. 1992*).

tions. Most recently, Stott *et al.* (*2001*) have produced valid age measurements, made on carbon from single fatty acid compounds isolated from cooking vessel residues.

ARCHAEOMAGNETIC INTENSITY

A promising, but as yet not widely applied, method for dating pottery is archaeomagnetic intensity analysis. The basic principle of this method is as follows. Clay often contains magnetic minerals (e.g. magnetite and hematite) as impurities and when heated to a point above the 'blocking temperature' of those minerals (500–700°C), the magnetic particles may record the direction and strength of the earth's magnetic field at that time. This type of magnetization is called thermoremanent magnetism (TRM). Since the earth's magnetic field changes in both direction and strength over time and space, it is possible to determine when an object of baked clay was last subjected to temperatures that were high enough to permit acquisition of TRM, by comparing its magnetic parameters with the known geomagnetic record for a particular region. Dating is only possible when a reference curve is established for the region concerned. The reference curve has to be calibrated by some chronometric dating method(s), ideally a high precision technique, e.g. historical records or dendrochronology. ^{14}C and TL can be used, but any uncertainty associated with such dates will also limit their ability to be used to calibrate the archaeomagnetic data.

Currently, within Europe one of the most detailed records available is for southeast Europe, which is based on material from radiocarbon-dated sites in Bulgaria and Serbia. With a few gaps, this reference curve covers the last 8000 yrs (*Kovacheva 1997*). The Bulgarian curve records changes in the direction of the geomagnetic field (inclination and declination) and variations in intensity. Directional data are not particularly useful when dealing with moveable objects, e.g. pots, but intensity values can be obtained from sherds and compared against the master curve.

In an effort to refine the chronology of the Starčevo culture, Manson (*1990; Manson & Schmidt 1991*) undertook archaeomagnetic intensity analyses of potsherds from nine Starčevo culture sites in Serbia. The standard double-heating method of Thellier and Thellier (*1959*) was used. This method is tedious and time-consuming, but it has features built into it that allow researchers to assess the reliability of the results for each sample. Any sample that fails to meet the standards for internal consistency can be removed from further consideration. If rigorous standards are followed, it is not unusual for the failure rate to be rather high – often, nearly a third of the samples will be rejected from a study. However, the remaining samples can then be used with a fairly high degree of confidence.

An average intensity value was obtained for each Starčevo culture site, and then compared against the published archaeointensity curve and tables for southeast Europe, particularly that published by Kovacheva and Veljovich (*1985*). Since the magnetic field intensity does not vary uniquely through time, a measured intensity may correspond to more than one possible age. Other evidence must be used to determine the most likely position of a site's intensity value on the archaeointensity curve. In the absence of reliable radiocarbon dates and deeply stratified sites, Manson's study utilized the ceramic typology of Aranđelović-Garašanin (*1954*) to determine the relative sequence of the sites and the most likely position of each site on the curve. In this way, Manson felt that most of the sites could be dated to within a 100-year time period (Fig. 9).

Manson's dating of Starčevo sites rests on two principal assumptions: (1) Each site represents a single phase of occupation with a short lifespan. (2) Aranđelović-Garašanin's ceramic typology is valid. The first assumption was based on the size, depth, and overall composition of the sites in the study (*see Manson 1995*). The second assumption appears to be supported at the few Starčevo sites that have well-defined vertical stratigraphy, such as Rudnik (*Garašanin 1979*). However, neither assumption has been rigorously tested by radiometric dating. Nevertheless, if suitable archaeointensity curves have been established for a region, archaeomagnetic intensity analysis shows great potential as a dating technique.

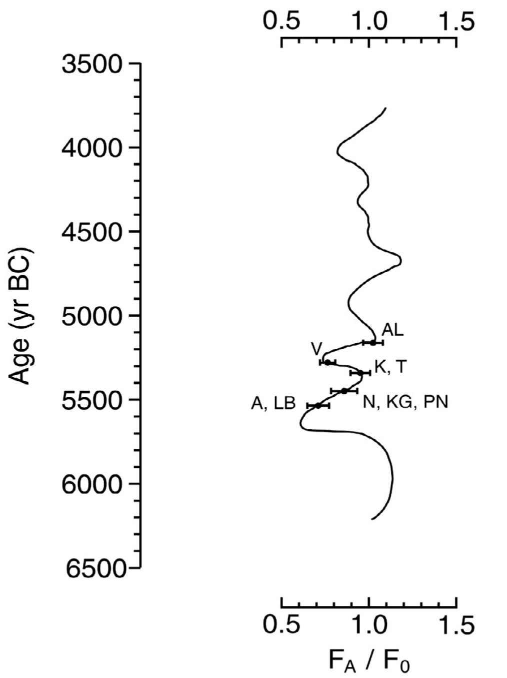

Fig. 9. Starčevo sites on the archaeomagnetic intensity curve: A = At; AL = Aradac-Leje; K = Kozluk; KG = Kaonik-Gradina; LB = Ludaš-Budžak; N = Nosa; PN = Pančevo-Nadela; T = Tečić; V = Vrtište (**after Manson & Schmidt 1991; based on Kovacheva & Veljovich 1985*****).***

CONCLUSIONS

Pottery sherds can be dated by at least *four* direct methods, three of which involve physical analysis of the sherd. Each method has its own sources of error and uncertainty and all, on occasion, produce anomalous results. Therefore, as Johnson *et al.* (*1986*) have observed, a combination of at least two of the methods is essential for reliable dating. One factor that is apparent from the literature on this subject is that most applications of luminescence and ^{14}C to pottery dating have been performed exclusively by dating 'specialists' with little input from archaeologists, and in some cases it is clear that there has been inadequate 'control' over the selection of samples for dating. Also, while many laboratories have attempted to date pottery, most studies have been on an *ad hoc* basis, and comparatively few of them have fully tested the reliability of the measurements. Yet, it is evident from the foregoing discussion that an effective collaboration between archaeologist and laboratory is critical to the successful application of luminescence dating, not least so that sample contexts can be dealt with in an appropriate way. This is also true of direct ^{14}C dating of pottery where a full understanding of the material origins needs to be coupled with an appreciation of the ceramic tradition and associated artefacts.

There is enormous scope for further studies involving the physical techniques and, in this respect, archaeomagnetic intensity analysis holds great appeal, especially in relation to the Neolithic of southeast Europe. However, in the absence of ^{14}C or luminescence dates on the same sherds, access to 'closed' pottery assemblages and suitable precision ^{14}C age measurements on associated archaeological materials from the same context are required. Ultimately, this necessitates that field techniques pay greater attention to site stratigraphy and to understanding site formation processes.

There are significant potential benefits in combining work on all methods. Good luminescence, radiocarbon and archaeomagnetic intensity cross-validation would be mutually beneficial, as well as providing the absolute chronometric framework required for assessing the validity of ceramic typologies.

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Documenta Praehistorica XXIX

Diet and cuisine: farming and its transformations as reflected in pottery

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ABSTRACT – *In the absence of direct evidence from organic residues, the character of pottery assemblages provides valuable indications of changes in diet and cuisine. This paper considers the possibility of major innovations in food-processing in the millennia following the introduction of farming, and relates these to contemporary processes of urbanisation in the Near East.*

IZVLEČEK – *Keramika nam daje dragocene podatke o spreminjanju prehrane in kuhanja, saj neposrednih organskih ostankov nimamo. V članku se ukvarjamo z možnostjo, da je v tisočletjih po uvedbi kmetovanja prišlo do velikih sprememb v pripravljanju hrane. Te spremembe primerjamo s sodobnimi procesi urbanizacije na Bližnjem vzhodu.*

KEY WORDS – *diet, prehistoric; cuisine, prehistoric; pottery, prehistoric; fermentation*

INTRODUCTION

The thesis of this paper is that the continent of Europe – and indeed much of the Old World – underwent three profound changes in diet during the Holocene period. The first of these was the beginning of farming, and the most recent was the Industrial Revolution; but it is the one in between these two, which concerns me here. This episode is what I once labelled the "secondary products revolution" (*Sherratt 1981*), and the rather cumbersome term which I chose for it was necessary because it had no counterpart in the terminology we have inherited from the "speculative historians" of the Enlightenment – the classic division into hunters, farmers and town-dwellers by which we traditionally classify the major contrasts in ways of life.[1] Since Gordon Childe invented the phrase "Neolithic Revolution", John Lubbock's archaeological term "Neolithic" has been equated with the beginning of farming; and in much of Europe (though not in China, Siberia, or Boreal Europe) the introduction of polished axes for forest-clearance – and pottery as food containers – is a reliable indicator of the major shift in food-sources and diet which accompanied the introduction of cereals. Thereafter, however, the equation between traditional terminologies and major dietary changes becomes unclear. Although some new species of crop-plants (notably tree-crops) and livestock (though mainly species important for transport) were added, the staple domesticates established in the Neolithic continued to provide the basic sources of food (though supplemented, first in the Roman period by the introduction of Oriental domesticates, and after the discovery of the Americas by New World ones). To a large extent, this was also true of the Industrial

1 Although in fact, as I shall argue below, the "Urban Revolution" was responsible for many of the changes which can be perceived in contemporary Europe – so the Enlightenment theorists were not entirely wrong in selecting their break-points. Where their model is inappropriate is in constructing unilinear, stadial models of change, whereas what is required here is a historical account of the historical effects of the co-existence of urban and non-urban societies (of the kind provided by world system theories). The Romantic critique of Enlightenment system-building is a necessary corrective to ahistorical models of the past (and world system theory is thus a Romantic rather than an Enlightenment construction).

Revolution: the dietary changes which took place then were more the result of new forms of food processing than of the use of newly domesticated species of plants or animals. It is this insight which I would like to deploy in trying to understand post-Neolithic dietary changes in Europe and the Near East, in concentrating on forms of food processing as important elements of dietary change in early times.

The point at issue may be formulated as follows. Farming introduced new sources of nourishment, such as cultivated cereals instead of collected seeds and nuts, and domesticated species of livestock instead of hunted mammals; but the types of food which were produced from them may not have been completely different from those consumed in Mesolithic times. Cereals undoubtedly made a major difference to diet in terms of their calorific contribution, and the evidence of rates of dental caries shows how this increased carbohydrate component affected oral health (as well as being important for demographic characteristics such as birth rates); similarly, the introduction of domestic animals was often accompanied a significant decline in the contribution made by fishing or the hunting of marine mammals. At the same time, the proliferation of pottery types (often carefully decorated) shows that food was being served in more elaborate ways than the "one-pot meals" of pottery-using Mesolithic groups such as Ertebølle. All of this points to a significant degree of alteration both in diet and cuisine associated with the beginning of farming. Nevertheless it would be misleading to imagine that this involved an instantaneous transition to the kinds of foods consumed by European peasants in medieval times, with their reliance on bread, beer and cheese. I would like to raise the possibility that the potential range of foods which could be produced from the plants and animals introduced in the Neolithic was only slowly explored, and that important forms of food processing made their appearance in Europe some millennia after the transition to farming. In particular, I would like to suggest that certain modes of food preparation involving fermentation are likely to have been pioneered outside Europe (or at least outside northern and central Europe), in areas where abundant sunshine was associated with sugar-rich fruits, or where complex societies allowed a greater degree of specialisation in production and processing.[2]

This formulation is, I hope, simply a matter of reasonable expectation. My further suggestion, however, relates to the timing of such changes and the pattern of their spread. It is here that the study of pottery becomes important as an indicator of how and when such innovations may have taken place. Although Europe lacks the pictorial record which is so informative in Egypt and Mesopotamia, the detailed typologies of pottery vessels created by European archaeologists (although compiled largely for chronological purposes and cultural taxonomy) can provide sensitive indicators of changing practices in the manipulation of stored staples, culinary processing, and the presentation of comestibles. Ceramic specialists have identified major alterations in the nature of pottery assemblages during the later fourth and third millennia BC. In south-east Europe, this is the fourth-millennium horizon which marks the end of "Eneolithic" assemblages and the beginning of "Early Bronze Age" ones (in quotation marks because this change does not coincide with the introduction of bronze, and because the widespread and easily recognisable changes in ceramic forms are a more useful marker of cultural changes than the rarer metal types). In central Europe this horizon is closely paralleled by the beginning of Baden, which has some echoes in the pottery forms of assemblages in the North European Plain; but in the latter area the more radical change occurs with the spread of Corded Ware in the third millennium, and in Atlantic Europe with Bell-Beakers. These continent-wide alterations are symptomatic of profound changes taking place over vast areas of Europe. They are undoubtedly associated with changes in the social significance of items of material culture (and not least in the beginning of a shift from pottery to metalwork as the carrier of messages about social status); but they are also, and most fundamentally, changes in the character of containers used for food and drink.

In asserting the importance of these changes as potential indicators of alterations in diet, I do not wish to erect an artificial contrast between subsistence and semiotics: changes in the types of food consumed are themselves closely related to social signalling, and the appearance of distinctive pottery types such as Beakers – which are prominently displayed in funerary depositions, and seem to have been closely associated with particular social roles – are themselves likely to be indications of socially differentiated patterns of consumption. Indeed, the use of comestibles requiring a concentration of particular ingredients (such as the sources of sugar required for fermentation, for instance) implies a de-

2 These two points are not independent, in that the growth of social complexity was in itself partly an outcome of this ecology.

gree of real power in commanding the mobilisation of relatively scarce resources. It is typical of the introduction of new dietary elements that they should first appear as the prerogative of a minority, before becoming more generally available to the population as a whole. Similar observations could be made about many material possessions – in this context about woollen clothing, metal axes, wheeled vehicles, or horses, for instance. In the long run, all of these items became relatively common items, at least in elite households. Their initial appearance as social markers does not preclude their contribution to a more general long-term transformation of patterns of possession and consumption. What it does represent, however, is an exploration of the "opportunity space" opened up by the initial innovations of domestication (and the arts of pottery-making, carpentry, and metallurgy which followed). In this sense, it was a predictable second round of innovations following on from the major transformation of the Neolithic itself. In terms of food and cuisine, it was expressed in more specialised forms of cultivation and herding, the concentration of particular resources, and longer chains of preparation (all of which increased the value and decreased the general availability of the final product): characteristics which depend as much on social arrangements as on the simple fact of the domestication of the species concerned (*Sherratt 1999*).

The dating of this round of innovations is significant for where it was initiated and how it took place. We have noted that the transformation moved from south to north (and more specifically south-east to north-west), and that it took place in the later fourth and third millennia BC – precisely the time at which the earliest urbanisation was occurring in the Near East. This at once suggests that the "Urban Revolution" may have been an important element in this transformation of Old World diets, since the larger scale of production and specialisation which accompanied it is likely to have resulted in new forms of specialised food preparation, just as it was marked by new forms of capital-intensive pottery production (using the potter's wheel), and the employment of animal traction. The socially differentiated and hierarchical character of the world's first urban communities would have provided the setting for experimentation in food-processing techniques, which later became more widespread and ultimately came to represent normal practice over a large part of the Old World.

This is the scenario, which I shall attempt to defend in the remainder of this paper – first by a brief discussion of models of change, then by some historical and ethnographic comparisons, and then by returning to the archaeological record.

MODELS OF CHANGE

The eight thousand years which separate the introduction of farming to Europe from the more familiar dietary patterns of the medieval period must undoubtedly have seen major changes in European eating habits, and it is worth asking how we might approach a problem of this magnitude. Just as the accounts of prehistoric Europe written by Gordon Childe and his contemporaries were constrained by the short chronologies then prevailing, and gave interpretations in terms of events such as megalithic missionaries, the intervention of Mycenaean merchants and prospectors, or military invasions (which all now seem anachronistically out of place in early prehistory, and were based on Childe's knowledge of the first-millennium world of Phoenicians, Greeks and Romans), so our models of food and dietary change need to be accommodated to the new perspective of deep time, and not just assume unchanging "traditional" practices persisting for what we now know are many millennia of prehistoric existence.[3] We need to recognise how very different such earlier practices may have been from the kind of homogenised theme-park reconstructions of life in the past, based on a mixture of historical illustrations and a liberal dash of romantic imagination, which are all too common in popular accounts of prehistoric life. Writing prehistory is a constant struggle to recognise this essential otherness of the distant past, and to guard against using anachronistic images of it. As a mental exercise, if nothing else, it is useful to try consciously to imagine how unfamiliar life in the Neolithic may have been, and to en-

3 A similar point may be made in connection with Egypt and Mesopotamia, where an abundant textual and representational record for the last five millennia tempts us to reconstruct "traditional" Egyptian or Mesopotamian practices, and to extrapolate them to time immemorial, ie prehistory. But these well-known practices are the traditions of already urbanised societies; and even ethnographic descriptions of, for example, rural Sudanese societies concern areas to which urban-generated practices had ample opportunity to spread, so they cannot be accounted representative of the indigenous practices of the early fourth millennium BC. Historical and ethnographic evidence may well be very helpful for later periods: but there is a danger that for earlier, prehistoric times it may be fundamentally misleading.

visage a world where many now common elements of it did not exist; and nowhere is this conscious effort of imagination more necessary than in talking about food and the practices of food preparation.

There is a danger here, of course, in opposing "the familiar" and "the other" in direct confrontation, so that we artificially create a revolutionary transition between what we know and what we can only imagine. (This has happened to some extent, in my opinion, in models of an "Upper Palaeolithic Revolution" giving rise to the "modern mind".) It is as well to be aware of this danger, but it is equally well to be aware that change may, indeed, take precisely this form. In the case of the Middle to Upper Palaeolithic transition in Europe, for instance, the replacement of the Neanderthals on the northern margins of the hominid distribution was just such a "revolutionary" event (in terms of Pleistocene chronologies), even though the emergence of modern humans in Africa or southern Asia is likely to have been a continuing and extended evolutionary process. The expansion of modern humans into Europe had an "event-like" character precisely because of this long earlier build up of innovations. This Pleistocene analogy may seem to be remote from our present concern with Holocene changes in food-practices, but in fact it is a useful reminder both of relative rates of change and of the scale on which explanations of such major transformations need to be constructed. In terms of relative timescales, it may be noted that both the Middle to Upper Palaeolithic transition and the development of farming systems based on secondary products were processes that were paced by a mixture of biological and cultural changes – in the former case by the bio-cultural coevolution of the human species itself, in the latter case by the development of new breeds of livestock or the domestication of new types of crop (or the discovery of new forms of processing which resulted from mixing their products). A Pleistocene perspective on rates of change in the earlier Holocene may be more appropriate for our purposes than the faster pace of change in historical societies of the later Holocene, nearer to the present day.[4] In the second place, understanding the Middle to Upper Palaeolithic transition requires putting European developments in a wider geographical context, including the adjacent parts of Asia and Africa where modern humans evolved. The same is true of the introduction of farming, in which developments in Europe can only be understood in relation to contemporary changes in the Near East; and I would argue that the same is true of the second round of dietary changes which are under consideration here.

FEEDING THE IMAGINATION

Bearing in mind the dangers inherent in using these methodologies (which are the only ones we have), we may continue to explore the implications of this line of thought. The ethnohistorical archive ("rural life"/folklore/European ethnography) and direct historical evidence (textual descriptions or visual illustrations) are an invaluable aid in giving life to the dry residues of the archaeological record. But we should ask ourselves how far back in time they continue to be useful. As a first approximation, we can use them as default assumptions in reconstructing the ways of life of "barbarian Europe" in the first millennium BC (using the term "barbarian" to designate the neighbouring, non-literate societies described by classical authors). In this sense Herodotus may be – in the phrase used by Kenneth Jackson to describe Old Irish epic literature – "a window on the Iron Age". Beyond the Iron Age, however, the familiar images of rural villages can potentially be quite misleading. While both the mud brick shrines of Neolithic Çatalhöyük (with their built-in vulture beaks) and the megalithic collective tombs of western Europe seem appropriately alien, the long-house villages of the LBK loesslands look reassuringly familiar in a way which may be deceptive (as can be seen from reconstructions which make LBK settlements look like medieval villages, with neatly ploughed fields). The Copper Age cemeteries of southeast Europe also have a deceptively familiar appearance; although the Varna "cemetery", whose many "burials" without bodies hint at ritual practices beyond the sorts of cultural norms implied by these terms, offers a warning against interpreting these interments as if they were examples of modern burial practices. Even where the evidence seems at first sight to be interpretable within the expectations gained from experience of more recent societies, we

4 Indeed, the late Pleistocene encounter of Neanderthals, biologically adapted to cold by their physique, with modern humans, culturally adapted by their ability to make skin clothing, offers a rather interesting analogy for the interaction in the fourth millennium BC between simple farmers developing on a "prehistoric" timescale, and dense urban communities whose society was already subject to "historical" rates of change. In both cases, two modes of evolution, broadly successive in time, temporarily confronted each other in a historical encounter.

should be aware that ancient lifeways might have been quite radically different from our own culturally situated expectations.[5]

If analogies from historical Europe cannot be projected back into the deep past, where else can we turn for guidance? The obvious answer is to world ethnography, which can suggest a wider range of possibilities than the limited body of later European experience. This is indeed a suggestive and informative body of observations; but we should again be aware of difficulties and biases. The most obvious is that societies recorded ethnographically exist for the most part (and with good reason) in very different environments from those of the inhabitants of prehistoric Europe – for instance in the tropics, or at any rate using different forms of crops and livestock from those we are considering. Also, they are not "prehistoric" in the same sense as the early inhabitants of Europe, having existed for many millennia alongside "historical" communities and in many cases been profoundly influenced by them. Nevertheless they can usefully provide analogies and models for certain aspects of European societies in prehistoric times, and alternative labels and descriptions for the earlier phases. The idea that early farming may have been quite small in scale, and involved gardening (horticulture) rather than large-field cultivation (agriculture), is a helpful one in imagining the nature of the earlier Neolithic, for instance. In fact the older literature on comparative ethnology (*Völkerkunde*) contains abundant information on matters such as dietary practices, often within an "evolutionary" framework and directed towards illuminating questions of long-term change, even when their evidence is primarily ethnographic. A good example is Adam Maurizio's *Die Geschichte unserer Pflanzennahrung von den Urzeiten bis zur Gegenwart* (such works are seldom less than encyclopedic!) of 1927, or his *Geschichte der gegorenen Getränke* of 1933, which contain both a mass of observations and a perceptive reconstruction of matters not often explicitly considered by archaeologists, but nevertheless quite fundamental to understanding prehistoric societies.[6] It is from these kinds of discussion that I have drawn in elaborating my scenario for the transformation of Neolithic Europe.

Consider the following description, from Gudmund Hatt's *Farming of non-European Peoples* (*1961. 230*),[7] reconstructing the development of culinary practices following the domestication of cereals. After adding water to the crushed grain, he argues, ... *one line of development leads via gruel and porridge to bread; another line, making use of fermentation, leads to beer, wine and to stronger alcoholic beverages* [and thus also to leavened bread]. *Alcoholic drinks were not originally known to all agriculturalists; they were unknown in North America north of Mexico, and to many of the semi- agriculturalists* [i.e. horticulturalists] *of South America. Bread is of more recent origin than porridge, but is probably older than beer and therefore more widely spread. The earliest kinds of bread are unleavened. The Indians of central and North America had two types of bread: boiled corn* [maize] *bread and baked corn bread. The latter kind, called* tortilla *in Spanish America is a flat cake or bannock*[8] *baked in the ashes or on a griddle. Similar flat cakes are known from many parts of the world, including Europe* [and the Near East]. *The baking of leavened bread started very early in Babylonia and Egypt, and seems to have to do with the brewing of beer; for grain was malted not only for beer but also for bread. Old fashioned unleavened bannocks continued to be made by European peasants until lately... The use of beer yeast in bread seems to have started in* [rural] *France as late as the seventeenth century.*

Here is a reconstruction, based on the relative extent of spatial distributions in the ethnographic record (and principally in the New World, which was closer in time to the origins of farming there) which suggests a temporal succession, from early simple uses of cereals to more advanced forms of processing and transformation involving fungal micro-domesticates, the yeasts, and methods of converting starches into sugars. It gives substance to the suggestion with which I began, that there should be a con-

5 The fairly recent recognition of Bronze Age "burnt mounds" in Britain as cooking-places, comparable to the ethnohistorically-known *fulachta fiadh* from Ireland, indicates the way in which cooking at this period may have been organised (for certain purposes) at a non-domestic level; and who knows how different Neolithic practices may have been?

6 Such books are often hard to find, but can be encountered on the shelves of libraries dealing with these now unfashionable subjects, such as the Balfour Library of the Pitt Rivers Museum in Oxford, home of lost causes.

7 Published together with E. Cecil Curwen's *Plough and Pasture: the early history of farming* in a paperback edition of that title in 1961. I have slightly altered Hatt's staccato punctuation and paragraphing to aid the flow of the quotation. Words in square brackets are mine.

8 "Bannock": a round unleavened loaf traditional in northern Britain – Hatt had conducted ethnographic fieldwork in Scotland!

trast between the diet of early farmers in Europe, and those of later prehistory and the historical period from which our principal direct evidence is derived. It suggests that the early farming inhabitants of Europe (and their predecessors in the Near East) may have had a radically different form of diet from their prehistoric successors, even where this was based on precisely the same species of crops. The two phases would have been separated by important innovations in food-processing, involving the use of fermentation techniques. This is the thesis that I would like to elaborate.

REVISITING THE SECONDARY PRODUCTS REVOLUTION

My original intention in setting out the concept of an SPR in 1981 was to carry out the agenda of "radical defamiliarisation" set out above: to approach the Neolithic as something alien and distant, which could not be understood simply by projecting backwards the kinds of "traditional farming" familiar from preindustrial Europe and western Asia. It was a liberating experience to realise that practices such as milking of the use of animal fibres for textiles need not have been part of the farming package as it was introduced to Europe in the seventh millennium BC. The more specific idea that the later fourth millennium constituted an era of revolutionary change came principally from study of the traction complex – a combination of the evidence for ploughmarks, figurines of yoked oxen, and wheeled vehicles (the last being studied at the time by *Stuart Piggott: 1983*). This was also the principal reason for treating it as a phenomenon centred in the Near East, and impinging on Europe as an intrusive complex. It was also the time at which Colin Renfrew (*1972*) was noting the connection between the use of treecrops (vine and olive) in Early Bronze Age Greece and the appearance of ceramic assemblages with jugs, cups and other vessels for manipulating liquids. (Many of these were clearly skeuomorphic copies of metal originals, of which third-millennium examples are known.) His own interpretation was that this represented agricultural diversification and the (local) emergence of the "mediterranean triad" of cereals, vines and olives, which he saw as a precondition for the emergence of social complexity in the Aegean through redistributive palatial economies which managed the exchange of these products. In the case of the Baden culture, however, where there was clear evidence of animal traction in the form both of cart models and paired-cattle burials, the contemporary appearance of jugs and cups could not be attributed to drinking wine, since vines were not cultivated in central Europe before the Iron Age/ classical period. Moreover the jugs and cups were prominent in precisely the same elite graves in Hungary as those which produced evidence for animal traction, so that both could be seen as part of an elite lifestyle introduced from outside. The same might also have been true of woollen textiles, and of domesticated horses.

This is not the place to consider the dating evidence for these features (which has accumulated considerably in the last 20 years, and I would claim still broadly supports my reconstruction: *Sherratt 1997*), but rather to inquire further into the significance of the ceramics. Seeking for some more basic liquid than Aegean wine as the substance served from elite drinking-vessels in central Europe, I plumped for milk and milk-products as an obvious possibility for a post-Neolithic innovation – not least because of the growing literature which indicated the relative rarity of lactose-tolerance in human populations, suggesting that milk-drinking was an unusual and possibly late practice.[9] This was a mistake, at least in part. Recent biochemical work on the identification of lipids from organic residues in prehistoric pottery (reported by *Richard Evershed in this volume*) has shown that milk has formed part of human diet since at least the beginning of the fourth millennium in the British Isles; and new interpretations of lactose tolerance have related it to the selective advantage of improved calcium absorption in areas where restricted sunlight reduces vitamin D production – especially among European populations, where fair hair- and skin-colour represents a parallel adaptation. Although milking is likely to represent a post-Neolithic innovation (and Richard Evershed has begun a systematic sampling programme of earlier Neolithic pottery from Europe and the Near East to identify the beginnings of its use), it was not in itself part of the SPR as defined by the introduction of the traction complex in the midfourth millennium.

9 The idea that milk, in societies in which it is rare or unknown, may have a special attractiveness is hard to grasp in societies such as ours which are saturated in dairy products; but the Viking settlers in Greenland noted that it was the single thing most desired by the native population, who of course were quite unfamiliar with it – and who would have had trouble in digesting it in large quantities, had it been available, because of their genetic intolerance to lactose. (Information from Klavs Randsborg, Copenhagen.)

Instead, I turned to alcohol as the more obvious magic ingredient of the drinking-vessels in Cycladic EBA cemeteries, Baden-culture graves, and also the beakers prominent in Corded Ware and Bell-Beaker graves in northern and western Europe in the following millennium (*Sherratt 1987*). (This allowed a series of jokes about the antiquity of "drinking and driving", in reference to the Baden-culture wagon-models, which are in fact wagon-shaped cups and perfectly exemplify the conjunction of these two elite elements.) While wine would have been the alcoholic beverage of the Aegean, other forms of fermented brews would have provided substitutes in temperate Europe. This was the beginning of a process of exploration, both of the history of alcohol and of other psychotropic substances, on which I reported in 1995 in an article entitled "Alcohol and its alternatives: symbol and substance in preindustrial cultures" (*Sherratt 1995*). Escaping from the essentialism of equating ceramic types with single substances, I discussed their role in conventionalised drinking rituals, practised in common over large areas and frequently singled out by archaeologists as the distinctive markers of cultural complexes. This interpretation chimed in with ideas then circulating about the social importance of the *symposium* in Homeric and classical Greek contexts, raised by Oswyn Murray (*1990*); and also with the work of Michael Dietler (*1990*) in a later period, who brought together ethnographic evidence for the importance of communal drinking and the spread of imported wine and drinking equipment amongst Celtic Iron Age groups in western Europe. Moreover the clear skeuomorphic echoes of metal vessels in Baden and Bronze Age Aegean pottery types provided an element of continuity with the practices of the classical world, as they were beginning to be discussed by my Oxford colleague Michael Vickers (*Vickers and Gill 1994*). It would be possible, therefore, to discuss this phenomenon simply in terms of modes of elite interaction and display, without any further implications for diet in general, and with the emphasis on new forms of human (especially male) sociality and interaction.

Nevertheless there are reasons for retaining a connection between subsistence and semiotics, or substance and style, and not rejecting the material basis of the original reconstruction. The association with tree-crops in the Aegean is real, and the association of these changes with a whole raft of innovations concerned with agriculture and livestock-raising leaves open the possibility that it did, indeed, coincide with profound alterations in the availability of certain types of food and the practices involved in their preparation. In particular, the emergence of an elite diet (and elite modes of clothing, or transport) implies a concentration of relatively rare substances such as fats and sugars (or animal fibres, or specialised forms of livestock) that are inherently expensive, and involved lengthened chains of preparation and investment in resources with alternative allocations and more immediate benefits. In the light of ethnographic descriptions (such as that from Gudmund Hatt quoted above) of the limited range of such expensive practices in the New World at the time of European contact, it seems not unlikely that expensive items of diet such as alcohol were introduced in elite contexts before they became more readily available to the rest of the population, rather than being promoted (and monopolised) from more general use. Indeed, one could go further and ask whether these practices would ever have arisen in the absence of some elite investment in such conspicuous modes of consumption.

All of these features – draught animals, woollen clothing, alcoholic drinks – were of course widespread in the Old World at the time of European expansion in the 16th century, and well-documented as far back as historical records extend: but these were all (by definition) contexts already affected by urban modes of consumption. As David Clarke would have said, temperate (and most tropical) Neolithic farmers are extinct; but those which have survived down to recent times in places like New Guinea do not practice extended modes of food preparation (or for that matter possess specialised types of livestock, or spend much time making clothes). Of course they have feasts, involving "admiration of fine and plentiful food, and the knowledge of its abundance" (*Malinowski cited in Young 1971.159*); but this takes the form of abundant pig-meat and piles of yams, not "cakes and ale".[10] It is this former mode of feasting, which provides the best model for Neolithic Europe before the mid-fourth millennium, and before the special, costly foods and drinks, which became available after it. Of course there are (and were) many cultivators in non-urban societies (for instance in Africa) who brew beer and provide good ethnographic analogies for later prehistoric Europe, but they are societies whose culture has already been affected in fundamental ways by practices pioneered in more complex societies – not least, in the case of

10 A traditional English phrase for merrymaking, used as the title of a comic book by the novelist Somerset Maugham in 1930.

Africa, by the spread of iron working. What I am suggesting is that our perceptions of earlier Old World prehistory have been fundamentally skewed by our knowledge of recent history and ethnography, which concerns cultures that were already transformed by urban consumption-patterns, and which therefore provide misleading analogies for what life was like in Europe before 4000 BC: *Die Vorzeit war ganz anders* (as Lew Binford's book[11] was perceptively titled in its German edition). In particular, the early phases of farming in Europe were very different from those of the last five to six thousand years, and in some respects may have been more comparable with those of the foraging groups which preceded them than those of the later Neolithic and metal ages. It remains to show where the expensive innovations of the SPR – in terms of diet as well as technology – may have had their origins.

THE IMPACT OF URBANISATION

The common thread which links the animal-derived items of the secondary products revolution and the plant-derived items of Renfrew's mediterranean triad (wine and oil) or their temperate equivalents ("cakes and ale") are that these are all practices which require a degree of capital investment, in the sense that they imply a "deferred enjoyment" of the fruits of labour (and not necessarily by those who did the work!), which involves a longer time-frame and planning depth. The raising of specialised draught animals such as plough-oxen (which take four years before they are useful) or the growing of perennial fruit-trees (which also take many years before they yield fruit – four or five in the case of vines), are cases in point. It is a further extension of the contrast pointed out by Claude Meillassoux between the "immediate return" of the forager and the "delayed return" of the farmer: the long-delayed return of the specialised agriculturalist. Plough-based farming or the cultivation of tree-crops are thus distant precursors of the very extended production-chains characteristic of industrial food production, so that there is a long-term evolutionary process in which the phenomenon which I characterised as the secondary products revolution takes its place as a logical step between the two. Unlike Renfrew, however, I would argue that these things did not emerge independently in prehistoric Europe (whether the plants and animals needed to produce them were already present or not), because such practices could only occur in societies capable of concentrating the initial capital. Just as farming did not spontaneously appear everywhere, but only in the restricted areas of origin which we call the "nuclear regions", and just as the Industrial Revolution was a breakthrough which took place in western Europe and more specifically in Great Britain before spreading across the globe, so, I believe, production and consumption practices which involved long-delayed returns and consequently expensive items of equipment or food made their initial appearance in a particular area of origin and in special circumstances – namely, in the Fertile Crescent in the fourth millennium BC. Moreover this initial "consumer revolution" was part and parcel of the genesis of urbanism itself, which cannot be understood in isolation from the elaboration of consumption patterns and the birth of commodities.

The key to many of these issues is to be found in the origins of writing – or, more precisely, in the pictographic symbols used to record transactions in the later fourth millennium at Uruk and other centres of early urbanism. Thanks to a major project in Berlin (*Nissen et al. 1990*), these tablets can now be understood; and they typically record the delivery of quantities of grain, malt and milk to temple estates for the brewing of various kinds of beer or the production of "cheese" and butter-oil (ghee), or the delivery of bales of wool for weaving. The pictograms show the characteristic containers for the former, and bales of the latter. Moreover it is now clear that these impressed signs were preceded by tiny clay models in the shapes of these commodities, the so-called "complex tokens", intended to be kept in a clay envelope marked with a seal-impression (presumably as a record of goods received); and the pictographs had their origins in the reduction of this three-dimensional recording system into the two-dimensional form of a clay tablet. What is especially exciting for the archaeologist is that these signs are in effect pictures of the commodities they represent, and that these correspond with remarkable accuracy to the classes of ceramic containers such as spouted jars which are so prominent a feature of Uruk ceramic assemblages – and not least the earliest forms of wheelmade pottery, which are mass-produced containers. It is clear that this was an economy of scale, concerned with the mobilisation of quantities of raw materials for the production of manufactured foodstuffs and textiles. (It is also notable that the pictograms include signs for ploughs and wheeled sledges, which are

11 In its original English edition rather more blandly called *In Pursuit of the Past* (*1983*).

amongst the earliest evidence for the traction complex.) The food (and drink) stuffs required large quantities of grain and milk probably produced on specialist temple estates using irrigation, ploughing and the kinds of intensive dairy herds shown on Uruk cylinder seals (*e.g. Sherratt 1997.Fig. 6.12*), supplying production-processes based on biotechnologies of fermentation using yeasts and lactic acid bacteria (*Hesseltine 1979*). It is precisely the artefacts associated with these forms of food-processing which provide the diagnostic markers of the "Uruk expansion", including the founding of colonies higher up the Euphrates, located to tap the raw materials of an extensive hinterland in eastern Anatolia, the Levant, and ultimately Egypt (*Algaze 1993*), thereby providing a mechanism for the dissemination of practices formerly confined to the alluvial area of the south Mesopotamian plain. It is thus particularly satisfying that one of the most puzzling but ubiquitous items associated with this diaspora, the crudely made "bevel-rim bowl", has recently been suggested to be a mould for the making of leavened bread (*Millard 1988*). Hatt's prediction about the association between leavened bread and beer may have its archaeological correlate in this culturally diagnostic container.

None of these containers could be described as "prestige drinking-sets" in the manner of Aegeo-Anatolian EBA and Baden jugs and cups; but Mesopotamian representations show that beer was drunk through straws out of a large vessel, and individual serving-vessels and containers were not used.[12] The origins of the "jug and cup complex" seem (as Renfrew originally perceived) to lie with wine-drinking: but the Aegean was on the edge of this area, or in a later extension of it, and its beginnings must be sought in the belt of mediterranean vegetation to the north of the Fertile Crescent, in eastern and central Anatolia and the adjacent parts of Iran. It is in this region that the earliest indications of viticulture have been found, and it seems likely that the formal conventions of wine-drinking emerged as a local response to the role of beer-drinking as it was introduced by Mesopotamian colonists. In both areas there was an intimate association between precious metal vessels and the precious alcoholic liquids drunk from them (*Sherratt and Sherratt 2001*), and the consumption of such expensive beverages was a mark of elite status (as, no doubt, was the consumption of leavened bread, the wearing of woollen textiles, and the possession of draught-oxen). These "knock-on effects" of the Uruk expansion form a plausible historical context for the spread to southeast and central Europe of the classic innovations of the secondary products complex – itself part of the larger transformation of patterns of production and consumption associated with early urbanisation. The association of drinking and driving was not fortuitous.

I have tried to show that the wave of changes in pottery types, which passed across Europe in the fourth and third millennia, altering as it went (as the cycle of outside stimulus and local response was repeated many times), can indeed be plausibly associated with innovations in diet. But what was the nature of these changes? What was drunk from Baden cups or Corded Ware beakers? The easy answer is "alcohol", but alcohol before the Industrial Revolution was never pure, and always part of a complex mixture (*Sherratt 1987; 1995; cf. Völger and von Welck 1981*), so it would be more accurate to say "local brews" (probably incorporating local psychotropic plant products already in use for smoking). Even this, however, is to oversimplify the picture, because it is the variety of new food practices, and the interactions between them, which is revealed by the Mesopotamian evidence. On the one hand there were dates (and their associated yeasts), important as a source of sugar added to cereal grains in both brewing and baking (*bappir*-bread), but which were restricted to the lowlands and whose role was to some extent transferred to other mediterranean fruits such as grapes (and in northern Europe to hedge-fruits and honey). Then there were milk products (such as ghee, possibly used for cooking but also drunk as a beverage, flavoured with herbs); and lactic acid bacteria which both add flavour to beer and bread and also produce the acidic conditions which assist in fermenting the sugars to alcohol, as well as inhibiting the action of less desirable microorganisms, enhancing keeping properties. It was often the combination of elements, in strange (and, to us, probably repulsive) mixtures for which we have no equivalent words in modern languages, which must have characterised the kind of cuisine I am attempting to describe. In the ultimate analysis it was not the individual technologies of food-preparation themselves which were distinctive as the fact that they involved a concentration of relatively expensive elements and implied lengthened production-chains and additional labour costs, so that they were not necessarily equally available to society as a whole: indeed, the whole process of using fermentation technologies is

12 Queen Pu-Abi was buried with a gold bowl and drinking-tube in the Royal Cemetery at Ur in the mid-third millennium.

one which has been described as "biological ennoblement" (*Platt 1964*),[13] and this metaphor itself conveys a degree of exclusiveness and added value.

Along with new foods would have been a change in the nature of feasting, from simply the provision of abundant food to the concentration of resources in order to prepare more complex items (and especially, but not exclusively, intoxicating beverages),[14] implying control of wider social networks to procure supplies of relatively rare or expensive resources. In this respect the provision of food parallels other items of material culture such as metalwork or clothing, which might also be described in similar terms. Social and material complexity form two aspects of a co-evolutionary process, in which social differentiation permits new forms of material manipulation, while new forms of consumption potentiate new types of social structures to control and monopolise them.

In the end, therefore, there is no simple label to substitute for my cumbersome phrase of the "secondary products revolution". In historical terms, it was one more episode in which the unusual conditions of western Asia and the east Mediterranean provided a conjunction of circumstances for a rapid burst of innovations, whose fallout affected neighbouring regions such as temperate Europe. In that respect, it is strikingly similar to the beginning of farming itself. If the picture which I have sketched is correct, however, and these innovations were essentially generated in the economies of scale which characterised the first cities (on the basis both of their distinctive local crops and their peculiar social institutions), then it was nothing other than Gordon Childe's Urban Revolution itself which was responsible for this second round of transformation in early European diets, cuisine, and ways of life. Selected, re-contextualised, and reinterpreted, the innovations to which it gave rise permeated the fabric of existing communities and permanently altered the character of prehistoric Europe.

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13 I owe this reference to Delwen Samuel – who nevertheless remains sceptical about my use of this argument.

14 The increasing (if initially limited) supply of alcoholic beverages would also have altered the role of other plant-products, previously used in a more exclusive or "shamanic" way to induce trance states of mind among privileged sections of the population. Indeed, we might expect a long-term trend – from individual trance states to collective inebriation – in which the use of alcoholic beverages took over the social role of quite distinct sets of substances with "magical" mind-altering properties: a process which I have called the "domestication of ecstasy".

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Documenta Praehistorica XXIX

Identification of animal fats via compound specific $\delta^{13}C$ values of individual fatty acids: assessments of results for reference fats and lipid extracts of archaeological pottery vessels

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ABSTRACT – *The possibility of obtaining molecular information from lipid residues associated with archaeological pottery has dramatically increased the potential for deriving new information on the use of ancient vessels and the commodities processed therein. Motivated by the high proportion of the archaeological potsherds that have been shown to contain animal fats, a new approach involving compound specific stable isotope analysis of remnant fats has been developed to retrieve information which will allow new insights into animal exploitation, dietary preferences and vessel use amongst prehistoric peoples. The new approach uses the $\delta^{13}C$ values of the major saturated fatty acid ($C_{16:0}$ and $C_{18:0}$) determined by gas chromatography-combustion-isotope ratio mass spectrometry (GC–C–IRMS) to characterise the origins of animal fat recovered from archaeological pottery.*

IZVLEČEK – *Danes je mogoče dobiti molekularne podatke iz lipidov, ohranjenih na arheološki keramiki, kar je močno povečalo obseg informacij o uporabi starodavnih posod in njihovi vsebini. Ker se je za velik del arheoloških fragmentov izkazalo, da so vsebovali živalske maščobe, so razvili nov način raziskav, ki je vseboval sestavljene analize specifičnih stabilnih izotopov v živalskih ostankih. S tem dobimo podatke, ki nam dajo nov pogled na izrabo živali, način prehranjevanja in uporabo posod pri prazgodovinskih ljudeh. Nov pristop uporablja $\delta^{13}C$ vrednosti najbolj nasičene maščobne kisline ($C_{16:0}$ and $C_{18:0}$), ki jih določimo s posebno masno spektrometrijo (gas chromatography-combustion-isotope ratio mass spectrometry: GC–C–IRMS), da določimo izvor živalskih maščob na arheološki keramiki.*

KEY WORDS – *$\delta^{13}C$ values; animal fats; fatty acids; lipids; archaeological pottery; organic residues*

INTRODUCTION

Natural variation in $\delta^{13}C$ and archaeological research

The use of stable isotopes in archaeological investigations is a relatively recent development which has focused largely on the use of bulk $\delta^{13}C$ and $\delta^{15}N$ measurements, providing information intractable using traditional archaeological techniques. The first applications in archaeology exploited the difference in $\delta^{13}C$ values between C_3 and C_4 plants reflected in bones collagen and apatite in order to assess the relative contributions of these plant types in the diets of ancient peoples (*Vogel and van der Merwe 1977; Jones et al. 1979; Teeri and Schoeller 1979; Tieszen et al. 1979*). Analyses have also enabled isotopic signals from marine and terrestrial sources to be distinguished as components of diet since the heavier isotope (^{13}C) is approximately 5–7‰ more abundant in the tissues of animals that consume marine foods (*Chisholm et al. 1982; Ostrom and Fry 1993*) with applications including the investigation of human migrations, status and social structure (*Sealy and van der Merwe 1986; Murray and Schoeninger 1988*).

Applications of stable carbon isotope analyses in animal nutrition and metabolism studies are numerous (*e.g. Boutton et al. 1988*) since the isotopic compositions of food and fluids ingested by animals have a strong influence on the isotopic compositions of the tissues they synthesise. However, the precise relationship between the isotopic compositions of ingested materials and a particular tissue or molecular component is complex, responding to changes in nutritional status, biosynthetic pathway and turnover rate of the tissue. Field studies have been conducted in order to elucidate the complexities of how different biochemical fractions translate into consumer tissues in food chains. Attempts have been made to show the offset in $\delta^{13}C$ values between different trophic levels; however, these depend upon the particular biochemical fraction, species type, diet and other environmental factors, and therefore can only be broadly estimated. Lee-Thorpe (*1989*) calculated differences in bulk $\delta^{13}C$ values between the vegetation, herbivore and carnivore trophic levels based upon measurements of meat, collagen and apatite, noting an enrichment in ^{13}C in species further up the food chain. Feeding studies have been carried out to elucidate the relationships between different levels of the food chain and to establish to what extent different fractions in the diet are routed or scrambled to particular tissues in consumers (*e.g. Ambrose and Norr 1993*), with initial findings suggesting some degree of routing of dietary components to specific body tissues.

It is assumed that at a particular location animals raised in antiquity would have consumed relatively restricted diets. Based on this assumption, the dietary contribution of $\delta^{13}C$ values to tissues such as adipose fat would be relatively constant (*DeNiro and Epstein 1978*). However, variation may arise particularly in non-ruminant domesticates due to food supplements (e.g. from domestic waste such as whey left over from cheese production or meat scraps) which would contribute a larger protein component to the diet. In non-ruminant animals, the direct routing of dietary fats to storage organs such as adipose fats means that the isotopic signal of the dietary lipids is retained and will be reflected in the isotopic composition of the tissue, although the situation is complex and varies between species. Tieszen *et al.* (*1983*) showed that fat tissue was 3‰ more depleted in ^{13}C relative to the diet and that the largest departure from dietary ^{13}C relative to other tissues is due to discrimination against ^{13}C during lipid synthesis (*DeNiro and Epstein 1977*). Fat tissue was found to have a relatively short half life of 15.6 days indicating that carbon turnover was relatively rapid compared to other tissues, requiring 208 days for complete recycling of carbon. DeNiro and Epstein (*1978*) showed that the fractionation of ^{13}C from diet to tissue is not identical in animals raised on different diets, possibly because of differential assimilation between the major biochemical fractions, however, the secondary fractionation of carbon isotopes by animal tissues is believed to be relatively small. A recent study of the stable carbon isotope ratios of fatty acids in the body fat of Redhead ducks strongly indicated that fatty acids in the diet are not the sole contributor to adipose tissues and that the ducks also synthesise fatty acids from other fractions in their diet, such as carbohydrates and proteins, which result in higher $\delta^{13}C$ values for the tissue fatty acids (*Hammer et al. 1998*).

Stable isotope analyses of organic residues in archaeological pottery

Morton and Schwarcz (*1985*) first applied stable isotope ($\delta^{13}C$ and $\delta^{15}N$) determinations to the study of residues associated with archaeological ceramics, using bulk measurements to examine carbonised deposits thought to originate from maize. The first application of compound-specific stable carbon isotope approaches to lipids in archaeological materials was that reported by Evershed *et al.* (*1994*). The $\delta^{13}C$ values obtained for individual higher plant leaf wax components in solvent extracts of pottery vessels from the Raunds area project, Northamptonshire, confirmed that the lipids being investigated were of C_3 origin. The distributions of components were consistent with the lipids in the potsherds having deri-

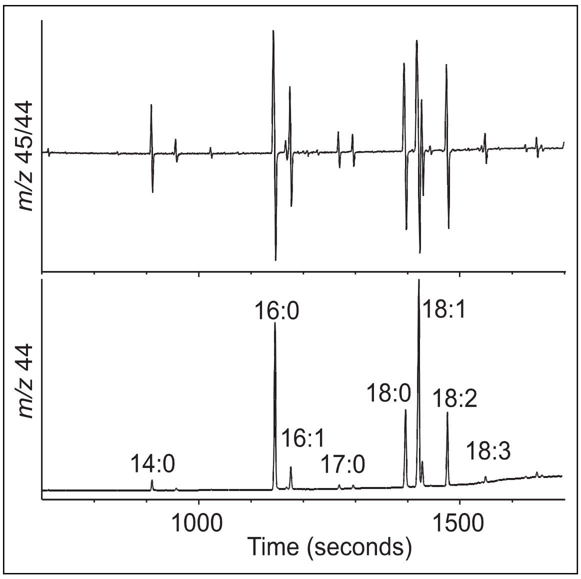


Fig. 1. Partial m/z 44 and m/z 45/44 traces obtained by GC–C–IRMS analysis of fatty acids (as their methyl ester derivatives) in modern pig adipose fat.

ved from *Brassica* species, such as cabbage. The latter study utilised GC–C– IRMS, which allows the isotope ratios of individual compounds within a mixture to be determined (*Santrock et al. 1985*). Compound specific analyses have proven particularly advantageous over bulk analyses in the study of diagenetically altered samples due to the fact that bulk $\delta^{13}C$ values will alter over time as a result of the preferential loss of labile components, e.g. polysaccharides, and the contaminating effects of effects of exogenous components migrating from the burial environment or introduced via the actions of microorganisms (*Evershed et al. 1999*).

Our laboratory was the first to observe the isotopic distinction between preserved fats of ruminant and non-ruminant origin based on the stable carbon isotope composition of fatty acids in sherds from a small assemblage of lamps and 'dripping' dishes from a medieval site at Causeway Lane, Leicestershire (*Evershed et al. 1997; Mottram et al. 1999*). Analyses of fresh cattle lamb and pork fat indicated that fatty acids in ruminant fats are isotopically lighter, by approximately 4‰ and 7‰ for the $C_{16:0}$ and $C_{18:0}$ components, respectively, than the equivalent fatty acids in non-ruminant fats. The variation is believed to result from fundamental differences in metabolic factors and dietary preferences between the species (*Koch et al. 1994*). The $\delta^{13}C$ values obtained clearly distinguished the fats from two different animal origins in the two vessel types, indicating the use of the lamps in burning ruminant tallow and the 'dripping' dishes for the collection of non-ruminant, e.g. porcine fats, perhaps during spit roasting. The isotopic analysis of the extract from a 'cauldron' from the same assemblage gave $\delta^{13}C$ values which were intermediate between those obtained for the lamps and the 'dripping' dishes, indicating that the vessel had once been used to process both ruminant and non-ruminant animal products (*Mottram et al. 1999*). In another study, the potential of compound specific $\delta^{13}C$ values of ancient fats was investigated in an effort to classify the origins of remnant animal fat residues in Late Saxon/ early medieval vessels from West Cotton, Northamptonshire (*Charters 1996*). Extracts of four vessels were studied, including a shelly ware jar (RP78 rim) and three spouted bowls (RP72, 93 spout and 94 rim/body). The mean $\delta^{13}C$ values obtained for the fatty acids in the bowls differed by approximately 4‰ from the values obtained for fatty acids in the jar. The extracts from RP93, 94 and 72 were interpreted as having a ruminant origin, while that from RP78 represented a mixture of fats from different origins, since the $\delta^{13}C$ values were intermediate be-

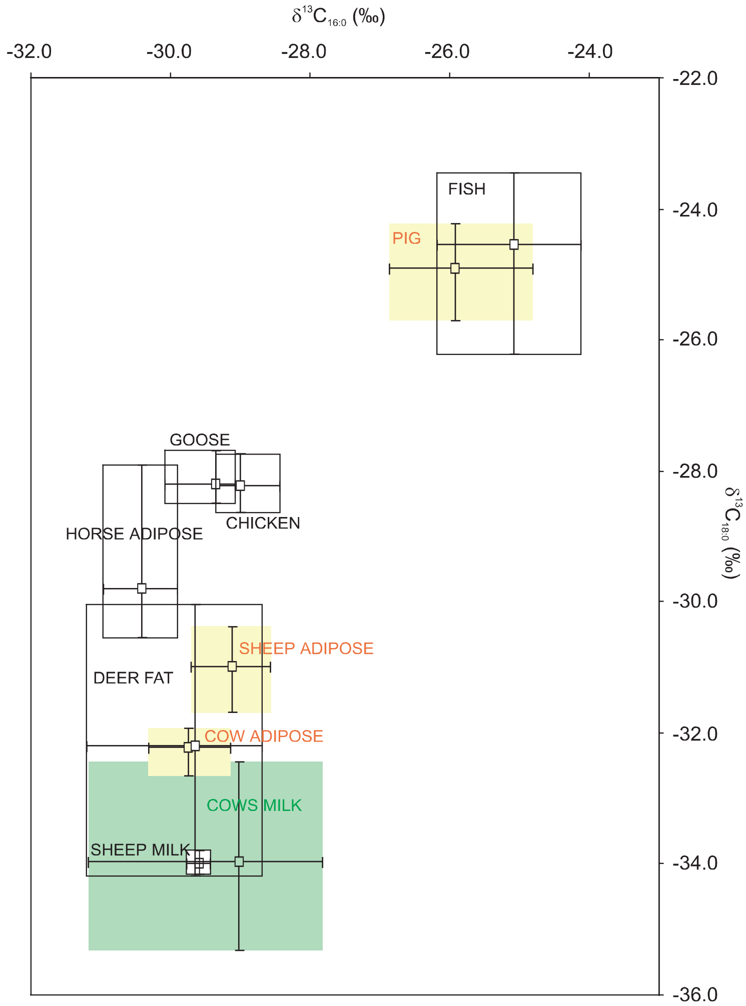


Fig. 2. Plot of the $\delta^{13}C$ values for the major n-alkanoic acid ($C_{16:0}$ and $C_{18:0}$) components of the solvent extracts of modern reference fats. The $\delta^{13}C$ values of the individual fatty acids were determined exactly according to the conditions given in Woodbury et al. (1995) with corrections for the addition of the derivatising methyl carbon. The $\delta^{13}C$ values for the fatty acids in the reference fats have been corrected for the post-Industrial Revolution effects of fossil fuel burning which has decreased the $\delta^{13}C$ value of atmospheric CO_2 by approximately 1.2‰ over the past 130 years (Friedli et al. 1986). The boxed fields encompass the ranges for reference animal fats with the ranges crossing at the arithmetic mean. Instrumental error is ± 0.3‰ and samples were run in triplicate. Instrument operating conditions are described in Dudd and Evershed (1998).

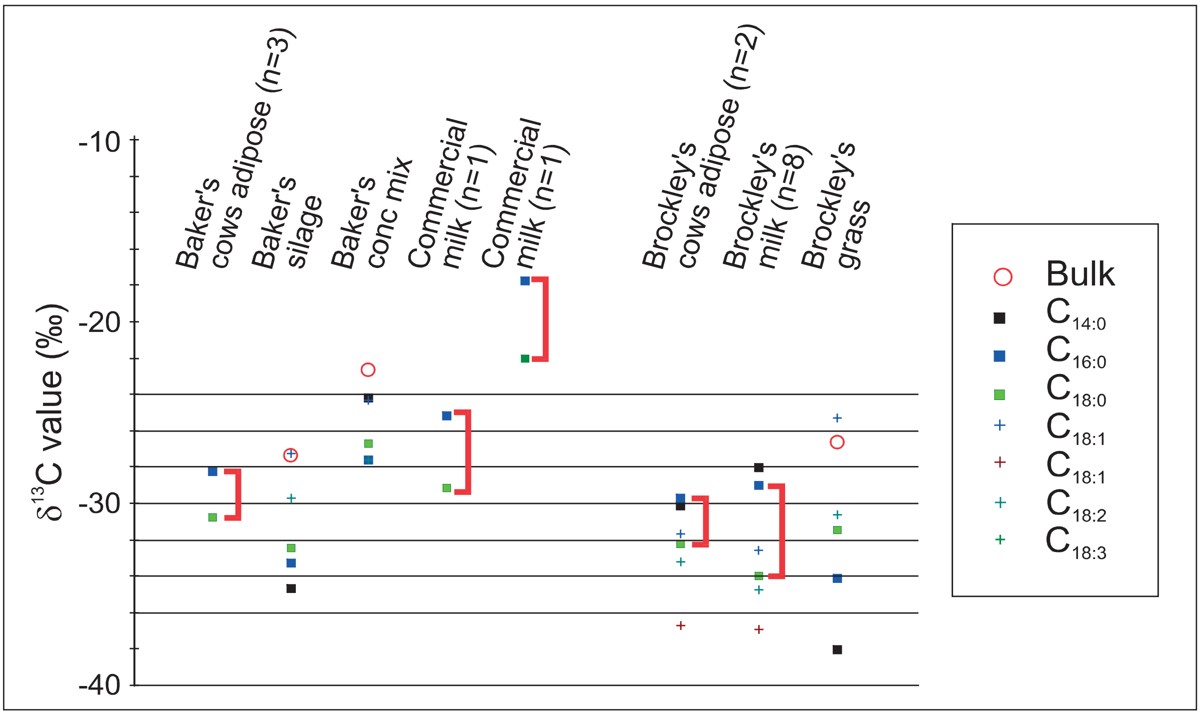


Fig. 3. The relationship between carbon composition of the diet and bovine adipose and milk fatty acids (the variation between the major $C_{16:0}$ and $C_{18:0}$ fatty acids in adipose and milk fats is shown by the red bars).

tween those measured for reference ruminant and non-ruminant adipose fats. The studies by Mottram *et al.* (*1999*) and Charters (*1996*), albeit on a relatively small number of samples, were the first to recognise that differences between the stable carbon isotope compositions of remnant fats could be used to make distinctions between archaeological fats of different animal origins, and provided the stimulus for the work described in this paper.

METHODOLOGICAL CONSIDERATIONS

The selection of modern animal fats as reference materials

The majority of farmed animals available today are unsuitable for comparison with archaeological fats due to the changes which have occurred in the composition of animal fats over the last several hundred years. Reasons for this include: (i) selective breeding, which has resulted in changes in the composition of the fat and milk of the larger domestic animals (*Johansson and Claesson 1957*); (ii) the widespread use of intensive farming methods necessary to maximise yields, which has included the use of nutrient-rich concentrates during the winter when temperatures are low (*Johansson and Claesson 1957, and references therein*); (iii) fossil fuel burning since the Industrial Revolution, and other factors resulting in changes in the isotopic composition of the atmospheric CO_2 which have been reflected in the enrichment of ^{12}C in the tissues of modern animal fats compared to their ancient counterparts, and (iv) C_4 plants (sugar cane) introduced into Europe in the 1500s, which have been incorporated into the diets of farm animals significantly altering the stable carbon isotope composition of their tissues.

In view of the above, reference animal fats for this study have been carefully selected from a number of sources, including:

❶ Fresh fats from modern animals raised on a known diets;
❷ Remnant fats extracted from well-documented ethnographic vessels;
❸ Remnant fats from archaeological pottery assemblages at sites where a preponderance of one species of animal is believed to have been farmed;
❹ Remnant horse fats obtained from a prehistoric permafrost burial.

Determination of compound specific δ^{13}C values of fatty acids

Compound specific δ^{13}C values are determined by gas chromatography-combustion-isotope ratio mass spectrometry (GC–C–IRMS). The instrument construction and operating conditions employed to obtain the results described in this paper have been exten-

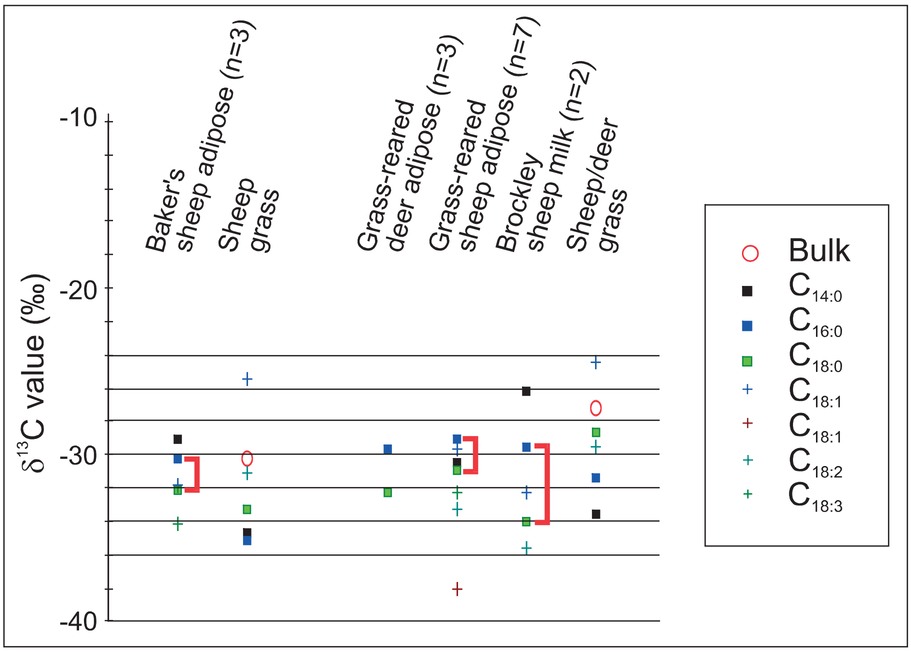


Fig. 4. The relationship between carbon composition of the diet and ovine adipose and milk fatty acids (the variation between the major $C_{16:0}$ and $C_{18:0}$ fatty acids in adipose and milk fats is shown by the red bars).

sively described elsewhere (*Evershed et al. 1994; Dudd and Evershed 1998; Dudd et al. 1999*). The stable carbon isotope ratios are measured as the relative difference between the isotopic ratios of the sample and standard gases, thus adopting the delta (δ) notation (*McKinney et al. 1950*):

$$\delta^{13}C(‰) = \frac{[R_{sample} - R_{s\tan dard}]}{R_{s\tan dard}} x10^3$$

where the δ^{13}C is the parts per thousand difference between the ^{13}C content of the sample and that of the standard and R is the *m/z* 45/44 ratio of the sample or standard gas. δ^{13}C values are expressed relative to VPDB. This standard has been assigned a δ^{13}C value of 0‰, thus the notation of the δ^{13}C value indicates whether the sample has a higher or lower $^{13}C/^{12}C$ ratio than VPDB. Samples are run in triplicate and the mean values obtained corrected for the additional carbon of the derivatising agent, BF_3MeOH. Modern fats and oils used as reference samples are corrected for the change in atmospheric CO_2 which has occurred since the Industrial Revolution (*according to Friedli et al. 1986*). Bulk δ^{13}C values reported below for homogenised plant materials and whey were obtained using using an NC 2500 elemental analyser coupled with the Finnigan MAT Delta-S isotope ratio mass spectrometer *via* an open split interface.

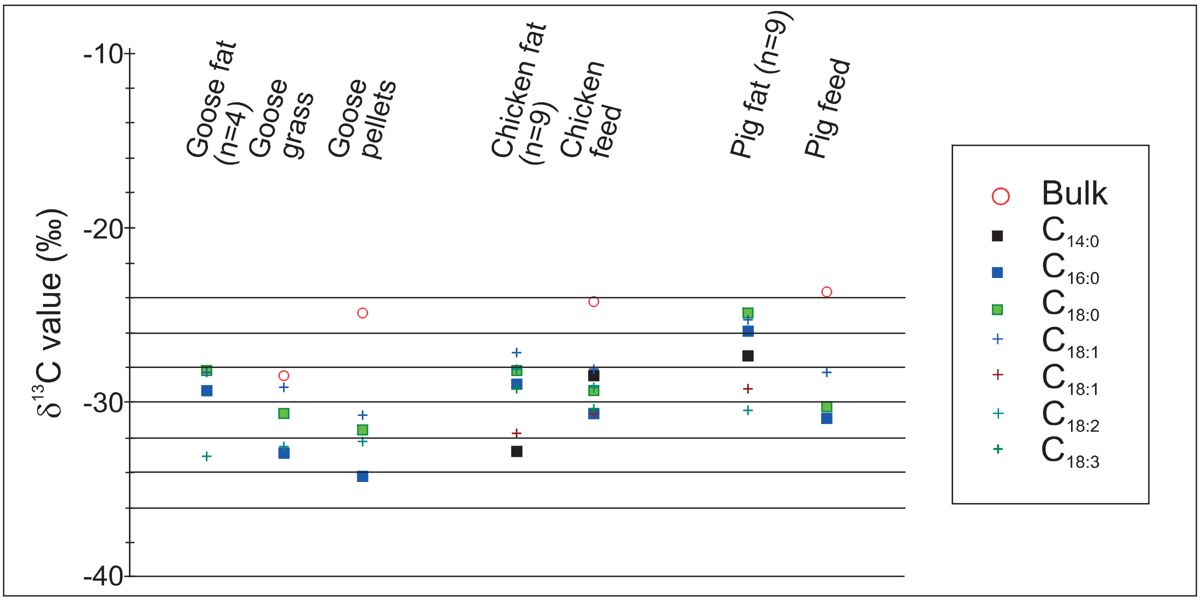


Fig. 5. The relationship between carbon composition of the diet and fatty acids in non-ruminant adipose fats.

Presented in this paper are the ranges of $\delta^{13}C$ values in the body and milk fats of animals known to have been the major domesticated species in antiquity, noting differences between individuals of the same species and between different species. Since the diets of the reference animals are known it is possible to test the relationship between the stable carbon isotope ratios of lipid components in the diet and in the animal fats. The report also constitutes by far the largest study of $\delta^{13}C$ values of individual lipids from archaeological pottery to date, and thus enables an assessment of the usefulness of the chemical information which can be obtained from this type of analysis. The study of prehistoric pot extracts has enabled us to establish whether the distinction in the isotopic signals previously observed between fats of different origin in the medieval pottery from Causeway Lane (*Mottram et al. 1999*) are retained in lipids from early Neolithic vessels.

RESULTS

Compound specific stable carbon isotope analysis of reference fats

An example of the results obtained from a reference animal fat is shown in Figure 1. The lower chromatogram shows the baseline resolution obtained routinely by GC analysis of FAMEs on a 50 m CP WAX 52 CB fused silica capillary column. The upper trace is a ratio of the *m/z* 45/44 ions in the sample detected by the GC–C–IRMS. The $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids for a range of modern reference fats from different species are shown in Figure 2. The numbers (n) of different reference fats analysed (in triplicate) were: pig adipose fat, n = 9; cow adipose fat, n = 4; sheep adipose fat, n = 7; chicken adipose fat, n = 8; cows' milk fat, n = 8; sheep milk fat, n = 2; horse adipose fat, n = 8; deer adipose fat, n = 7. All the animals were raised on C_3 diets, isotopically representative of the archaeological period, and for this reason numbers of samples suitable for this work were limited.

From the data shown in Figure 2 the following trends have been observed:

❶ Adipose fats from the major ruminant (e.g. ovine and bovine) and non-ruminant (e.g. porcine) domesticates are distinguishable from one another by greater depletion in ^{13}C in the $C_{16:0}$ and $C_{18:0}$ fatty acids in ruminant fats. The mean $\delta^{13}C$ values obtained for adipose fats

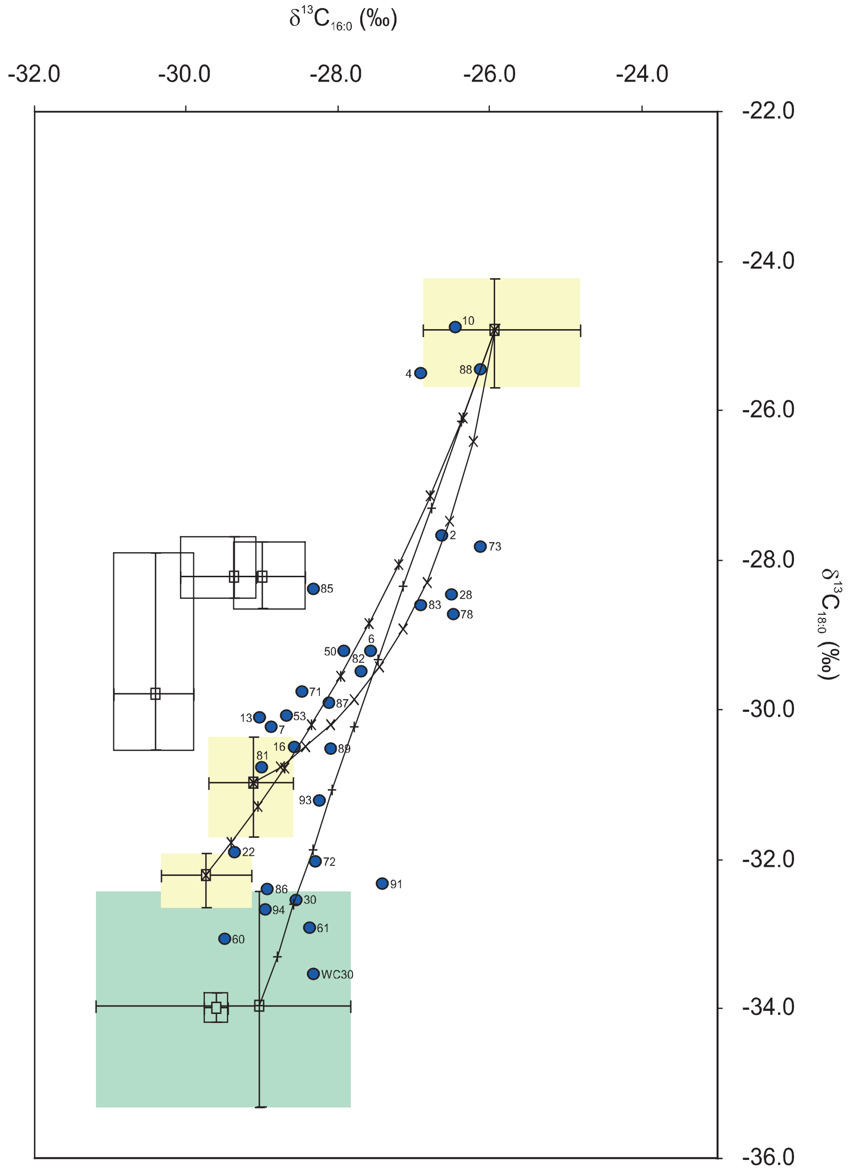


Fig. 6. Plot of the $\delta^{13}C$ values of the major n-alkanoic acid components ($C_{16:0}$ and $C_{18:0}$) from the lipid extracts of potsherds from the Late Saxon/early medieval site of West Cotton, Northamptonshire. The blue-filled circles represent the archaeological fats; sample nos. are labelled. The mixing curves have been calculated to illustrate the $\delta^{13}C$ values which would result from the mixing of ovine and porcine fats (x), bovine and porcine fats (✶) and cow's milk/porcine fats (+) in the vessels.

from the reference pig and sheep differ by 3.2‰ in the $C_{16:0}$ fatty acid and 6.1‰ in the $C_{18:0}$ fatty acid;
❷ The $C_{16:0}$ and $C_{18:0}$ fatty acids in porcine adipose fats and salt-water fish tissues show the least depleted δ^{13}C values of the reference fats analysed;
❸ The mean δ^{13}C values obtained for the cattle adipose fats are more depleted than the sheep adipose, by 0.6‰ and 1.2‰ for the $C_{16:0}$ and $C_{18:0}$ fatty acids, respectively;
❹ A distinction can be made between the δ^{13}C values of fatty acids in ruminant adipose and dairy fats, primarily based on the greater depletion of the $C_{18:0}$ fatty acid in dairy fats (ca. 2–3‰);
❺ The mean δ^{13}C values obtained for the sheep milk are very similar to the mean values for the cow's milk;
❻ Depot fats from chicken and goose show almost identical δ^{13}C values for the $C_{18:0}$ fatty acid and a difference of only 0.4‰ between the mean values obtained for the $C_{16:0}$ fatty acid;
❼ The fatty acids in horse adipose fat are slightly more depleted than the other non-ruminant fats, with mean δ^{13}C values of –30.4‰ and –29.8‰ for the $C_{16:0}$ and $C_{18:0}$ fatty acids, respectively;
❽ The mean δ^{13}C values of the deer adipose fats are similar to the other ruminant adipose fats, however the range of values obtained is significantly greater. This variation is surprising due to the fact that all these animals were of the same breed and raised on the same pasture;
❾ The δ^{13}C values for the depot fats of individual animals are closely grouped (with the exception of deer fat), however, in contrast, the range of δ^{13}C values obtained for the milk fats varied by up to 3.4‰ for the $C_{16:0}$ and 2.9‰ for the $C_{18:0}$ fatty acid.

The relationship between the stable carbon isotope composition of lipid components of adipose fats and diet

The mean δ^{13}C values for the major saturated and unsaturated fatty acids in the reference ruminant animal fats and their diets are plotted in Figures 3 and 4. Data have been included from cows fed concentrates as a supplement to the diet in order to compare with the data from C_3 grass-fed animals. The fatty acids in adipose tissue from the concentrate-fed and the grass-fed cow differ by ca. 2‰, with the former reflecting the higher δ^{13}C values of the concentrate supplement. For the silage and fresh grasses analysed, the bulk δ^{13}C value is significantly less depleted in ^{13}C, by ca. 6‰, than the individual $C_{16:0}$ and $C_{18:0}$ fatty acids. Since the majority of higher plant tissue is composed of carbohydrate, with only ca. 7% lipid, the

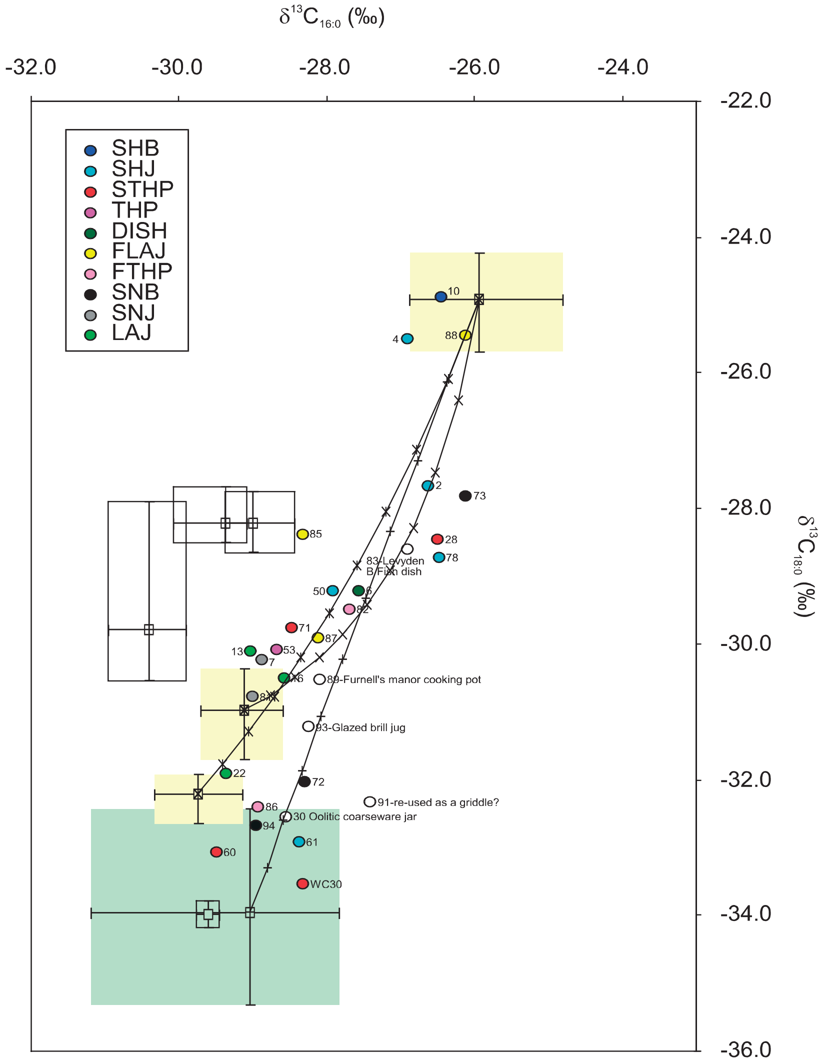


Fig. 7. Plot of the δ^{13}C values of the $C_{16:0}$ and $C_{18:0}$ fatty acid components from the lipid extracts of potsherds from the Late Saxon/ early medieval site of West Cotton, Northamptonshire, correlated with vessel form. The abbreviations denoting vessel form are as follows: SHB, shelly ware bowl; SHJ, shelly ware jar; STHP, shelly ware 'top hat' pot; THP, 'top hat' pot; DISH, dish; FLAJ, Furnell's Manor Lyveden A ware jar; FTHP, Furnell's Manor 'top hat' pot; SNB, St. Neots bowl; SNJ, St. Neot's jar, and LAJ, Lyveden A ware jar.

bulk value obtained reflects the isotopically heavier carbohydrate. δ13C values for individual fatty acids in the grasses have shown that the $C_{14:0}$ is most depleted isotopically, followed by the $C_{16:0}$ and the $C_{18:0}$ fatty acids.

The variations in δ13C values obtained for the individual fatty acids in the grasses and those from cow adipose tissue illustrate that the relationship between diet and tissue is extremely difficult to interpret. This is due to the complexity of the metabolic and physiological processes determining adipose fat formation in different animal species, as mentioned above. The $C_{14:0}$, $C_{16:0}$ and $C_{18:0}$ in cow adipose tissue are generally less depleted than the same fatty acids in the diet indicating that a proportion of these components are synthesised *de novo* and reflect a contribution from other sources of carbon in the diet, e.g. carbohydrate and protein. The relationship between diet and fat cannot be explored fully without examining the routing of different sources of dietary carbon and utilisation of stored carbon in the whole animal (*viz DeNiro and Epstein 1978*). The δ13C values for the sheep from Baker's farm fed some supplements to their diet are very similar to those for the grass-reared sheep from Brockley since the bulk of their diet was grass.

In ruminant animals there is a large (ca. 3‰) difference between the δ13C values for the $C_{16:0}$ and $C_{18:0}$ fatty acids in adipose and an even larger difference of up to 6‰ between the same fatty acids in milk fat. This relatively large difference in the δ13C values of the fatty acids indicates different sources for these components, i.e. the direct routing of dietary fatty acids and the synthesis of components in different organs of the body, e.g. liver, adipose, mammary gland, etc. from different precursors which may result in differing degrees of isotopic discrimination in fat synthesis. The direct routing of fatty acids in the formation of adipose fats is thought to be minor since the fat content of the diets of the major domesticated animals is relatively low (<5%) and thus the major portion of the fat deposited as adipose fat will be biosynthesised by the animal itself (*Emery 1980*).

In the cow adipose and milk samples, including those from concentrate-fed animals, the $C_{16:0}$ is less depleted in 13C than the $C_{18:0}$ fatty acid. The δ13C values of the $C_{18:0}$ fatty acids in cow's milk are depleted by approximately 2‰ relative to the $C_{18:0}$ fatty acid in adipose fat and may reflect a direct contribution from the more depleted fatty acids in the grass/forage (Fig. 3). The relative importance of these different contributions are discussed further below. The δ13C values of fatty

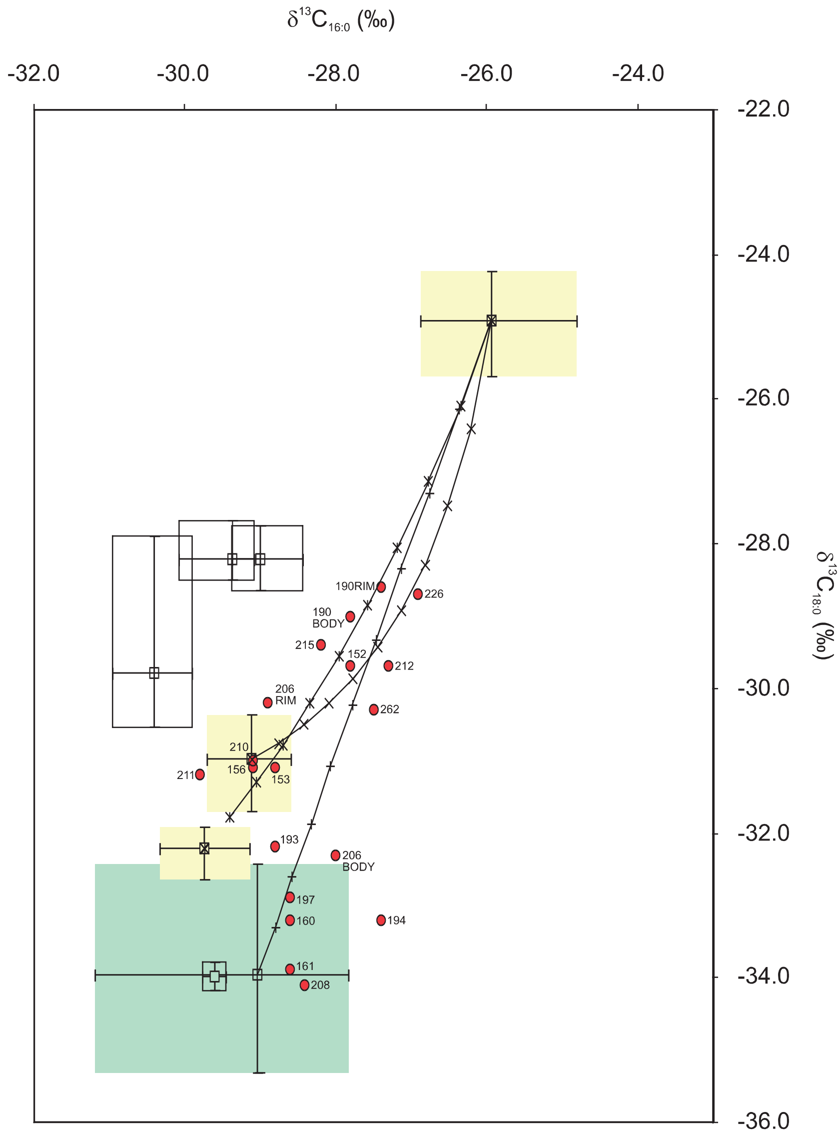


Fig. 8. Plot of the δ13C values of the major n-alkanoic acid components ($C_{16:0}$ and $C_{18:0}$) from the lipid extracts of potsherds from the Iron Age/Romano-British site of Stanwick, Northamptonshire, compared with data from modern reference fats.

acids in milk from concentrate-fed animals are less depleted than milk from grass fed animals due to the influence of the supplements in their diet, however, the $C_{18:0}$ is still significantly more depleted in ^{13}C than the $C_{16:0}$. The $\delta^{13}C$ value of the $C_{18:0}$ fatty acid is also depleted relative to the $C_{16:0}$ by ca. 4‰ in sheep milk (Fig. 4). The difference between the $C_{16:0}$ and $C_{18:0}$ fatty acids in sheep adipose is of lower magnitude (ca. 2‰). The effect of diet on the composition of milk fats is clearly shown by the relatively higher $\delta^{13}C$ values (up to –18‰) of the fatty acids in dairy fats from cows fed concentrate supplements. Thus, there appears to be a distinction between the $\delta^{13}C$ values of milk and adipose fats from ruminant animals probably reflecting differences in the physiological and metabolic processes involved in their production.

Non-ruminant fats comprise fatty acids have higher $\delta^{13}C$ values in the order $C_{14:0}$<$C_{16:0}$<$C_{18:0}$ (Fig. 5). However, in ruminant milk and adipose fats the opposite is the case, with the $C_{14:0}$ displaying the higher $\delta^{13}C$ value (Fig. 4). In non-ruminant body fats there is less variation (ca. 0.5–1‰) between the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids compared with ruminant fats. The fatty acids in the tissues display significantly higher $\delta^{13}C$ value than the fatty acids in the diet and more closely reflect the bulk $\delta^{13}C$ value obtained for the diet. The ~2–4‰ depletion in ^{13}C relative to the bulk diet is possibly due to discrimination against ^{13}C during *de novo* fat biosynthesis in non-ruminants.

The lipid components of the porcine fats are ca. 5‰ more enriched than that of the herbivores, probably reflecting several factors, including: i) the isotopic composition of the diet; ii) the proportion of protein components in the diet (e.g. meat protein); iii) the degree to which different animals rely on different fractions of the diet for energy metabolism [e.g. carnivores depend mainly on protein for energy metabolism, whereas herbivores and omnivores may use excess protein for energy (*Krueger and Sullivan 1984*)]; iv) the presence of the rumen in herbivores which facilitates breakdown and absorption of complex organic materials, and v) the differences in metabolism by which different fractions in the diet are routed or scrambled into the production of body fats. Studies have suggested that carbon in dietary proteins is routed to collagen in rats (*Chisholm et al. 1982*) indicating that some routing occurs rather than simple scrambling of all the different components in the diet (*Schwarcz et al. 1985; Spielmann et al. 1990*). However, at present, factors controlling the isotopic composition of tissues of

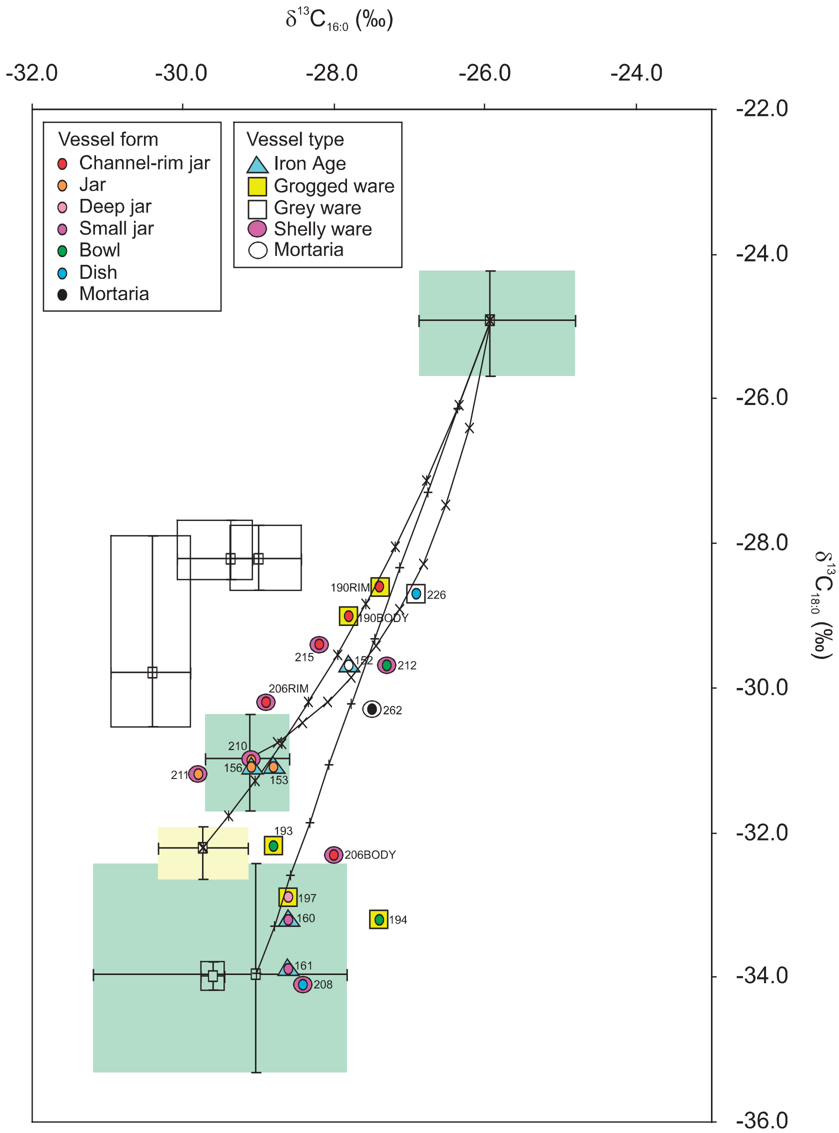


Fig. 9. Plot of the δ13C values of the major n-alkanoic acid components ($C_{16:0}$ and $C_{18:0}$) from the lipid extracts of potsherds from the Iron Age/Romano-British site of Stanwick, Northamptonshire, compared with vessel type and form.

different herbivorous and omnivorous animals are poorly understood.

Figure 5 shows that a distinct pattern exists in the relationship between the diet and adipose tissue of non-ruminant animals, with both the $C_{16:0}$ and $C_{18:0}$ fatty acids equally enriched in ^{13}C relative to the diet. The degree of enrichment is variable between species, with differences of ca. 1‰ between fatty acids in chicken feed and adipose fat, and up to 5‰ between fatty acids in pig feed and pig adipose fat.

Compound specific $\delta^{13}C$ values of animal fats preserved in archaeological pottery

Archaeological samples were selected for stable carbon isotope analysis on the basis that the overall distribution of lipid components resembled a degraded animal fat, and that they contained sufficient quantities of $C_{16:0}$ and $C_{18:0}$ fatty acids for analysis by GC–C–IRMS. Extracts in which leaf wax components were also identified were generally avoided in order to obtain pure animal fat signals (*Charters et al. 1993*). In order to assess the effect of mixtures of fats from different reference animals on the isotopic signal, theoretical mixing lines have been constructed according to Woodbury *et al.* (*1995*); such mixing curves take into account both the relative proportions of the major *n*-alkanoic acids and the $\delta^{13}C$ values of the acids present in the pure fats. The $\delta^{13}C$ values for mixtures of fats in varying proportions are plotted for comparison with the archaeological data.

Sites with well-documented faunal assemblages

West Cotton (Late Saxon/early medieval) – $\delta^{13}C$ values were obtained for the $C_{16:0}$ and $C_{18:0}$ fatty acids in the selected remnant fats from West Cotton. The data are plotted in Figure 6 together with $\delta^{13}C$ values obtained for the fats of modern equivalents of the domesticated animals represented in the faunal assemblage at West Cotton. Three archaeological fats, sample nos. RP4, 10 and 88, correspond closely with the data obtained for the reference pig fats. The majority of the remainder contain fatty acids with $\delta^{13}C$ values which plot along the mixing curves between the reference ruminant and non-ruminant adipose fats and in the region of the reference ruminant fats. Several of the archaeological fats from West Cotton were found to correspond to the data obtained for the reference ruminant milk fats, including RP30, 60, 61, 86, 94 and WC30, distinguished by a lighter isotopic signal (mean –33‰) for the $C_{18:0}$ fatty acid. Two other archaeological fats, sample nos. RP72 and 91, cluster around the mixing curve between the reference milk and non-rumi-

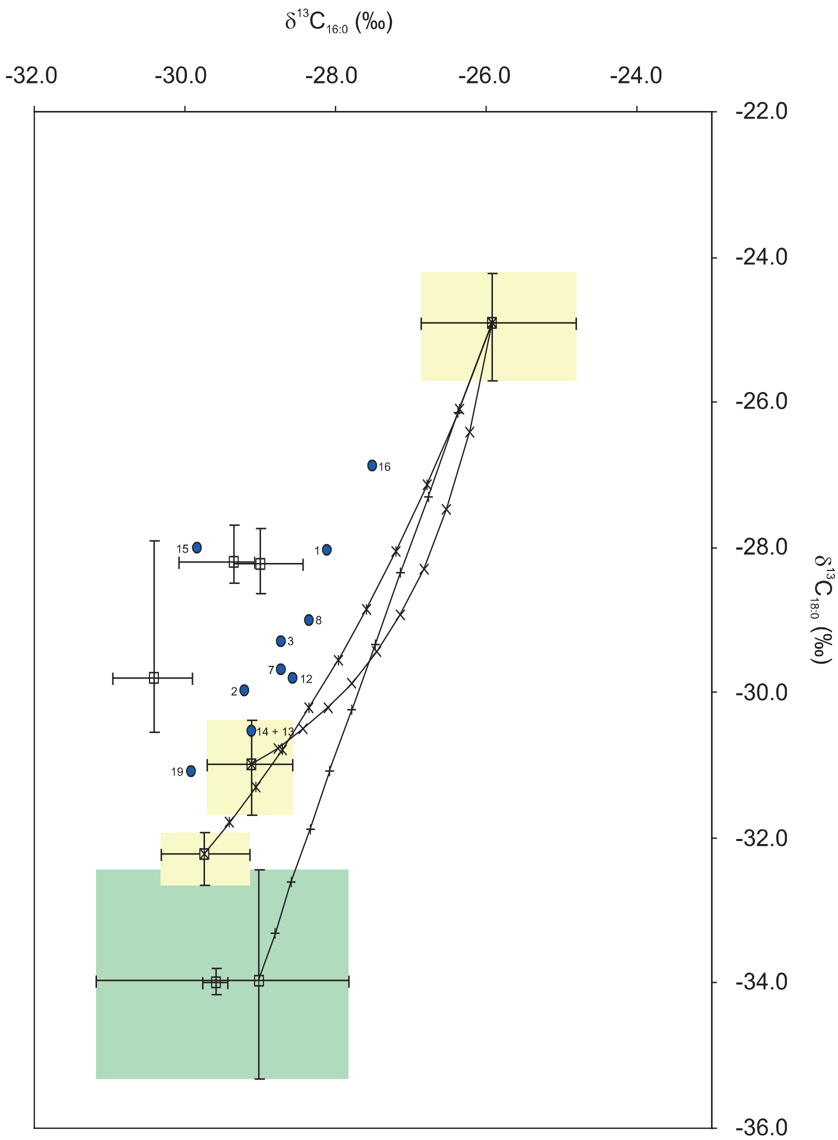
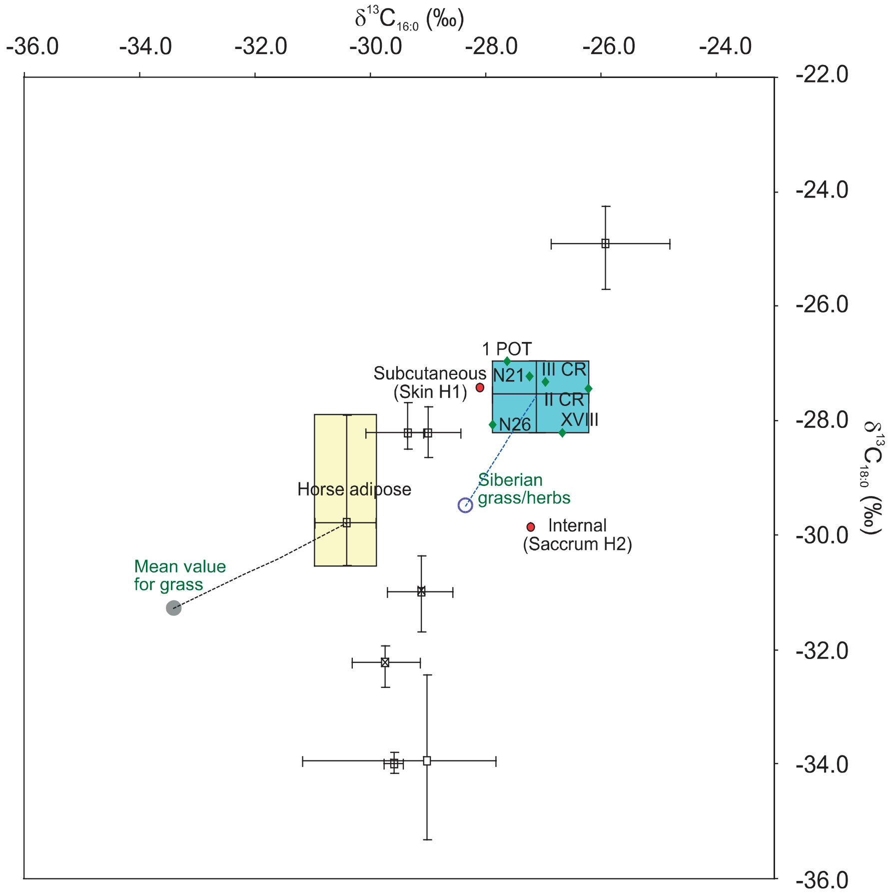


Fig. 10. Plot of the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids in solvent extracts of Wicken Bonhunt potsherds compared with data from modern reference fats.

nant fats. Based on the distributions of lipid components, it had previously been assumed that the majority of remnant fats from West Cotton derived from degraded adipose fats (*Charters 1996*), probably of an ovine origin due to the high abundance of sheep bones recovered from the site. However, in the light of these new data, at least six remnant fats appear to have a dairy origin based on their $\delta^{13}C$ values. WC30, the medieval 'top hat' vessel from West Cotton contained an appreciable abundance of short-chain fatty acids which are diagnostic of milk fats. It is notable that the $\delta^{13}C$ values for the $C_{16:0}$ and $C_{18:0}$ fatty acids from this residue plot in the range for the reference milk fats since this unusually well-preserved residue helps to validate the methods described herein for the detection of acid fat. None of the other remnant fats from West Cotton contained such a high abundance of short-chain fatty acid components which could identify them as dairy fats, the only evidence indicating their dairy origin has been obtained through determination of the $\delta^{13}C$ values of their $C_{16:0}$ and $C_{18:0}$ fatty acid components.

The $\delta^{13}C$ values obtained in the re-analysis of the West Cotton vessels previously studied by Charters (*1996*) show that the original interpretations still stand, with vessel RP78 derived from either a ruminant adipose origin or from a mixture of ruminant and non-ruminant fats. The results of the re-analysis also indicate that the fats from the spouted bowls all derive from ruminant animals, with $\delta^{13}C$ values correlating with those obtained for the reference dairy fats. The $\delta^{13}C$ values indicate a common function for these spouted bowls. Since sub-samples of the same potsherds were re-extracted prior to stable carbon isotope analysis as part of this study, the close similarity of the results obtained in analyses by Charters (*1996*) and the new data provide further validation of the analytical procedures employed and illustrate the reproducibility of the compound-specific $\delta^{13}C$ analyses.

Figure 7 shows a plot of the $\delta^{13}C$ values compared with vessel form. Vessel function does not correlate well with form, although some observations can be made, e.g. both of the St Neots Jars [refer to Charters (*1996*) for a detailed description] have given $\delta^{13}C$ values which indicate ruminant adipose fats are present. Shelly ware jars were apparently used for a range of culinary functions since various sherds from these vessels have isotope values corresponding with ruminant adipose and dairy fats and non-ruminant fats; $\delta^{13}C$ values from the Shelly ware bowl indicate the presence of non-ruminant fat.



Some correlation can be observed between $\delta^{13}C$ values and date, including: i) the Late Saxon residues plot in the region of the ruminant adipose and dairy fats; ii) the early medieval pots, ca. 1100 to 1150 AD (site of an early medieval settlement and manor) plot in the region of the ruminant adipose and in line with the mixing curve indicating mixtures of ruminant and non-ruminant fats, however, there is no isotopic evidence for dairy

Fig. 11. Plot of the $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids in extracts of archaeological potsherds from Botai, Kazakhstan, compared with values for reference animal fats and the fatty acid components in their diet.

or pure non-ruminant fats; iii) data from four sherds dating ca. 1150–1225 AD include two which plot closely together quite high up the mixing curve towards the reference porcine fats and two which plot together in the region of the dairy fats, and iv) all of the sherds dating between 1225 and 1300 AD (site of medieval manor and hamlet) plot in the region of the ruminant adipose fats. Unfortunately, dates are not known for all of the sherds analysed; however, it appears that residues from both ruminant adipose and dairy fats are associated with all periods at West Cotton. A larger data set for the main periods would provide a clearer picture of changes or trends in vessel and commodity use.

Stanwick (Iron Age/Romano-British) – Figure 8 is a plot of the stable carbon isotope data obtained for the $C_{16:0}$ and $C_{18:0}$ fatty acids from archaeological fats from the Stanwick assemblage compared with the same reference fats and mixing curves as previously described. The clustering of archaeological fats clearly illustrates the predominance of ruminant adipose and dairy fats in these Romano-British and Iron Age sherds. In contrast to West Cotton, none of the remnant fats from Stanwick plot with the non-ruminant (e.g. porcine) reference fats; however, a number of the archaeological fats plot along the mixing curve between the ruminant and non-ruminant fats. Several of the fats appear to have a dairy origin due to their close correlation with data obtained for the modern reference milk fats, including ST193, 206 body, 197, 160, 194, 161 and 208. The reliability and wider application of the stable isotope approach is re-enforced by the data obtained from these analyses since the spread of $\delta^{13}C$ values from Stanwick, seen in Figure 8, mirrors that seen in Figure 6 for the West Cotton extracts, except for the notable absence of non-ruminant (e.g. porcine) fats amongst the Stanwick assemblage.

The correlation of vessel form/fabric type and stable carbon isotope ratios of the fatty acids in the Stanwick vessels shown in Figure 9 illustrates that both Grogged ware bowls contain residues which plot with the reference dairy fats, and both sherds from the Grogged Channel-rim jar plot closely together on the mixing curve between the reference ruminant and non-ruminant adipose fats. The two Iron Age Channel-rim jars correlate with the reference dairy fats and both of the Iron Age jars plot in the region of the reference ovine adipose fats.

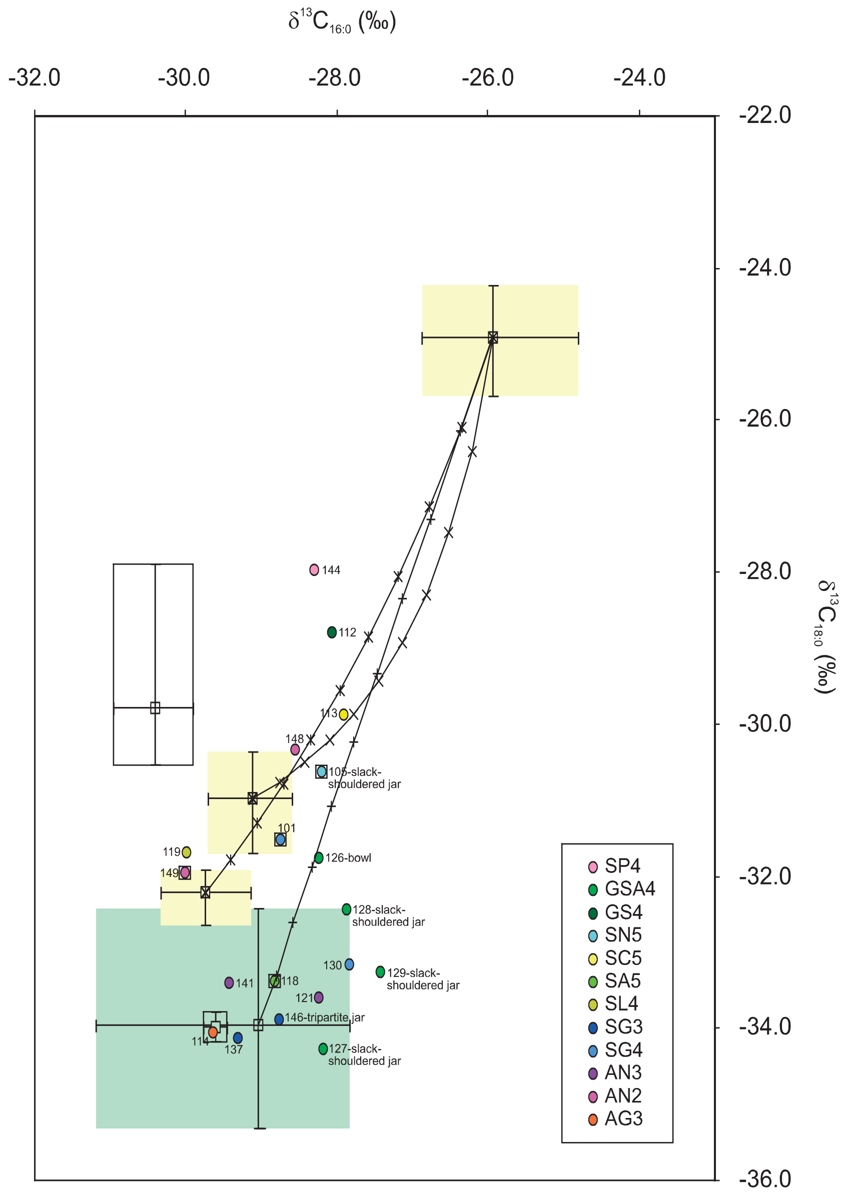


Fig. 12. Plot of the $\delta^{13}C$ values of the fatty acids from lipid extracts of the Yarnton Cresswell field assemblage correlated with vessel fabric and form (where known) and compared with the values obtained for the modern reference fats. The fabric type abbreviations are explained fully in Table 7, Appendix 1 of Dudd (1999).

Sites with an unusually strong bias in the faunal record

Wicken Bonhunt (Romano-British/Middle Saxon) – The aim of these analyses was to investigate whether the high proportion of pig bone present at the site was reflected in residues preserved in the potsherds. The $\delta^{13}C$ values obtained for the potsherd extracts from the Middle Saxon site plot in a broad distribution between the modern ruminant and non-ruminant reference fats (Fig. 10). The fatty acids from the archaeological extracts are more depleted than those in the modern reference pig fats by up to 6‰. Several of the remnant fats plot close to the reference sheep adipose, although the majority of archaeological fats plot along the line of the mixing curve, indicating that these data may represent mixtures of fats processed in the same vessel or multiple usage of vessels. There is no clear correlation between the archaeological data and the porcine reference fats, nor is there any indication from the stable carbon isotope data that any of the archaeological fats from Wicken Bonhunt derive from a dairy origin.

Botai (early Neolithic) – Potsherds from Botai were sampled in anticipation of retrieving data from degraded horse fats due to the strongly attested association of this site with horse breeding. The $\delta^{13}C$ values obtained for fatty acids in the potsherd extracts are shown in Figure 11. The data points group together with mean $\delta^{13}C$ values of –27.1‰ for the $C_{16:0}$ and –27.5‰ for the $C_{18:0}$ fatty acids, but are distinct from the modern reference fats. The grouping of the data for the archaeological fats is relatively tight, indicating that these remnant fats all derive from the same animal origin. The remnant fats are less depleted by ca. 2–3‰ (in both the $C_{16:0}$ and $C_{18:0}$ fatty acids) than the modern reference horse fats from the UK. However, this difference can be attributed to differences in the isotopic composition of the diet of the horses raised in Kazakhstan from that of modern horses raised on forage in the UK. The data indicate that comparison of the stable isotope data from the fats of animals raised in different geographic locations are not directly comparable.

Prehistoric British archaeological sites

Yarnton Cresswell field (early-middle Iron Age) – The $\delta^{13}C$ values for the majority of the Yarnton Cresswell field extracts are relatively depleted in ^{13}C and plot in the region of the ruminant adi-

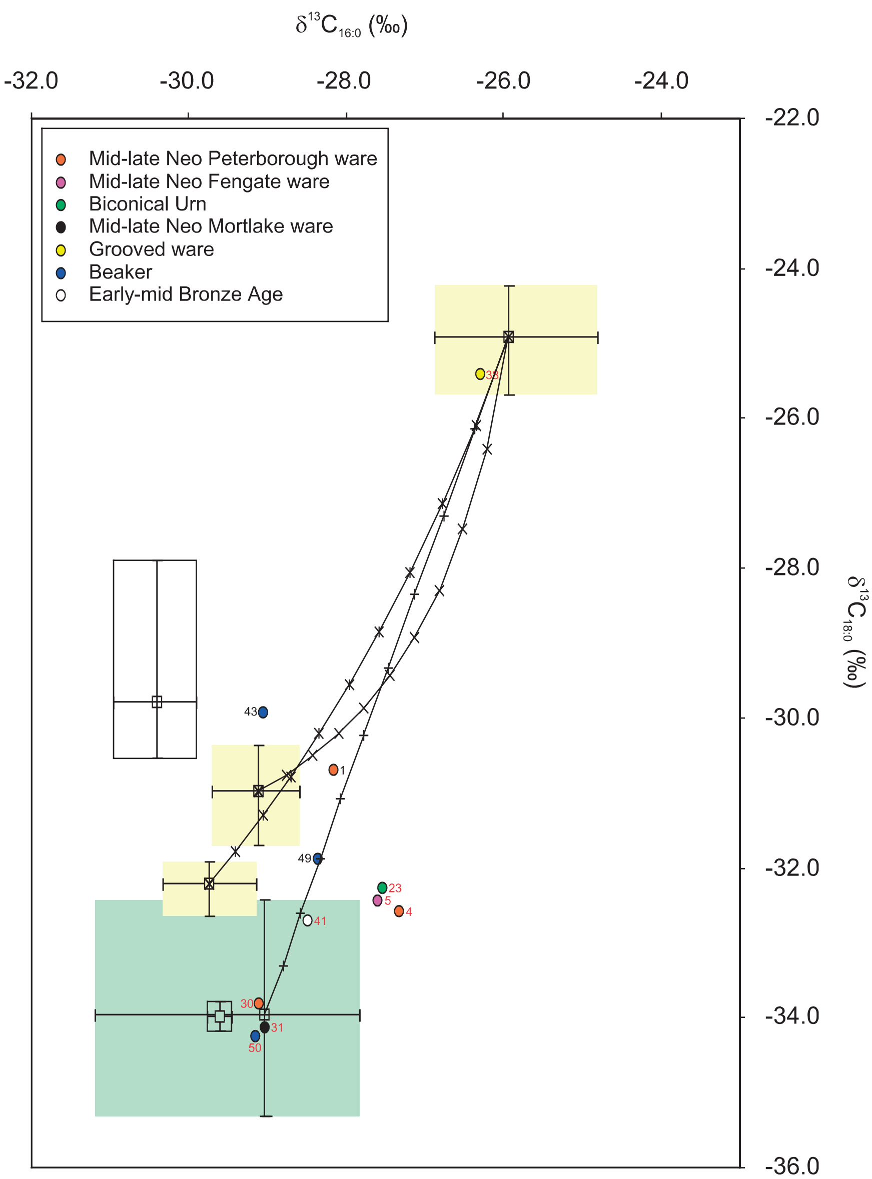


Fig. 13. Plot of the $\delta^{13}C$ values of the fatty acids from lipid extracts of the Yarnton flood plain assemblage correlated with vessel type and compared with the values obtained for the modern reference fats typical of the archaeological period.

pose and dairy fats (Fig. 12). Approximately half of the archaeological extracts plot within the range of the modern reference cows' milk. Several extracts plot close to the mixing curves between the ruminant and non-ruminant reference fats. None of the remnant fats correlate with the reference porcine fats. There is some correlation between fabric types from Cresswell field and the $\delta^{13}C$ values of the extracts (Fig. 12), with the majority of the GSA4 (grog, shell and quartz sand; coarse textured) and SG3 (shell and grog; medium coarse textured) types plotting within the range for reference dairy fats as does sample 114 [fabric type AG3 (quartz sand and grog; medium-coarse textured)]. Sample 144 [fabric type SP4 (shell and clay pellets; coarse textured)] contains the remnant fat exhibiting the least depleted $\delta^{13}C$ values.

Yarnton flood plain (Neolithic-Bronze Age) – The stable carbon isotope data for fatty acids from the Yarnton flood plain extracts are plotted in Figure 13. The majority of the archaeological data points cluster in the region of the ruminant fats, with 4 vessels plotting well within the range for the reference cows' milk fats. Only one data point (sample 38) out of 11 analysed falls within the range of the non-ruminant (e.g. porcine) reference fats. Several vessels, including sample nos. 49, 23, 5 and 4 plot around the mixing curve between the milk and non-ruminant reference fats. In general, the archaeological vessels comprising higher abundances (>100 µg g^{-1}) of absorbed lipid also exhibited more depleted $\delta^{13}C$ values, resembling dairy fats. This is possibly a reflection of the ease with which certain fats are absorbed within the porous pottery, or the different ways in which vessels were used to process commodities, i.e. boiling or roasting. During the dosing of sherds for laboratory decay experiments we noted that substantially larger quantities of fat are absorbed when soaked in butter fat than in milk (*Dudd, Aillaud and Evershed, unpublished data*), suggesting that archaeological vessels containing substantial quantities of remnant dairy fats may have derived from butter rather than milk fats.

Correlation of vessel type with $\delta^{13}C$ values reveals a distinction between the residues from the Peterborough ware and the Grooved ware vessels, with the former yielding $\delta^{13}C$ values comparable to the reference ruminant fats and the latter consistent with reference porcine fats. This result is significant since we have recognised the same distinction in residues from Peterborough and Grooved ware vessels from the Neolithic settlement at Upper Ninepence, Walton (*Dudd et al. 1999*). Figure 13 also indicates that a range of different vessel types, including Peterborough and Mortlake wares from the mid-late Neolithic, a beaker and an Early-Mid-

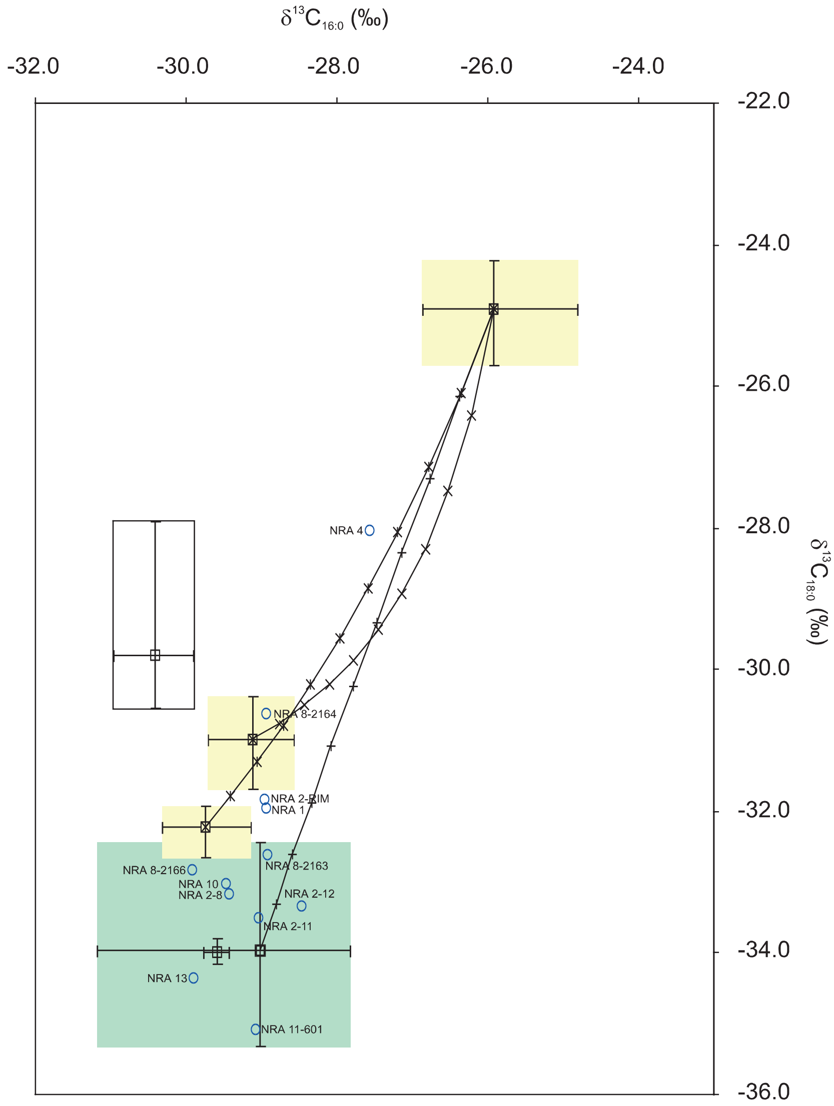


Fig. 14. Plot of the $\delta^{13}C$ values of the fatty acids from lipid extracts of the Eton Lake End Road assemblage compared with the data obtained for the modern reference fats.

dle Bronze Age vessel, appear to have been associated with the processing of dairy fats.

Eton Lake End Road (late Neolithic-Early Bronze Age) – Similar to the Eton Rowing Lake assemblage, the majority of the extracts from Eton Lake End Road plot within the region of the reference ruminant dairy fats, with $\delta^{13}C$ values of <-28‰ for the $C_{16:0}$ fatty acid and <-32‰ for the $C_{18:0}$ fatty acid (Fig. 14). Three of the extracts, NRA 8-2164, NRA 2-rim and NRA 1 are slightly less depleted in ^{13}C, particularly in the $C_{18:0}$ fatty acid, and cluster with the reference ruminant adipose fats. Only one sample, NRA 4 is less depleted still and falls along the mixing curve between the ranges of the ruminant adipose and non-ruminant fats, possibly representing a mixture of ruminant and non-ruminant fats.

Eton Rowing Lake (early Neolithic) – All of the $\delta^{13}C$ values for the Eton Rowing Lake samples cluster within the ranges of the reference ruminant adipose and dairy fats (Fig. 15), indicating that all of the remnant fats are derived from a ruminant source. Samples 12 and 20 are less depleted than the other samples and correlate with the ranges for the reference adipose fats, while the remainder correlate well with the reference dairy fats. None of the extracts have $\delta^{13}C$ values suggesting a significant non-ruminant fat contribution.

Upper Ninepence (early-late Neolithic) – The $\delta^{13}C$ values of the $C_{16:0}$ and $C_{18:0}$ fatty acids in three absorbed residues from the Peterborough ware (P1, P3 and P5), two absorbed residues from the Grooved ware (P66 and P68) and three carbonised (interior) surface residues from the Grooved ware (P33, P38 and P39) are plotted in Figure 16. Clearly, there is a distinction between the absorbed residues from the Peterborough ware and the Grooved ware and between the absorbed and carbonised residues from the Grooved ware, based on differences in the $\delta^{13}C$ values of both the $C_{16:0}$ and $C_{18:0}$ fatty acids. The absorbed archaeological fats from the Grooved ware (both from site context 133) plot together near to the non-ruminant (e.g. porcine) reference fats, whilst the three archaeological fats from the Peterborough ware plot in the region of the ruminant fats, within the range of the reference dairy fats. The carbonised residues adhering to three other Grooved ware vessels, all excavated from the same pit, plot with the reference dairy fats, with the exception of sample P39, which is more depleted in ^{13}C. The absorbed residues from these same vessels were poorly preserved, all comprising <13 µg g^{-1} of lipid. The Grooved ware vessels associated with ruminant fat residues were excavated from a different archaeological feature

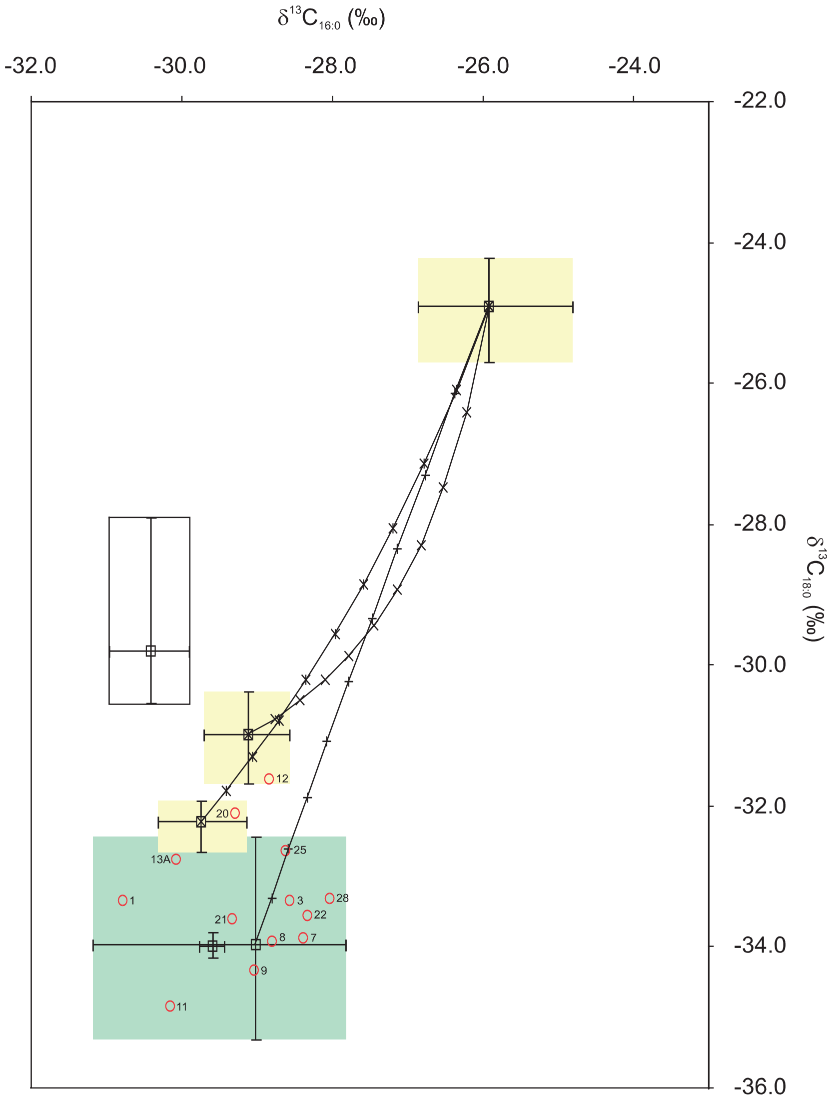


Fig. 15. Plot of the δ13C values of the fatty acids from lipid extracts of the Eton Rowing Lake assemblage compared with the values obtained for the modern reference fats typical of the archaeological period.

than those of the same period corresponding with the non-ruminant reference fats.

Archaeological horse fats and tissues – Since the remnant fats from Botai were not directly comparable with UK reference horse fats, we obtained samples of Siberian horse fats for use as reference data. The sample of stomach lining from Horse 1 comprised free fatty acids and highly abundant hydroxy acids. The degraded fat contained some intact triacylglycerols, however these were present in very low abundance. The lipid components of the stomach contents were also analysed, with the saponified, methylated extract comprising a range of long-chain, saturated and unsaturated free fatty acids. The subcutaneous fat (skin; Horse 1) comprised free fatty acids, hydroxyoctadecanoic acid, cholesterol and a greater abundance of intact triacylglycerols than in the sample of stomach lining from the same horse (Fig. 17). The Sacrum meat and crumbled flesh associated with the coccygeal vertebra from Horse 2 yielded an abundance of free fatty acids and also di- and triacylglycerols in low abundance. The lipid components are similar in distribution to the subcutaneous fat from Horse 1. The distributions of free fatty acids, mono-, di- and triacylglycerols in this sample are consistent with other degraded animal fats described and are remarkably well preserved due to the permafrost burial conditions.

The $\delta^{13}C$ values obtained for the $C_{16:0}$ and $C_{18:0}$ fatty acids in the archaeological horse fats from the Siberian tomb are less depleted than the modern reference horse fats, particularly with respect to the $C_{18:0}$ fatty acid (Fig. 11). The $\delta^{13}C$ values of the fatty acids from the internal (sacrum) and subcutaneous (skin) fat samples from the Siberian horses vary by ca. 1‰ and 2.4‰ for the $C_{16:0}$ and $C_{18:0}$, respectively. This may reflect the fact that the fat sample from the sacrum resembled adipocere, consisting predominantly of free fatty acids, which may have been contaminated by fatty acids from micro-organisms. There may also be some natural variation between tissues from different parts of the body.

The bulk $\delta^{13}C$ values obtained for the grass in the stomach of the Siberian horse were more depleted by approximately 2‰ than modern UK grasses (25.9‰ compared with 27.9‰); this was also reflected in the $\delta^{13}C$ values of the individual fatty acids in the grass (Fig. 11). The stomachs of these horses were found to contain a wide range of herbs and grasses typical of a rich upland pasture, whereas the diets of our modern reference horses was dominated by one or two grass species, from heavily grazed fields. Since non-ruminants and pseudo-ruminants are believed to be more directly

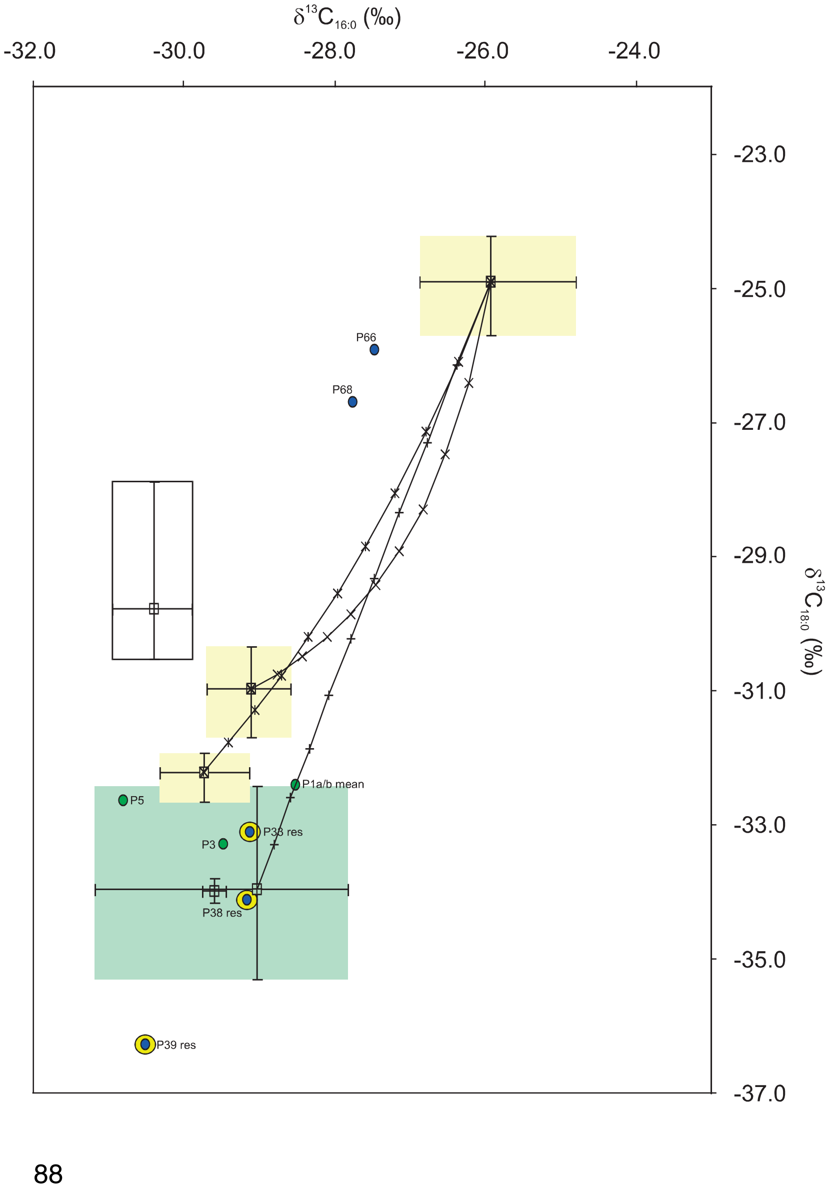


Fig. 16. Plot of the $\delta^{13}C$ values for the major n-alkanoic acid ($C_{16:0}$ and $C_{18:0}$) components of the lipid extracts of potsherds from the Walton assemblage: Grooved Ware = blue-filled circles; Peterborough Ware = green-filled circles; Carbonised surface residues = yellow ring around the data point.

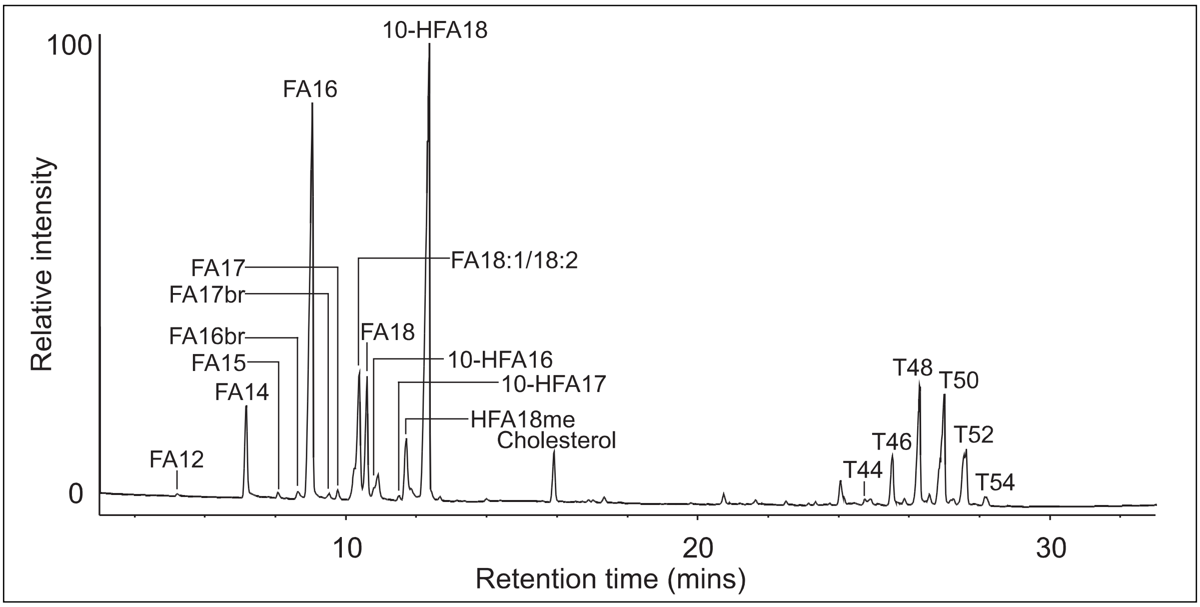


Fig. 17. Partial HTGC profile of the trimethylsilylated total lipid extract of the remnant fat associated with the horse skin/hide from the 'Ice Princess' burial in the Altay mountains. Peak identities are: FA12, FA14, FA15, etc. correspond to n-alkanoic acids with 12, 14 and 15 carbon atoms, etc., respectively; FA17br refers to a branched-chain alkanoic acid with 17 carbon atoms; FA16:1 and FA18:1 refer to monounsaturated n-alkanoic acids containing 16 and 18 carbon atoms, respectively; T44, T46, T48, etc. correspond to triacylglycerols bearing 44, 46, 48, etc. acyl carbon atoms, respectively; IS = internal standard (n-tetratriacontane) added at the extraction stage to enable quantification of lipid. All peak assignments have been confirmed by GC/MS analysis. In addition, 10-HFA 16, 17 and 18 refer to 10-hydroxy fatty acids with 16, 17 and 18 carbon atoms, respectively; HFA 18 me refers to methyl ester of the C18 10-hydroxy fatty acid.

influenced by their diet, the differences in the $\delta^{13}C$ values of their tissues can be readily related to differences in the composition of the diet. Clearly, the heavier dietary carbon consumed by the Siberian horses had led to less depleted values for the fatty acids in their depot fats compared with our modern reference horses.

The data from the Siberian horse fats are clearly more comparable with the data obtained for the remnant fats from the Botai potsherd extracts than the modern horse fats. This positive correlation obtained for remnant fats from the more similar geographical region indicates that the absorbed residues in the Botai potsherds are, indeed, derived from horse fats processed in the vessels in antiquity.

DISCUSSION

Reference fats

The compound specific $\delta^{13}C$ values recorded for individual fatty acids have enabled clear distinctions to be drawn between adipose fats from the major species of domesticated ruminants, non-ruminants and poultry, and furthermore, has shown that significant differences exist between the composition of adipose and milk fats from dairy animals based on $\delta^{13}C$ values of the major saturated fatty acids.

Inter-species variation – The $\delta^{13}C$ values obtained for the reference ruminant adipose fats are relatively similar between different individuals of the same animal species. The sheep adipose gave mean $\delta^{13}C$ values of –29.1‰ ± 0.6 and –31‰ ± 0.7 and the cow adipose gave mean values of –29.7‰ ± 0.6 and –32.2‰ ± 0.4 for the $C_{16:0}$ and $C_{18:0}$ fatty acids, respectively. The variation can be attributed to the way in which ruminants can break down and reassimilate components from various sources of carbon in the diet and also to the fact that body fats represent an average value for carbon accumulated over several months. Conversely, the $\delta^{13}C$ values measured for the bovine dairy fats cover a broader range (mean values of –29.0‰ ± 2.2 and –34‰ ± 1.5 for the $C_{16:0}$ and $C_{18:0}$ fatty acids, respectively), which is thought to be partly a reflection of the recent diet of the animal, due to the turnover of carbon in milk production being significantly faster than that of body fats (*Tieszen et al. 1983*). Thus, the composition of the dairy fats may vary significantly in isotopic composition, e.g. according to the availability of particular forage materials or seasonal variations in $\delta^{13}C$ values of the plant tissues. No correlation could be found between the stable isotope composition of the reference milk samples and the time of year or stage of lactation during which they were collected.

The range of $\delta^{13}C$ values measured for fatty acids in the porcine fats is similar but, slightly greater than for the ruminant adipose fats, and is probably representative of the range of foodstuffs a pig will consume and the direct routing of dietary fats to body fats. It is well established that in non-ruminants such as pigs, little modification of the fats occurs unless utilised for energy (*Christie et al. 1972*). The range of $\delta^{13}C$ values for fatty acids in tissues of goose and chicken fats were comparable with the ruminant reference fats, however, the values for the same fatty acids in deer adipose fats varied significantly, by up to 2‰ and 4‰ in the $C_{16:0}$ and $C_{18:0}$ fatty acids, respectively. Since the deer fats were all taken from animals of the same herd raised on the same unimproved pasture, the $\delta^{13}C$ values are surprisingly variable. To some extent this may be a reflection of 'ecological variability', referred to as the 0.2–2‰ standard deviation found for animals of the same species raised in similar environments on the same diets (*DeNiro and Epstein 1978; Teeri and Schoeller 1979; Tieszen et al. 1983*).

Contribution of dietary fat to milk – It has been recognised that the $\delta^{13}C$ value of the $C_{18:0}$ component of milk obtained from cows grazing on C_3 pastures differs isotopically from the same compound in subcutaneous adipose fat of cattle grazing on the same pasture. This distinction reflects the well-established pathways involved in the formation of milk and adipose fats in ruminant animals (*Church 1988; McDonald et al. 1988*), demonstrated by Tove and

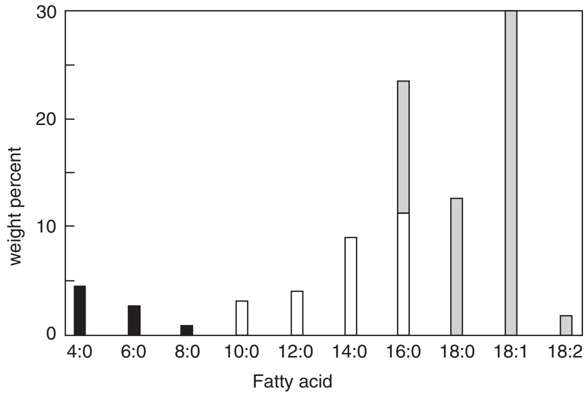


Fig. 18. Probable origin of fatty acids in ruminant milk (from* Dimick et al. 1970*): 4-carbon unit ■; malonyl-CoA pathway □ and circulating blood lipids ▩.

Mochrie (*1963*) in an investigation of tissue and milk fats sampled simultaneously from cows fed whole ground soybeans. They observed that the percentage of both $C_{18:0}$ and $C_{18:1}$ increased markedly in the milk fat. This was compensated for by a decrease in the percentage of $C_{14:0}$ and $C_{16:0}$, and confirmed the contribution of dietary long- chain fatty acids to milk fat in ruminant animals.

Figure 18 illustrates the probable contribution of carbon from different sources to milk lipids according to Dimick *et al.* (*1970*). The substantial proportions of short- and medium-chain fatty acids in milk lipids are a result of a very active *de novo* synthesis from the simple metabolites acetate and β-hydroxybutyrate, which are supplied to the mammary gland (*Dils 1983*). It is well-established that a proportion of the $C_{16:0}$ and essentially all the C_{18} acids are derived *via* the circulating blood lipids. $C_{16:0}$ is known to be derived from two sources; pre-formed from the

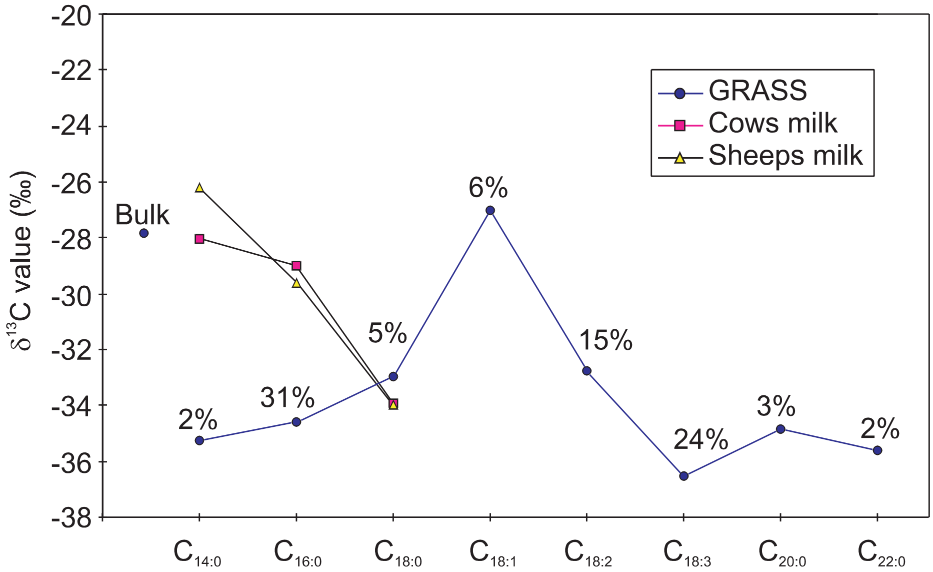


Fig. 19. Stable carbon isotope data obtained for the major saturated fatty acids in cows (mean of 8 individuals) and sheep (mean of 2 individuals) milk compared with δ13C values for the bulk diet (grass) and individual fatty acids in the diet. The relative abundances (mean %) of the different fatty acids in grass are shown.

blood, and synthesised within the mammary gland from 2 carbon units (*Dimick et al. 1970*). Triacylglycerols in the blood may arise either directly from absorbed (exogenous) fat or from endogenous fat *via* liver synthesis of very low density lipoproteins (VLDL; *Dils 1983*).

Various studies have been carried out to determine the proportions of dietary fat which contribute directly to fatty acids used in milk production. Banks *et al.* (*1976a*) showed that a low fat ration limited milk production, and tracer studies have indicated that 54% of dietary C_{18} fatty acids (*Banks et al. 1976b*) and 76% of dietary $C_{18:2}$ (*Palmquist and Mattos 1978*) are transferred directly to milk fat. However, estimates are dependant upon the physiological state of the animal and will also reflect changes in the contribution of endogenous (adipose) fatty acids to milk secretion as fatty acid intake varies, and contributions from rumen-synthesised fatty acids. Other isotopic labelling studies have estimated that 44% of milk fat is of direct dietary origin with approximately 6% of long-chain fatty acids from endogenous sources (*Garton 1963*). Plowman *et al.* (*1972*) noted a rapid change in milk fatty acid composition when protected fat was fed to lactating ruminants; milk fat with increased polyunsaturated fatty acids was produced by feeding cows a diet containing a H_2CO-treated safflower oil-casein particle. The treatment protected the $C_{18:2}$ acid in safflower oil from biohydrogenation in the rumen and $C_{18:2}$ acid content in the milk increased from 3 to 35% of the total fatty acids.

It has been suggested that in the mammary gland, long-chain fatty acids are produced by chain elongation. This has been demonstrated in ruminant adipose tissues by the formation of labelled $C_{18:0}$ and $C_{18:1}$ from [1-^{14}C]-acetate *in vitro*, where between 45–55% and 60–70% of the fatty acids synthesised in bovine (*Pothoven et al. 1974*) and ovine (*Deeth and Christie 1979*) adipose tissue slices, respectively, were elongated to C_{18} fatty acids. The $C_{18:0}$ in milk fat could therefore be partially derived from the $C_{14:0}$ and $C_{16:0}$ fatty acids in the diet following chain elongation, and would thus incorporate the relatively depleted carbon from these fatty acids. It should also be remembered that many other forage materials, including herbs and shrub vegetation, will also contribute long-chain fatty acids to the diet. As previously mentioned, these fatty acids are believed to be significantly more depleted than those in grass and probably contribute to the more depleted values for the $C_{18:0}$ in milk fat. Figure 19 shows the relative abundances of the individual long-chain fatty acids in a typical ruminant diet (mainly grass). The $C_{18:0}$ component comprises only 5% of the total, while together the unsaturated C18 fatty acids with $\delta^{13}C$ values of less than –34‰ constitute a total of 29%.

The stable isotope data obtained for the $C_{14:0}$, $C_{16:0}$ and $C_{18:0}$ fatty acids in the reference ruminant milk fats are also compared in Figure 19. There are large differences between the $\delta^{13}C$ values of the major fatty acid components of the milk fats, amounting to ca. 6‰ and 8‰ between the $C_{14:0}$ and $C_{18:0}$ in cow's milk and sheep milk, respectively. The $\delta^{13}C$ value of the $C_{14:0}$ in milk is clearly not consistent with a direct dietary origin, due to the difference in $\delta^{13}C$ value from the $C_{14:0}$ in the grass, but reflects the value for the bulk diet (i.e. mainly carbohydrate). The $\delta^{13}C$ value of the $C_{18:0}$ fatty acid in the milk fats does not reflect the bulk value for milk which indicates that this component is derived, at least partially, from a source other than the carbohydrate in the diet. The relatively depleted $\delta^{13}C$ values recorded for the C_{16} and C_{18} fatty acids in the diet (ca. –27 to –37‰) indicate that these components could be contributing to the depleted values of the C_{16} and C_{18} fatty acids in the milk fat.

The almost linear relationship between the $C_{14:0}$, $C_{16:0}$ and $C_{18:0}$ fatty acids shown in Figure 19 supports the work by Dimick *et al.* (*1970.Fig. 17*) who have suggested that the $C_{14:0}$ fatty acid is derived predominantly from the malonyl-CoA pathway while the $C_{16:0}$ fatty acid forms from approximately equal contributions from both the circulating blood lipids (including dietary fatty acids) and *de novo* synthesis. The majority of the C_{18} is reported to be derived from circulating blood lipids which include up to 50% of long-chain dietary fatty acids ($C_{18:0}$ and unsaturated C_{18} after biohydrogenation).

Stable carbon isotope analyses of the different biochemical fractions which comprise grasses and herbs from unimproved pastures are currently under investigation in our laboratory in order to investigate the various sources of carbon available to animals which consume them. Results obtained to date have shown C_{18} fatty acids with highly depleted $\delta^{13}C$ values in the range of –36‰, e.g. in herbs such as clover (*Docherty and Evershed, unpublished data*). The consumption of these highly depleted fatty acids would explain the more depleted $\delta^{13}C$ values for the $C_{18:0}$ components in milk fat since herbivorous grazers will consume a variety of foliage and herbage as well as grass. The regulation of milk production and adipose fat formation is far from simple and as yet not fully understood but since fatty acid output in the milk of lactating cows usually exceeds daily intake of fatty acid, lipid metabolism must play an important, if not central, role in the energy economy of the lactating cow.

In addition to dietary fat content and metabolic variations, the range of stable carbon isotope values obtained for the reference and archaeological milk samples probably reflect variation in the proportion of fibre in the animals diets, the effects of a range of environmental stresses on the animals and also the stage of lactation. Palmquist and Mattos (*1978*) suggest that their estimates of fatty acid transfer from the diet may not be valid during the non-steady state when the cow is rapidly losing adipose stores during early lactation.

Changes in plant carbon isotope ratios may occur due to environmental heterogeneity which are most likely associated with either large differences in soil moisture content (affecting plant water status) or light intensity (*Fogel and Cifuentes 1993; Lockheart et al. 1997*). Lowdon and Dyck (*1974*) have shown that the $\delta^{13}C$ values of maple leaves and a grass species collected at a single location may vary more than 5‰ during the growing season. A recent study of the $\delta^{13}C$ values of individual fatty acids in vegetable oils has shown sources of variability relating to geographical origin of the oil, year of harvest and the particular variety of the oil (*Woodbury et al. 1998*).

Archaeological pottery

All of the archaeological fat extracts prepared as FAME and analysed by GC-C-IRMS have yielded $\delta^{13}C$ values which correlate closely with the range of data obtained for the modern reference fats. The data from each site appear to correspond either with the ruminant dairy, ruminant adipose, non-ruminant adipose or lie along the line of the theoretical mixing curve between ruminant and non-ruminant adipose fats. None of the values appear to be erroneous or affected adversely by decay so that they lie far from the reference fat data points. Coupled with the distributional data, which show that the fats comprise an abundance of saturated $C_{16:0}$ and $C_{18:0}$ fatty acids characteristic of animal fats, the $\delta^{13}C$ values have also indicated that all the archaeological fats studied derive from a terrestrial source rather than a marine source.

The study of assemblages from the well-documented sites of West Cotton and Stanwick has provided an excellent starting point for the exploratory use of compound specific $\delta^{13}C$ values in the identification of remnant fats, since the major domesticated animals at these sites are known to be predominantly of ovine, bovine or porcine origin, enabling assumptions to be made about the remnant fats processed in the vessels. The data from West Cotton have shown how compound specific $\delta^{13}C$ values can be used to distinguish between remnant fats which derive from non-ruminant, ruminant adipose and ruminant dairy fat origins. A number of remnant fats plotted along the mixing lines between the reference ruminant and the reference non-ruminant fats. These are thought to represent adipose fats, the intermediate $\delta^{13}C$ values derived from the mixing of different fats, the non-specific use of individual vessels in processing animal products or possibly shifted isotopic values due to a different dietary regime in antiquity. The data for the Stanwick extracts exhibit a comparable spread of $\delta^{13}C$ values for the ruminant fats, however, no non-ruminant (e.g. porcine) fats are present.

The $\delta^{13}C$ analysis of the Saxon pottery residues from Wicken Bonhunt has not provided clear evidence for the dedicated processing of pigs in these vessels, however, based on comparison with the theoretical mixing curves we have tentatively identified mixtures of appreciable amounts of porcine and ruminant fats. The apparent lack of pure remnant porcine fats may be a reflection of cooking methods, since pigs are traditionally thought to have been cooked by spit-roasting, perhaps with processing in pottery vessels of secondary importance. Furthermore, since faunal evidence of other animal species have also been recovered from the site, it is likely that these species are also represented in domestic wares with the more depleted $\delta^{13}C$ values representing fats from the ruminant species identified amongst the faunal remains. The emphasis at this site clearly appears to be on the production and processing of animal meat/fat in preference to dairy products.

The ranges of $\delta^{13}C$ values for the prehistoric assemblages from Yarnton flood plain and Cresswell field assemblages are comparable, with the majority of residues from both sites corresponding to the reference ruminant fats. At both sites there are examples of archaeological samples which plot just outside the range for the reference cows' milk fat. These residues would appear to represent degraded dairy fats or mixtures of dairy fats and non-ruminant fats, as would arise in multiple uses of vessels (*discussed by Charters 1996*). In the earlier, Neolithic assemblage, one residue corresponds to the reference non-ruminant fats. In the later period, there are a number of residues which would appear to represent mixtures of ruminant and non-ruminant fats. Similarly, at Eton Rowing Lake, the early Neolithic assemblage contains residues which cluster within the region of the ruminant fats, whilst the Neolithic/ Bronze Age sherds from the nearby Lake End Road site also contain residues which are less depleted isotopically and may represent more varied vessel use.

The analysis of materials from Siberia and Kazakhstan have illustrated that caution needs to be taken when comparing isotopic data from samples originating from different geographical locations, probably largely due to the variation in the $\delta^{13}C$ values of dietary components, e.g. grass and forage, rather than differences in metabolism or physiology of different breeds of horse. Nonetheless, the stable carbon isotope data have clearly indicated that the Botai potsherd residues derive from horse fats due to the close correlation between the Siberian horse fats and the archaeological pot residues. These data provide direct evidence for the exploitation of horses for their meat as well as for work animals by the Kazakhstan peoples.

CONCLUSIONS

Based on the stable carbon isotope analyses carried out on the modern reference animal fats and archaeological fats, the following conclusions can be drawn:

❶ Stable carbon isotopic analysis has enabled distinctions to be drawn between modern fats from the major domesticated ruminant and non-ruminant animal species. The less depleted $\delta^{13}C$ values seen for the fatty acids in non-ruminant fats compared to the fatty acids in ruminant fats reflect differences in the complex metabolic and biochemical processes involved in the formation of body fats between the different species and to a lesser extent reflect differences in diet. These distinctions are clearly reflected in the archaeological fats from West Cotton.

❷ Fats from a number of archaeological sites have been identified as deriving from a ruminant dairy origin based upon the greater depletion in the $\delta^{13}C$ values of $C_{18:0}$ fatty acids in dairy fats compared with adipose fats. It is proposed that the difference in the isotopic signal of the $C_{18:0}$ fatty acid in milk and adipose derives largely from known metabolic pathways involved in lactation, the physiological demands of which result in a shift in the energy balance such that a greater proportion of the $C_{18:0}$ fatty acid present in milk is derived directly from the long-chain fatty acids in the diet. The $C_{18:0}$ fatty acid is produced partially through biohydrogenation in the rumen, therefore reflecting the depleted $\delta^{13}C$ values of the $C_{18:1}$, $C_{18:2}$ and $C_{18:3}$ fatty acids which predominate in grass and forage materials, and partially through chain elongation of the $C_{14:0}$ and $C_{16:0}$ fatty acids in the diet. The more negative $\delta^{13}C$ values (ca. –32.5 to –34.0‰) seen for $C_{18:0}$ in milk compares favourably with the depleted values recorded for C_{18} fatty acids in pastures and fodders, i.e. up to –36.5‰. These distinctions are clearly reflected in the archaeological fats from West Cotton and Stanwick.

❸ It is a well recognised fact that $\delta^{13}C$ values of fatty acids of plants will always be more depleted, by approximately 5‰, than those of carbohydrates from the same source (*Deines 1980*). Thus, notwithstanding the proportion of carbon routed from stored fat and dietary carbohydrate, milk and adipose fats from animals raised on similar diets are separable since the isotopic relationships between the major biochemical fractions, in this case milk and adipose fats, will always be qualitatively preserved, thus establishing a secure basis for detecting dairying at different geographical locations and during different periods in prehistory (*Dudd and Evershed 1998*).

❹ The isotopic data have provided the first direct evidence for the processing of dairy fats at prehistoric sites, and has indicated that a large number of vessels from both Yarnton and Eton were probably used for the storage or processing of milk or milk products. The fatty acids recovered from the vessels exhibited highly depleted $\delta^{13}C$ values for the $C_{18:0}$ components which correlates closely with the dairy fats from modern animals raised on C_3 pastures.

If the trends in the $\delta^{13}C$ values are supported by a range of other chemical criteria being considered, including fatty acid and triacylglycerol compositions (*Evershed et al. 1997; Dudd 1999; Mottram et al. 1999*), then the close correlation between the $\delta^{13}C$ values obtained for the remnant fats and the modern fats is remarkable considering the great age of some of the assemblages and thus the potential for alteration of the original isotopic signal. Clearly, based on the data presented herein, the measurement of $\delta^{13}C$ values has proven the single most effective criterion of those considered in distinguishing between degraded fats of ruminant, non-ruminant and dairy origin.

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Documenta Praehistorica XXIX

The development of dairying in Europe: potential evidence from food residues on ceramics

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ABSTRACT – *Providing evidence of dairying is crucial to the understanding of the development and intensification of Neolithic farming practices in Europe, beyond the early stages of domestication. Until recently, research in this field had been limited to traditional archaeological methods, such as the study of pottery styles, faunal remains and specialised material artefacts. Although suggestive, these methods are unable to provide direct evidence of dairying. Advances in biomolecular methods now allow the identification of remnants of dairy products on ceramic vessels and the application of these methods to Neolithic ceramic assemblages across Europe is underway. There is no doubt that these new methods offer much scope for investigating hypotheses such as the 'secondary products revolution', but there are limitations. The cost of analyses prohibits indiscriminate sampling and differential survival is likely to prevent direct comparison of samples from different sites. Only by incorporating these techniques within the wider frameworks of archaeological research may theories be properly tested. Approaches to achieve this goal are discussed.*

IZVLEČEK – *Iskanje dokazov za mlekarstvo je ključnega pomena za razumevanje razvoja in intenziviranja kmetovanja v Evropi po začetnih stopnjah udomačitve. Do nedavnega so bile raziskave na tem področju omejene na tradicionalne arheološke metode, kot je raziskovanje stilov keramike, živalskih ostankov in specialnih predmetov. Čeprav mnogo povedo, pa te metode niso mogle zagotoviti neposrednih dokazov za mlekarstvo. Razvoj biomolekularnih metod danes omogoča določevanje ostankov mlečnih produktov na keramičnih posodah. Raziskave neolitske keramike po Evropi že potekajo. Nedvomno lahko z novimi metodami natančneje raziščemo hipoteze, kot je na primer 'sekundarna revolucija proizvodov', toda tudi tu so omejitve. Cena analiz onemogoča sistematično vzorčenje, diferencirani načini preživljanja pa bodo verjetno preprečili neposredno primerjavo vzorcev z različnih najdišč. Le če bomo vključili nove tehnike v širši okvir arheoloških raziskav, bomo lahko teorije primerno preverili. V članku razpravljamo o načinih za dosego tega cilja.*

KEY WORDS – *organic residue analysis; Neolithic ceramic; dairying; secondary products revolution*

INTRODUCTION

Identification of the original contents of archaeological pottery has fascinated archaeologists and scientists alike throughout the 20th century. In fact, it was Johannes Grüss who in 1933, first identified an amorphous black residue on a ceramic vessel from the Hallstatt period, as overcooked milk by conducting some basic chemical tests (*Grüss 1933*). Although these analyses may have lacked the necessary rigor, which is now demanded from archaeological scientific investigations, this early work helped pioneer a new approach to artifact analysis.

In the last decade, the development of biochemical techniques such as gas and liquid chromatography, mass spectrometry, immunology and stable isotopic analysis have provided much greater scope for the reliable identification of residues. Issues of contamination from the burial environment have been addressed by careful sampling methods (*Heron et al. 1991*), simulated degradation of replica pots have led to greater understanding of post-depositional processes (*Dudd et al. 1998; Craig et al. 2000*) and numerous procedural controls have been implemented to rule out contamination. Finally, a greater appreciation of the many and varied uses of archaeological pottery, including multiple inputs, re-use and a range of non-culinary uses, has tempered interpretations based on residue analysis alone.

Many studies involving residue analysis of ceramic artifacts have been undertaken, including the identification of tars, waxes and resins (e.g. *Heron & Pollard 1988*) and characterization of absorbed food residues on ceramics (*Heron & Evershed 1993;* for review). Lipids (fats) present within the fabric (rather than visible on the surface) of ceramics have been characterized by their fatty acid distributions (*Evans & Hill 1982; Rottländer 1986*), the presence of specific biomarkers (*Evershed et al 1991*; *Evershed et al. 1992*), and recently by the isotopic composition of individual compounds (*Evershed et al. 1997*; *Dudd & Evershed 1998*).

In keeping with Grüss's pioneering work of the 1930s, it is the identification of milk residues that has returned to become a focus for more recent studies and with good reason. Not only does milk contain a unique range of lipids and proteins, which are suspended in solution and free to adsorb to the ceramic surface, but also, residue analysis may provide the only way to unequivocally identify the use of this important and versatile product in prehistory. Many of these studies have centered around defining the development of dairying in the European Neolithic. Whether dairying was a principal component of a neat package of innovations that spread widely across Europe in 3rd millennium BC (*Sherratt 1981; 1983; Harrison 1985*) – the so-called secondary products revolution – or was present earlier in the Neolithic, perhaps on a smaller scale (e.g. *Bogucki 1984a; 1984b; Chapman 1982*), remains unresolved. Until the appearance of pictorial tablets depicting milking scenes (*Green 1980*), evidence for dairying is restricted to interpretations of archaeozoological data (e.g. *Bogucki 1984a; Milisauskas & Kruk; 1989; Greenfield 1988; 1991; Harrison 1985; Legge 1981a; Legge 1981b*) or from distinctive vessel forms (*Sherratt 1981; Bogucki 1984b*).

Clearly, residue analysis offers new research opportunities to tackle this problem, but how should these methodologies be effectively applied? This paper will review the archaeological issues surrounding the development of dairying and examine the potential of new methods for residue analysis of milk, before considering the role that residue analysis can play in the investigation of the origins of dairying in Europe.

THE DEVELOPMENT OF DAIRYING IN EUROPE: GENERAL PERSPECTIVES

The identification of dairying as an economic activity poses a number of challenges to archaeological researchers. As evidence of exploitation of domestic ruminants can be found in faunal assemblages from sites across Europe, often dating to the earliest phases of the Neolithic, it is reasonable to assume that milk was available for human consumption from these animals at this time. Dairying is not a specific technology nor is it necessarily limited to specific strains of livestock (*Sherrat 1997. 206*). Whether or not the inhabitants of Early Neolithic Europe had the necessary genetic adaptation to digest the lactose in fresh milk (*Sherratt 1981*) is ambiguous from modern phylogenetic data (*Akoi 1986; Holden & Mace 1997; Bodmer & Cavalli-Sforza 1976.279*) and is largely irrelevant considering the wide range of low lactose, easily stored products that can be made from milk. Therefore the key archaeological issue is not to provide evidence for the utilization of dairy products, but rather the scale of production and the significance of this activity in prehistoric economies.

The intensification of dairying in the 3rd millennium BC in many parts of Europe was first proposed over 20 years ago (*Sherratt 1981*) as a component of the secondary product complex, an economic package that had far reaching social and cultural implications and represented a unilinear progression of farming practice. Although initially implied, rather tentatively (see *Chapman 1981*), by the appearance of new ceramic vessels associated with the manipulations of liquids, weight has been given to this hypothesis by analysis of post Neolithic faunal assemblages'; e.g. from Britain (*Legge 1981a*), Spain (*Harrison 1985*) and the Balkans (*Greenfield 1988*). In these cases, a cattle-based dairy economy optimized for maximum production with the potential for exchange is implied, as kill-off patterns, dominated by juveniles and/or adult female bones, compare favorably with those obtained from modern herds optimized for milk production (produced by *Payne 1973*).

However, similar evidence for an optimized dairy economy can be found at earlier Neolithic sites; for example, Boguki has argued that the mortality profiles of linear pottery (LBK) faunal assemblages from temperate Europe are not inconsistent with Payne's models (*1984a*) and evidence from the Early Neolithic layers of Arene Cadide, in the West Mediterranean, shows that sheep kill off patterns also fit well with the optimized milk production strategies (*Rowly-Conwy 2000*). Legge has also noted female bias in adult cattle at Neolithic 'ceremonial' sites in the UK and at other Neolithic sites in Switzerland (*1981b*).

Using faunal kill-off patterns to define the scale and specifics of prehistoric animal husbandry practices has been criticized. Besides problems inherent with preservation and recovery of animal bones, ancient livestock may have different productivity compared to their modern counterparts (*Halstead 1998*). In addition, Halstead demonstrates, with reference to modern pastoralism in Northern Greece, that the decision to utilize livestock for meat or milk and when to cull is dependent on a range of economic and environmental factors, which may fluctuate from season to season (*Halstead op. cit.*). Furthermore, high juvenile culling need not indicate a dairy economy but could imply also as a mechanism to preserve fodder (*McCormick 1998*); indeed, the presence of calves may be a prerequisite of early cattle dairying in order to assist milk 'let down' (*McCormick 1992*). Equally, high frequencies of adult females in the animal assemblage, rather than indicating an optimized dairy strategy may reflect a sexual bias in maturity rates and thus meat productivity (*McCormick op. cit*).

A number of ecological and economic arguments are often cited in relation to this debate. It is often implied that dairying must have been practiced as soon as domesticated ruminants were available, as it offers by far the most energy efficient use of uncultivatable land (*Holmes 1970; Ingold 1980.176; Legge 1981a*) and results in products that are suitable for storage, which gives them additional economic value (*Bogucki 1987*). Others point out that the large herds/flocks, implied by a strategy optimized for dairy production (*Dahl & Hjort 1976.220*), are labor intensive and economically untenable in landscapes without easily accessible pasture (*Halstead 1996*), such as the relatively narrow riverside environments inhabited by early Neolithic farmers of central Europe. Halstead argues that a mixed farming strategy, where small numbers of a variety of animals are kept for a mixture of products (e.g. meat, milk, wool), principally for domestic use, not only seems more economically plausible in such environments, but also is evident in the considerable heterogeneity that exists in Neolithic faunal assemblages (*Halstead 1996*). Even at sites which show other supposed indicators of dairying, such as high numbers of juveniles, other domesticates are always present (e.g. *Rowley-Conwy 2000*).

These arguments support the concept that a specialized dairy economy could only develop towards the end of the Neolithic, after substantial amounts of primary forest were cleared which, in turn, fits within the framework of a 'Secondary Products Revolution' (*Sherratt 1981; 1983*). However, this does not necessarily preclude the independent localized development of large-scale milk-based pastoralism at earlier periods in the Neolithic. For sedentary communities, provision of cultivated or collected fodders and stalling of animals could have compensated for limited pasture. Large-scale seasonal movement of animals to exploit fresh pastures offers an alternative strategy. For example, the lowland LBK communities of the Northern European plain seem to have focused their economic activities on cattle herding rather than grain cultivation (*Bogucki 1987*). Settlement patterns, here, suggest a high degree of residential mobility consistent with a mobile milk-based pastoralist economy; the presence of perforated ceramic sherds, putatively interpreted as cheese-strainers, recovered from many of these 'camps', have been taken as further evidence (*Boguki 1984a; 1984b*). The socio-economic relationship between these semi-mobile intensive dairy farmers and the sedentary grain cultivators of the loess is unclear but it is interesting to speculate upon the potential for exchange, further complicating economic inferences made from faunal analysis alone.

Whether economic factors favour dairying or meat production may be less significant than the cultural value that may be obtained from pastoralism. In addition to 'allocative' resources such as milk and meat, animals may provide an 'authoratative' resource in terms of their socio-political significance (*Hall 1986*). The requirements of animals for ritual use cannot be overlooked (*Keswani 1994*), and caution has to be taken when interpreting economic regimes from animal assemblages recovered from ceremonial centers (*Enwhistle & Grant 1989*). The association between cattle and power through conspicuous display, exchange transactions and redistribution is exemplified by the complex pastoralist societies of Southern and Eastern Africa (*Reid 1996*). In particular, mobile pastoralism is likely to enhance social intercourse between neighboring households and villages through contact and exchange. Thus, the social, ideological and political demand for large herds or flocks may provide the impetus for a specialized economy, such as dairying, and may explain the resulting economic risks. Similarly, the existence of taboos may prevent dairy consumption, irrespective of the economic benefits.

Defining the scale of dairying is complicated by these cultural, economic and ecological factors. The available evidence neither demonstrates or disproves a unilinear progression from small-scale household dairying as part of a mixed economic strategy to the development of a large milk-based pastoral sector in the 3rd millennium BC, as originally proposed by Sherratt (*1981; 1983*). What role, then, can the identification of milk residues play in the study of prehistoric dairy economies?

METHODOLOGIES FOR THE IDENTIFICATION OF MILK RESIDUES ON CERAMICS

Milk is unique to mammals and is only produced by the lactating mammary gland. It contains the necessary nutrients to support the infant during development and thus has a distinctive range of proteins, lipids and sugars, which are dissolved or suspended in solution. During the processing of raw milk into different dairy products, the relative amounts of these biomolecules will change and some molecules may become chemically altered. Residue analysis has focused on the detection of the lipid and protein components of milk because lactose, the principal sugar in milk, is thought to be lost rapidly to bio-degradation and leaching in the burial environment.

Identification of milk lipids

Lipids can be extracted from archaeological ceramics with organic solvents and analysed by high temperature gas chromatography or gas chromatography/mass spectrometry (*see Heron & Evershed 1993; for review*). Fresh milk contains a characteristic distribution of lipids, a range of fatty acids with carbon chain lengths of between 4 and 20 including branched chain and monounsaturated species and a complex range of triacyglycerol (TAG) species (*Mottram & Evershed 2001*). However over time many of the shorter chain fatty acids, which are characteristic of milk, are lost and the TAG distribution is altered to more closely resemble animal adipose fat rather than milk fat (*Dudd & Evershed 1998*). Therefore although lipid yields from archaeological pottery are generally high, there are no single lipid compounds that are unique to milk.

Dudd & Evershed (*1998*) overcame this problem by measuring the stable carbon isotope ratio (^{12}C:^{13}C) of the most prominent unsaturated fatty acids (with carbon chain lengths of 16 [$C_{16:0}$] and of 18 [$C_{18:0}$]) using gas chromatography combustion isotope ratio mass spectrometry (GC-C-IRMS). The relative proportion of light (^{12}C) and heavy (^{13}C) carbon atom in these molecules reflects the source of carbon from which the molecule was synthesised. The ratio between these two carbon molecules – the carbon isotope ratio, ($\delta^{13}C$), expressed in parts per thousand relative to an international standard – in the $C_{16:0}$ and $C_{18:0}$ fatty acids is different in various animal products. Fats from non-ruminant animals have similar isotope values for both acids, but in ruminants the $C_{18:0}$ fatty acid contains less ^{13}C than the $C_{16:0}$, it is therefore said to be isotopically "lighter" or "depleted"; significantly this difference is even more pronounced in ruminant milk fats. The absolute isotope ratios of these fatty acids in milk are a function of the animal's diet, but in all cases the $C_{18:0}$ fatty acid in ruminant milks is between 3–5‰ depleted in the heavier (^{13}C) stable carbon isotope compared to the $C_{16:0}$.

This new approach has a number of methodological advantages. The $C_{16:0}$ and $C_{18:0}$ fatty acids are the most commonly encountered fats on archaeological pottery. They can be easily extracted and analysed and have been shown to be derived from pottery usage rather than the depositional matrix (*Heron et al., 1991*). Furthermore, as the absolute isotopic measurements made on these fats are direct indicators of animal diet, information concerning types of pasture and fodder provision may be obtained and directly related to husbandry strategy (i.e. milk/meat exploitation). However, there are problems of interpretation of the isotopic values derived from only two fatty acids. Both are present at variable concentrations in most animal and vegetable products; consequently, multiple inputs in pottery will result in a mixed isotope signal, which may be hard to interpret. This problem can be overcome by taking into account other diagnostic lipids in the pottery (*Dudd & Evershed op. cit.).*

Identification of milk proteins

A number of proteins are unique to milk; these include whey proteins and caseins (α–, β–, γ–casein). Of these, α-casein is the most attractive for study; not only is it the most abundant protein in milk (13.7 g l^{-1} in bovine milk; *Jenness 1970*) but also it is thermostable (*Wells 1908*). Its stability is demonstrated by the fact that bovine α-casein can be detected in baby vomit (*Sato 1992*) and in milk that has been heated at 75°C for 2 days; once complexed with ceramic it can survive an order of magnitude longer (Tab. 1). The immunological methods em-

Sample	Treatment	DACIA response[1] (ng g^{-1} sample)
Simulated pot[5] (Bovine milk)	None	>500
	Buried 2 years in controlled plots[6]	100–500
	Heated 75°C, 2 days, anoxic, 95% humidity	100–500
Bovine Milk[2]	No Treatment	>500
	Heated 75°C, 2 days, anoxic, 95% humidity	n.d.
Ethnographic Milk Pot[7]	None	>500
	5 day continuous leaching experiment[3]	>500
Blank ceramics	None	n.d.
	Buried 2 years in controlled plots	n.d.
Simulated pots[5] (Bovine adipose)	None	n.d.
	Buried 2 years in controlled plots	n.d.
Soil samples[4]		n.d.

1 DACIA using anti-bovine α-casein monoclonal antibody. Two separate extractions all s.d. <10%. Positive twice background values;
2 against 100 µl;
3 experiment performed by Carl Challinor, University of Bradford;
4 range of soil samples (clay, loam, sand);
5 simulated pot 'open' fired high porosity and 'kiln' fired low porosity (*Craig 2000*);
6 burial experiments repeated in two plots with measured hydrology, microbial biomass/activity, and pH. n.d. – not detected;
7 obtained from N.E. India used for c. 10 years for heating bovine milk discarded 1988.

Tab. 1. Identification of milk proteins on control samples using Digestion and Capture Immunoassay.

ployed for detecting milk proteins on ceramic involve using indirectly labeled antibodies, which will bind tightly to specific regions of the α-casein structure. The regions that are targeted by antibodies are unique to that particular protein, and can be even used to distinguish α-caseins that are derived from different species of animal. This is in part due to the random structure of the casein molecule, which facilitates the production of antibodies against its primary amino acid sequence (*Enamoto 1990*), and because of a number of amino acid substitutions that exist between α-caseins from different species.

However the application of immunological methods to archaeological materials poses a number of problems. Perhaps the greatest methodological challenge has been the removal of proteins, such as caseins, which have survived by strong association with the mineral (ceramic) surface (Tab. 1). Extraction with conventional solvents yields insufficient quantities of protein for analysis. An improved method has been developed (digestion and capture immunoassay: DACIA) to increase yields, this involves digesting the mineral surface with hydrofluoric acid and simultaneously capturing any released molecules for subsequent immunological detection. The sensitivity and specificity of this technique has been demonstrated by testing a range of simulated and ethnographic ceramics with known input (Tab. 1 and *Craig & Collins 2000*).

Another problem with immunological based approaches is the use of inappropriate methods, which result in non-specific cross-reactions with contaminants or compounds derived from the burial environment generating a positive response in the assay even when the target protein is absent. Such issues have been widely discussed in connection with earlier immunological studies of residues, notably those which have attempted to identify species of blood on stone tools (*Gurfinkel & Franklin 1988; Smith & Wilson 1992; Cattaneo et al. 1993; Manning 1994; Downs & Lowenstein 1995; Child & Pollard 1992; Leach & Mauldin 1996; Tuross et al. 1996; Leach 1998*). To address these criticisms, experimental design has to include an appropriate range of negative controls to confirm the specificity of the test; these may include blank ceramic, blank ceramics that have been exposed to the burial environment, ceramics with non-milk input also exposed to the burial environment, and soil samples (Tab. 1).

Preservation of organic residues on ceramics

The potential for preservation for the different classes of organic residues encountered on archaeological pottery is highly variable and dependent on a number of factors. These include mode of use, physical properties of the ceramic, depositional environment and post excavation treatment. Organic residues present within the porous matrix are likely to be protected from microbial degradation and are less susceptible to leaching. In addition, organic-mineral interactions at the ceramic surface stabilise organic structures and retard chemical and biological degradation mechanisms (*Evershed 1993; Heron & Evershed 1993; Craig et al. 2002*). Charring of residues may also provide a mechanism for protection (*Oudemans & Boon 1991*) but is likely to result in substantial structural modification preventing routine extraction and identification, especially using immunological methods.

The length of time in the depositional environment may not be as important as the nature of the environment itself (i.e. pH, redox potential, hydrology, microbial activity). Burial experiments have shown that whilst the majority of the protein component of absorbed milk residues is lost within the first few months of burial probably by leaching, subsequent degradation of the remaining fraction is greatly reduced (*Craig 2000*). Lipids, which are hydrophobic and less susceptible to leaching, may stay at high concentrations in sherds for thousands of years (e.g. *Charters et al. 1993*). They are also more resistent to structural modification than proteins. Immunological methods rely on the preservation of large, hydrophilic protein subunits (polypeptides), which undergo side chain modification and hydrolysis (chain splitting). Lipids are therefore likely to survive over longer timescales and in a wider range of environmental conditions than proteins (e.g. *Regert et al. 1998*).

Contamination of potsherds post-deposition and post-excavation is more of a problem for lipid residue analysis than for protein residue analysis. Although proteins are mobile in the burial environment and easily transferred during handling, contaminating proteins will not usually be detected due to the specificity of the immunological tests (of course, extra precautions would have to be taken if research is directed towards the detection of human proteins). Post-excavation contamination with lipids is particularly significant especially when no provision has been made for residue analysis prior to excavation and post-excavation analysis. Contamination with plasticizers, glues and skin lipids are commonly encountered and can interfere with analysis, especially if they are in high concentration. Washing and brushing of sherds is also likely to result in loss of information, although no systematic study of this has been carried out. It is recommended that newly excavated sherds, which have previously been selected for residue analysis, are as handled as little as possible, air-dried together with any adhering soil and wrapped in aluminium foil or acid-free tissue and then bagged.

The cost of analysis is likely to be a decisive factor when assessing the impact of residue analysis to archaeology. Generally, lipid analysis is expensive, especially when combined with isotopic measurements needed to identify dairy products, but provides more information into pottery use per analysis (e.g. analysis of other plant and animal lipids and contaminants). Protein analysis is cheaper but only a single compound can be detected per analysis (e.g. bovine milk protein). These factors will obviously affect the sampling strategy and ultimately the type of questions that can be addressed. Furthermore the costs associated with residue analysis highlight the need for these techniques to be utilised efficiently, for example to augment less expensive forms of pottery use analysis such as determination of the form/function relationship and use-wear analysis. One final but important consideration is the discrimination between food and non-food residues. For precisely the same reason that products such as milk and blood are the most prepossessing products for residue analysis, they also provide excellent products to seal pots that lack the required porosity. For example, Ethiopian potters use milk to seal ceramic vessels immediately after firing (*Rice 1987.163*). Discrimination between sealants and food residues is methodologically challenging but characteristics such as vessel permeability may be used to aid interpretations.

In conclusion, given the relative strengths and weaknesses of both approaches, there is clear advantage in combining the two different methods of residue analysis for the study of dairying. The two methods are entirely independent, in that they target different biomolecules using different analytical methods, and provide complementary information.

DEVELOPMENT OF DAIRYING IN EUROPE: THE POTENTIAL OF RESIDUE ANALYSIS

There is no doubt that the successful identification of milk residues on ceramics may contribute to the study of the origins and impacts of dairying, but at present only limited studies have been undertaken. Milk residues have been detected at a number of UK sites: milk proteins in Late Bronze Age/Early Iron sites in the Western Isles of Scotland (*Craig et al. 2000*), milk lipids in Iron Age and Early Medieval ceramics from Northamptonshire (*Dudd & Evershed 1998*) and Late Neolithic sherds from the Welsh borders (*Dudd et al. 1999*). These cases unequivocally demonstrate that milk was an element of the prehistoric economy. In the Western Isles, where faunal assemblages are exceptionally well preserved, the detection of milk residues supports the interpretation of a large developed dairy economy based on the high number of associated neonatal cattle bones, a feature of settlements in this area (*Parker Pearson et al.* 1996; 1999). However, without other palaeodietary indicators, differential preservation, contamination and multiple uses of ceramics (such as sealing) complicate a more quantitative approach to residue analysis, which aims to define the scale of animal husbandry practices. Furthermore, biases associated with small sample sizes (implicit considering the amount of ceramic generally recovered from sites and the costs of analysis) limits inter-site and temporal comparisons.

The analysis of specific ceramic artifacts

One way to overcome biases involved in sampling a random selection of domestic pottery is to target specific ceramic artifacts. Much debate involving an early or late origin for dairying has involved speculation of the techno-function of pottery shapes or specific ceramic artifacts. The appearances of new forms of Bronze Age and Copper age vessels across Europe, that have been associated with dairying (*Sherratt 1981; 1983*), provide obvious avenues for a targeted investigation. In central Europe, both cattle and new forms of drinking vessels were included in the graves of the Copper Age Baden culture (*Whittle 1996.123*). The increased significance of cattle and the appearance of these new vessel forms may point to the intensification of dairying and could be tested by residue analysis and compared with earlier late Neolithic vessels from the region. Similarly, a systematic study of the function of LBK ceramic sieves, interpreted as dairy-processing utensils (*Bogucki 1984a; 1984b*) provides a clear hypothesis to test using residue analysis. Identification of milk on these artifacts would imply the presence of a developed dairy economy, much earlier than originally hypothesized (*Sherratt 1981; 1983*). Nevertheless, clear distinctions should be made between regional specialization, i.e. by early Neolithic semi-mobile cattle herders of the Northern European plain, and the adoption of a wide spread dairy sector in the 3rd millennium BC.

Defining specific dairying practices

At most sites residue analysis is confined to the analysis of undifferentiated pottery with unknown techno-function, often from domestic contexts. Identification of milk residues in these cases is of limited value to our wider understanding of the significance of dairying, unless this is integrated with other lines of enquiry. Assessment of settlement distribution and size, availability of surrounding resources combined with analysis of plant and animal remains and stable isotopes extracted from human bone can provide some scope for broadly determining the maximum scale of specific economic activities. Evidence for the scale and significance of dairying may also be obtained through a greater understanding of production and consumption practices. Associating vessel contents with broad classifications of ceramic typologies (e.g. storage vessels, cooking pots, serving wares), use-wear and depositional context provides one way of achieving this. Identification of vessels that have been dedicated for milk use, evident from the fatty acid isotopic signal, would also be useful in this respect. In addition, information concerning specific consumption practices, such as feasting, may be gained by relating food residues to distinctive pottery styles, methods of deposition and context.

Finding evidence for fodder provision is also crucial in defining specific animal husbandry practices. If dairying is suggested in marginal environments or at sites where surrounding pasture is limited, such as many Early Neolithic European settlements, then provision of fodders must be envisaged. Besides the economic implications, the deliberate provision of gathered and cultivated fodders implies a different relationship between humans and their livestock. Evidence of cattle byres (*Nielsen et al. 2000*) and twig foddering of sheep and goats (*Rasmussen 1993*) have been found at the earliest Neolithic settlement sites in Switzerland. Stable carbon and nitrogen isotopic analysis of animal bone collagen and of sectioned teeth can be used to reveal variations in cattle diets, including seasonal changes and weaning (*Balasse et al. 1997; 1999*). This approach may be particularly applicable to the identification of foddering regimes, such as the supplement of marine or C4 fodders like maize and millet, for specific practices when combined with direct isotopic measurements of ruminant adipose or milk fats in pots (*Craig et al., in prep*).

Dairy products have also been implicated as important commodities for exchange (*Bogucki 1987*). The identification of milk-containing vessels not produced locally, at sites with no other evidence of an indigenous dairy based economy, may be the only way of substantiating this interpretation. Similarly, targeting storage vessels, suitable for transport, may facilitate the identification of producer and consumer sites, especially if the products transported can be related to economic practices at specific sites. Finally, it is worth noting that identifying the original species of dairy products, using an immunological approach, is vital to the interpretation of dairying in the past. Although cattle, sheep and goats can all be exploited to obtain a product with similar nutritional properties, the archaeological implications of these activities are very different.

CONCLUSIONS

Dairying can only be placed in the proper economic, social and cultural context by knowing its scale and significance. Although the identification of milk residues provides unequivocal evidence of dairying, it provides little information relating to these aspects. Whilst, residue analysis of specific ceramic artifacts may be used to give weight to theories, such as the 'Secondary Products Revolution', it is hard to see how these methods can be used to track the supposed intensification of dairying through the Neolithic, when used in isolation. As Bogucki has pointed out, new ways of food production were not introduced uniformly throughout Europe (*1987*), hence it is vital that regional and site specific studies are undertaken. In this respect, it is crucial that residue analysis is integrated with other forms of cultural, dietary, economic and environmental evidence to look at specific animal husbandry practices. When used in this way, information additional to pottery use may be gained, such as the nature of exchange networks, seasonal mobility, consumption practices and strategies for fodder provision.

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Documenta Praehistorica XXIX

Defining function in Neolithic ceramics: the example of Makriyalos, Greece

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ABSTRACT – *Recent development in chemical analyses of organic remains in archaeological ceramics gives new possibilities to the study of pottery use. They could be of crucial importance in assessing vessel's use, especially when combined with contextual, technomorphological and use-alteration analysis data. Using the example of the late Neolithic pottery from Makriyalos, Northern Greece, we discuss some of the problems in determining the use of the vessels from archaeological context, and show the benefits of integrating chemical analysis of organic remains in approaching this issue.*

IZVLEČEK – *Sodobni razvoj kemičnih analiz organskih ostankov v arheološki keramiki odpira nove možnosti raziskav njene uporabe. Te analize bi lahko bile ključnega pomena pri ocenjevanju uporabe posodja, še posebej v kombinaciji z drugimi kontekstualnimi ter tehnološko-morfološkimi podatki in podatki o spremembi namembnosti. Za primer smo vzeli poznoneolitsko keramiko z najdišča Makriyalos v severni Grčiji. Razpravljamo o nekaterih težavah pri določevanju uporabe posod na podlagi arheološkega konteksta in pokažemo prednosti, če upoštevamo kemične analize organskih ostankov.*

KEY WORDS – *pottery function; residue analyses; lipids; GC–MS; late Neolithic; Makriyalos; Northern Greece*

INTRODUCTION

The relation between pottery and the introduction of the Neolithic way of life has always been considered a very close one. Traditionally, pottery has been connected to sedentism, storage and large-scale food production, which are regarded as the broad results of the introduction of farming. Pottery in this sense was viewed as an integral part of an intensification process established in the relation between humans and nature (*Arnold 1985*). The functionalist aspect of this approach has rightly been questioned by recent archaeological thought and as a result of this critique more emphasis is now laid on the independence of the ceramic phenomenon. Pottery in this sense should not be viewed as a subordinate part of the "Neolithic package", serving the needs of the "Neolithic", but as a potentially important aspect of the material culture invested with a multiplicity of meanings grounded on practical use. It is very meaningful, in this respect, that although in some cases pottery follows the introduction of agriculture (though not directly connected with it, as in the case of the Near Eastern Aceramic), in others, pottery clearly predates this distinct shift in production means and relations (*Zhang Chi 1999; Ikawa-Smith 1976; Kotsakis 2001)*.

Pottery, therefore, is, one way or another, closely related to everyday practices. It seems, however, that in some parts of the world the emergence of first pottery was not connected with such activities. During the last decade some scholars (*Vitelli 1989; Perlès 2001; Björk 1995*) have questioned the prevailing opinion which relates the beginning of production of pottery with the everyday needs in preparation and storing of food. It has been observed that the use and the role of the first pottery worldwide were not the same. Even in a relatively limited geographical area such as Mediterranean region and the

Balkans considerable differences exist. Thus, while in Southern Italy, France, Northern Balkans and Bulgaria first vessels had more utilitarian character (*Perlès 1992.153; Plucienik 1997; Perlès 2001. 217–218*), it seems that in Greece, to the contrary, the first pottery was not produced for cooking and storing (*Vitelli 1989; 1993; 1999; Björk 1995*). It is suggested that the early Neolithic Greek vessels were used merely for consumption and display. Furthermore, vessels role, their meaning and their practical use throughout the Neolithic gradually changed. Thus, concerning Greek Neolithic it has been proposed that early and middle Neolithic vessels were not utilitarian and only in the late Neolithic they became widely used in everyday life for cooking, storing, serving and the consumption of food. In particular, in the early Greek Neolithic period no vessel was recognized as cooking pot, while in the late Neolithic approximately 30% of the pots were used for cooking. The absence of cooking pots in the early Neolithic and their appearance almost 1000 years after the emergence of the first pottery in Greece, indicate the differences in diet and food habits between the early and the late Neolithic in Greece. The beginning of the use of pottery for cooking suggests the introduction of new forms of food preparation and changes in food habits. This change probably involves the introduction of new kinds of food as well (*Hansen 2000*).

Preparation and the consumption of food and drink are closely related to all aspects of social, economic and political life. The study of food and food habits, as a form of cultural expression, could provide evidence about the whole field of social relations. Pots as an integral part of the practices related to eating and drinking embody particular cultural perceptions which society has on food. The complexity and combination of a ceramic assemblage will almost certainly reflect or represent a particular set of social relations. These make the pottery, food and the activities related to its preparation and consumption powerful means for study and understanding the structure of any given society. Moreover, they are of particular importance for the study of Neolithic societies, as the information about the palaeodiet and food habits in this period is mainly restricted to archaeozoological and often scarce archaeobotanical remains. The absence of figurative representations and written sources, which appear in Greece from the Bronze Age onward, make the Neolithic pottery basic source of information concerning food habits, social relationships and social identity of the members of certain society.

POTTERY FUNCTION

To approach the aforementioned issues through the study of pottery it is necessary to understand their practical use. Weather vessels are viewed as exchange or symbolic objects, non-utilitarian or utilitarian artefacts the majority of them were produced for certain purposes. Their morphological, technological and stylistic characteristics are correlated to the practical task for which they were manufactured, and are closely related to the social context of their makers and their users. Elements such as fabric, morphology, decoration and surface treatment all structure the way the pot is socially perceived, and will determine how it is used in specific social contexts. At the same time these elements determine the suitability of the pots for certain practical use.

It is obvious from the above that the issue of pottery use is of crucial importance for understanding the structure and the complexity of past human societies. It is also important for understanding technological, morphological and stylistic variability of pottery assemblage since both the practical and the social aspect of vessels are inseparable part of their identity.

Although it is one of the basic aspects of pottery, archaeologists have given relatively little consideration to the question of vessels use. Research concerning vessel function has been developed especially during the 80's where the focus was on the morphological and technological, mainly physical and mechanical characteristics of the pots, as well as on the use alteration of vessel's surfaces. In the last decade the efforts have been put on the recognition of the actual food cooked, consumed and stored in the vessels by applying various methods of chemical analysis of organic remains.

Identification of vessel function has been approached so far by analysing:

- morphological characteristics (including shape and size);
- use alteration of vessel surfaces (soot deposition, charred organic remains, oxidation discoloration, interior surface pitting);
- physical and mechanical properties of the vessels (including paste and temper composition, thermal shock resistance, mechanical strength);
- studies of preserved contents;
- chemical analysis of organic residues;
- pollen analysis;
- archaeological context in which vessels are found.

The study of vessels function is based on the believe that pots are tools and are made to be used for certain purposes. They should have appropriate physical and mechanical properties to fit certain activity. The subject is approached by studying observable and measurable properties such as vessel shape and size (*Smith 1988; Hally 1986; Henrickson and McDonald 1983*), fabric including paste composition (*Braun 1983; Steponaitis 1984; Bronitsky 1986*), surface treatment (*Shiffer 1988b; 1990*), and use-alteration analysis (*Hally 1983; Skibo 1992; Kobayashi 1994*). Using materials science analytical techniques the study focus on behaviorally relevant performance characteristics including impact and thermal shock resistance (*Bronitsky 1986; Brinitsky and Hammer 1986; Mabry et al. 1988*), abrasion resistance (*Shiffer and Skibo 1989*), and heating and evaporative cooling effectiveness (*Schiffer 1988; 1990; 1994*). Mach of the effort was put on seeking the attributes – predictors of use – that would have universal value and cross cultural applicability. The research on pottery function could be broadly divided on the study of intended vessel function and the study of actual vessel function (*Rice 1987.207–242; Skibo 1992.35*). The former aiming at reconstructing what a vessel was manufactured for, and the latter how the vessel was in fact used.

Recent development in analytical chemistry and biochemistry has opened up new possibilities in the study of pottery use. A growing number of studies, most of them focusing on the analysis of lipids, show the potential of chemical analysis of visible and absorbed organic residues in approaching the issues of palaeodiet and the actual use of vessels of archaeological origin. Among various techniques applied so far, a range of chromatographic techniques is preferred, with notable success of gas chromatography and gas chromatography-mass spectrometry (*Heron & Evershed 1993 for review*). Based on the ability to resolve the individual components of the often complex mixture of lipids found in potsherds, these techniques have been successively used in the identification of natural products such as resins, tars, pitch and beeswax (*Aveling & Heron 1999; Hayek et al. 1990; Heron et al. 1994; Regert et al. 1998; Evershed et al. 1997*). Also, to identify the components of foodstuff processed or stored in ancient vessels (*Stern et al. 2000; Evershed et al. 1991; Evershed et al. 1997*).

Most of the studies concerning pottery function draw on only a few of the parameters mentioned above, which were not always applied to the whole pottery assemblage. Moreover, many of these parameters have been developed within the frame of ethnographical research where whole vessels were studied. As expected, there could be difficulties in applying methods developed from the study of whole pots to approach the use of pottery assemblage from archaeological context, usually comprised of thousands and thousands of fragments that seldom complete whole pots. What could be easily perceivable on the whole pots, especially those still in use, as it is in ethnographical context, could be difficult to recognize or measure on the fragments, often scaly and abraded, scattered around and out of their context of use.

The study of pottery function becomes even more complex by the fact that vessels could have multiple uses, or could be reused after being considered not proper for their primary function (*Skibo 1992.38; Deal 1998.107–111; Rice 1987*).

Using the example of the late Neolithic pottery from Makriyalos, Northern Greece, we discuss some of the problems in determining the use of the vessels from archaeological context, and show the benefits of integrating chemical analysis of organic remains in approaching this issue.

MAKRIYALOS SITE

The Neolithic settlement at Makriyalos is situated in the coastal area of Pieria, Northern Greece, less than 2 km from the sea (Fig. 1). Fifteen km to the west lie the Pieria Mountains. The settlement is located on the gentle slopes of a natural low hill. The prehistoric settlement covers about 50 ha and is one of the largest non-tell sites in prehistoric Macedonia. Two main phases of occupation, Makriyalos I and II, both dated to the Late Neolithic period, are clearly distinguished (*Pappa and Besios 1999*).

The pottery

The results we discuss here regard the study of pottery use that belongs to the earlier settlement phase dated to the second half of the 6th millennium, namely to the period between 5400–4900 BC. Pottery study is still in progress although some parts of it have already been accomplished. The study of pottery use is a part of a detailed contextual study of vessels' use life that includes production, use and deposition of the pots throughout the whole settlement. To this end a series of analytical techniques is employed, as well as a traditional examination of the pottery. These involve analysis of technological, morphological and stylistic characteristics of the vessels, use-alteration and residue analysis. It should be mentioned that Makriyalos earlier phase gave enormous amount of pottery sherds. Although approximate numbers of pots haven't been calculated yet, there are certainly a great number of vessels. For illustration, more then 200 cups have been recorded so far. Despite the great amount of pottery sherds there is limited number of vessels for witch the whole profile could be reconstructed. No whole vessel is found.

On the base of shape, size and use-wear characteristics 4 broad functional classes are defined: table ware (Fig. 2: 1–3), vessels suitable for serving/storage/transferring of liquids (Fig. 2: 4–6), cooking pots (Fig. 3: 1), and long term storage vessels (Fig. 3: 3). Considerable number of vessels couldn't be assigned to any concrete use.

Within each broad functional group notable morphological variability is observed, although not to the same extent in each group. As expected, the variability increases when technological and stylistic characteristics were considered together with morphological. It is beyond the scope of this study to discuss these results in detail. However, it should be mentioned that some of the subgroups are remarkably standardized in terms of shape, size, fabric and decoration such as bowls and to lesser extend long term storage vessels. Somewhat greater variability shows the vessels for Serving/Storage/Transferring liquids and extreme variability small vessels – i.e. cups.

Concerning cooking pots limited variability has been observed. The majority belong to coarse shell-tempered fabric. Medium to fine quartz-tempered cooking pots were also recognised, although they comprise a minor group. It should be noted that in shell-tempered ware several different shapes has been recorded such as large shallow basins, conical and hemyspherical bowls and spherical pots with restricted rim and the upper part. Medium/fine quartz-tempered cooking pots were recognized only by charred organic remains deposited on the bottom of their oxidized bases. There is no indication about the shape of these pots. The variability in fabric, to certain extend, has been ascribed to the context of their production. However, it could also be related to cooking techniques, since the medium/fine quartz-tempered pots seem to be less porous then their

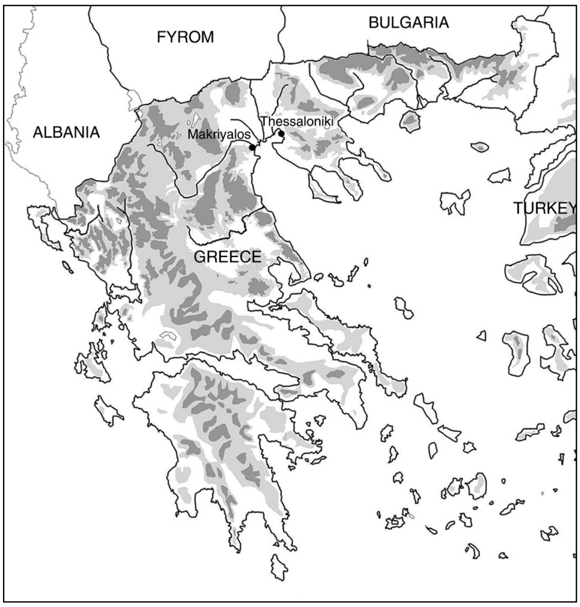

Fig. 1. Location of Makriyalos site.

course shell-tempered counterparts. Thus, it seems reasonable to suppose that low porous cooking pots were used for boiled food and the other for cooking of less liquid food.

It should be mentioned that in the case of Makriyalos pottery assemblage, comprised mainly from fragments, sooting clouds, which is proposed as one of the basic means for recognizing cooking pots, were not always of much help since they could be mixed up with uneven colouring formed during the last phase of manufacturing process – firing of the pot itself. This is not surprising, since Makriyalos pots are fired in open fire that often result in pottery with uneven coloured surfaces. Uneven colouring has been found on many vessels that were not used for cooking, such as table ware including cups and bowls, as well as storage vessels (Fig. 4). Very often they do not differ from that on cooking pots.

Oxidation discoloration, also proposed as one of the basic means in recognition of pots used over fire, could be misleading as well, as the case with the bases of medium/fine quartz-tempered cooking pots show. These oxidized bases are, in terms of their fabric, surface treatment and colour, similar to jags for short-term storage of liquids and their sherds could be easily mixed up, since the jugs were fired in oxidized atmosphere, which gave them reddish colour often similar to this of cooking pots bases. Only burnt organic remains deposited onto the bottom of the bases indicate their use over fire. It is observed that the Makriyalos cooking pots have oxidized bases and soot deposition on the middle and the upper part of the outer side of their body, which indicate that they were placed in the fire thus being in a direct contact with fuel. The presence of charred organic remains on the bottoms of cooking pots is not rare.

The study of pottery distribution, although still in progress, gives interesting evidence about the practices concerning preparation and the consumption of food. It is observed that distribution of different cooking pot types is not homogeneous throughout the settlement, nor it is in relation to the dwellings and their environment. This suggests that different cooking practices, like baking, boiling and stewing, were not done at the same place. According to the distribution of cooking vessels, baking took place most probably outdoors and is not connected to each pit, while boiling and stewing seems to be more indoors practices and linked to individual pits.

The results of technomorphological and use-alteration analysis and the evidence of the pottery distribution stress the needs for better understanding of the actual pottery use, especially of those used for cooking.

Chemical analysis of organic remains

In order to understand how observed technomorphological and stylistic variability is correlated to the actual use and to the food cooked, consumed and stored in the pots, chemical analysis of organic remains was planed. To this end a pilot study, results of which we represent in part here, was carried out in the Department of Archaeological Sciences at the University of Bradford, UK. The aim of the study was twofold. Since the Makriyalos vessels are more then 7000 years old, our main consideration was, on the one hand the **level of surviving** of organic residues, and on the other the possibilities to **reassess the use** of the pots indicated by technomorphological, stylistic and use-alteration analysis. To this end sherds of 19 pots that represent a range of categories of vessel shape, size and fabric were selected. They belong to the main use categories, although the emphasis was put on cooking pots. Three sherds from the vessels, which couldn't be assigned to any concrete use, were also included.

In an effort to avoid the effects that could have different burial environments on the preservation of organic residues, all samples were taken from similar environments, namely from two pits. The majority of samples come from one pit and only two belong to the other. Some sherds had visible remains and some had no indication of any organic residue. All pottery was subjected to the ordinary post-excavation treatment including washing with tap water and storing in plastic bags. One of the factors that could affect the results of chemical analysis is contamination from burial environment, post-excavation and laboratory handling of pottery. In order to control the contamination issue, sampling procedure involved the removal of potential contamination by scraping the surfaces, followed by samples taken to a 1–2 mm depth from the interior of the inner end the outer side of the vessel's wall. Samples from the surface layer and the sherd interior were treated separately. The samples were analysed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC–MS) analytical techniques. The procedure applied to all but one sample is the same as described in Urem-Kotsou *et al.* (in press).

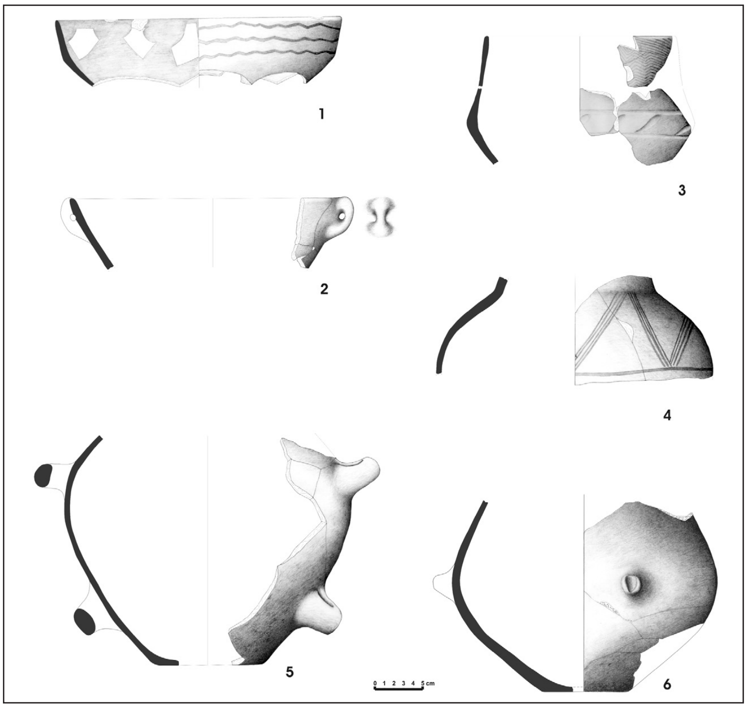

Fig. 2. Main shapes of table ware (1–3), closed shape amphorae (4–6).

Results

Use assessment analysis

Three vessels types were chosen for use assessment analysis, these are each represented by two sherds. Two fragmented base sherds represent the 4-handled jugs (Fig. 5). Two fragmented bases represent medium/fine quartz tempered cooking pots of unknown shape. Both vessel types are similar in terms of their fabric, surface treatment and colour. This makes distinguishing the vessel types difficult without diagnostic morphological features. Two large sherds (upper part of the vessels including rim) represent the large conical bowls (Fig. 3: 2) similar to the medium/fine quartz tempered cooking pots in terms of their fabric.

Technomorphological and use-alteration analysis of 4-handled jags gave controversial indications about their actual use. They are of closed shape, low-porosity and fired in oxidized atmosphere which was not always well controlled judging from uneven colour of their surface (Fig. 5). Their morphological and technological characteristics indicate serving/storing/transferring of liquids. However, soot depositions on the bases of some of similar vessel types indicate a possible reuse as cooking pots. This hypothesis was supported by the traces of black organic remains deposited onto the bottom and the lower part of several other jugs of the same type, which initially looked similar to burnt food remains.

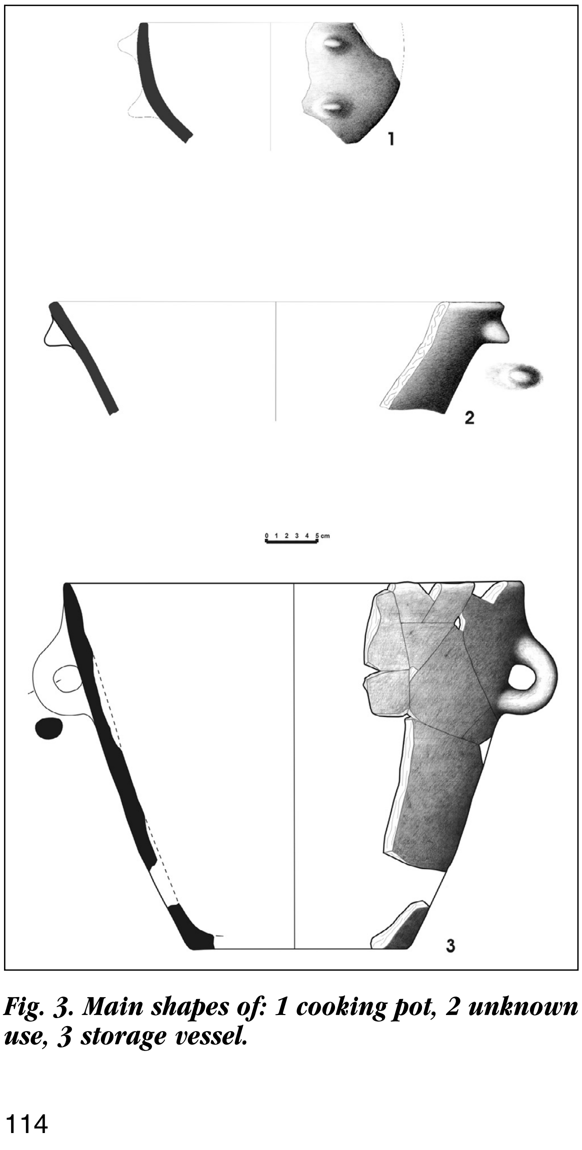

Fig. 3. Main shapes of: 1 cooking pot, 2 unknown use, 3 storage vessel.

Two fragmented bases of 4-handled jugs selected for analysis had scanty traces of black remains, deposited onto the bottom and the lower part of the inner vessels walls, which looked as burnt food residues that indicate their use over fire.

In order to examine the relation between 4-handled jugs and medium/fine quartz-tempered cooking pots, two fragmented bases of the latter were selected. Macroscopically both were similar to the bases of 4-handled jugs, oxidized and with black organic remains on their bottoms.

Of possible interest to the issue of medium/fine quartz-tempered cooking pots is the case of two large conical bowls (Fig. 3: 2). Both, on the base of technomorphological and use-alteration analysis, couldn't be assigned to any concrete use. Both bowls are of medium to fine quartz-tempered fabric and low porosity. Their surfaces are smoothed and of greyish uneven colour. Both belong to the same vessel type and are of similar size judging from their rim diameter (35 and 37 respectively), wall angle and wall thickness. No visible traces of organic remains were observed.

Organic residue analysis

The results of chemical analysis by GC–MS show that black organic remains from the bottom of the 4-handled jugs are not burned food residues but remains of birch bark tar (*Urem-Kotsou et al. in press*). This highlights the importance of chemical analysis in the identification of amorphous visible residues. These residues were found only on the interior surface, suggesting that the birch bark tar was used for lining the interior walls of the vessels, possibly to reduce the permeability. The intention to reduce the permeability of the pots, especially those of close shape, indicates that vessels contained liquids.

Chemical analysis of visible organic remains from the bottom of two medium/fine quartz tempered cooking pots bases didn't show any traces of birch bark tar.

Chemical analysis of two large bowls revealed the presence of free fatty acids, such as palmitic ($C_{16:0}$) and stearic ($C_{18:0}$) acids. Traces of ketones were also detected in both vessels. Unfortunately, it is not pos-

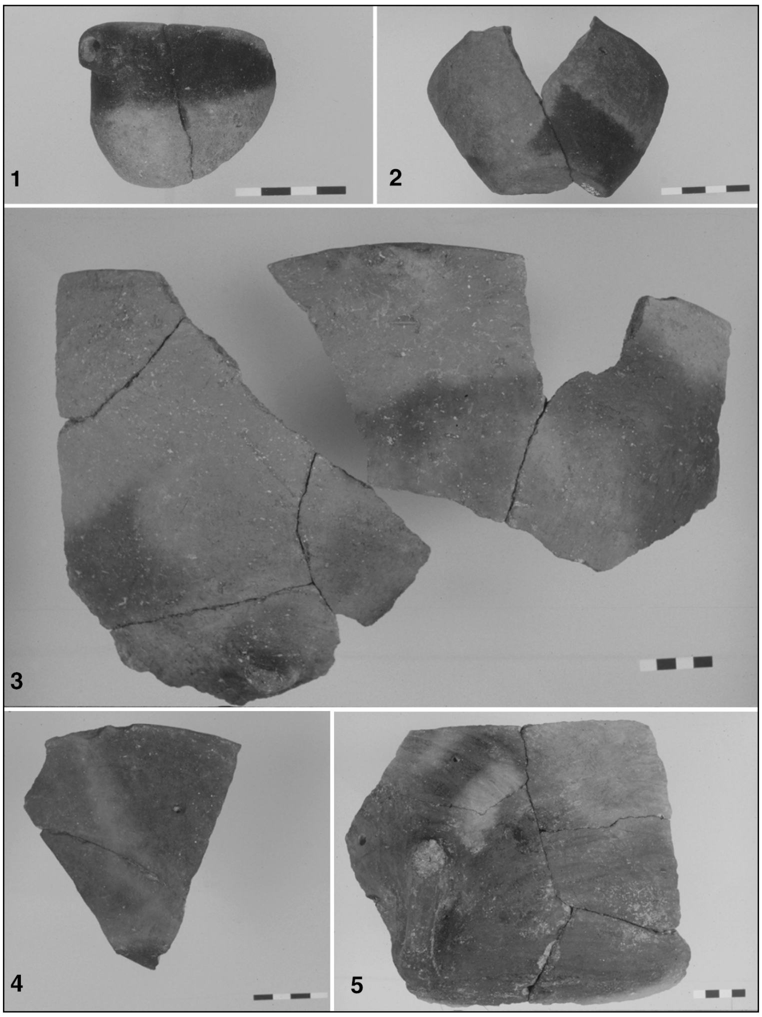

Fig. 4. Vessels of different use-types with sooting clouds: 1–2 cups, 3 cooking pot, 4 table ware, 5 storage vessel.

sible to further identify the ketones. However, by comparison to previously published work, were retention time and the range of proportion of ketones are published, the ketones found in both Makriyalos pots could be K31, K33 and K35 (*Evershed et al. 1995; Raven et al. 1997*). In this work is pointed out that K31, K33 and K35 are formed by pyrolysis of acyl lipids, although ketones absorbed in vessel's matrix could also derive from cooking of food of plant origin (*Charters et al. 1997*). Concerning two Makriyalos large bowls, ketones were detected in all but one sample. In particular, they were identify in the samples taken from the interior of the sherds of both vessels, in the same range proportion and retention time as published above. In the surface layer sample of one large bowl ketones are not recorded. This sample yields negligible amounts of lipids and differs from the composition of the subsequent sample taken from the sherd's interior. This suggests that ketones in this vessel are not a result of soil contamination, but originate from the vessel's content. However, although their presence in the interior and exterior of sherds from both vessels suggests they could have migrated through the vessel by the successive use in processing food, contamination from the soil cannot be excluded.

At the present state of research, consequently, chemical analyses cannot fully support the use of large bowls for cooking, since there is no carbon numbers to identify the ketones. They, nevertheless, give an interesting direction to the study of Makriyalos pottery, indicating a possible group of vessels to which fine quartz-tempered pots bases belong.

DISCUSSION

As already noted, there are a number of parameters proposed for the study of pottery use. Many of them have been developed in ethnographical research. As we found out in the study of Makriyalos pottery, there are difficulties in applying proposed methods to archaeological ceramics. Thus, some basic parameters to assess pottery use, such as soot deposits and interior surface pitting, were not of much help in our study since pottery is remarkably fragmented, abraded and sometimes scaly. Even visible organic remains could be misleading, as the example of 4-handled jugs coated with birch bark tar show. What looks very much as burnt food residues could very well be something completely different.

Considerable effort has been put during the last two decades in the study of cooking pots technology, in order to find relevant attributes, which would help the recognition of cooking vessels. Besides the use-alteration characteristics, one of the basic attributes proposed for recognition of cooking pots is their fabric, and in particular, the type, size and the quantity of non-plastic inclusions in ceramic matrix. Thus, as predictor-of-use characteristics for recognition of cooking pots, coarse fabric is proposed with shell-temper as most suitable, although sandy-tempered and quartz-tempered cooking pots are also reported. While the growing number of studies concerning clay

Fig. 5. Closed shape vessel with sooting clouds on its base.

non-plastic inclusions show that type of inclusions is not that important, the coarseness of the pot fabric is stressed as a crucial factor.

However, Makriyalos medium/fine quartz-tempered cooking pots show that coarseness should not be taken for granted. Even when, in a ceramic assemblage, cooking pots of typical fabric composition exist, different cooking ware technologies could equally be present. This is the case of Makriyalos, where apart from coarse shell-tempered pots, medium and fine fabrics could also be connected to cooking activities. In a situation like this, predictor-of-use characteristics are potentially misleading.

It has already been observed by some scholars that proposed relationship between various parameters, such as relationship between form, fabric and function, could be ambiguous and that cultural dimension of technical behaviours shouldn't be ignored (*Woods 1986; Gosselain 1998*). Makriyalos medium/fine cooking pots show that fine fabric could also be used for manufacturing cooking pots. Thus in the same assemblage the whole range of fabrics in cooking pots could be found. This can be linked to the context of their production but could also be linked to the cooking techniques. Not to mention that these variability could be related to the kind of food as well. Chemical analysis of organic remains could substantially contribute to this issue.

Although not easy to be traced, the understanding of actual vessels use directly affect our understanding of the activities concerning food preparation and consumption, and their relation to the use of space, among others. As could be seen on Makriyalos example, contextual study of pottery use indicate that baking was most probably a matter of group of households and took place outdoors, which indicate sharing between people. Boiling and stewing were more matter of individual household, since boiling and stewing pots were found in individual pits. These are important information for understanding the food habits of past human societies. In conclusion, we could stress the importance of combined ceramic and chemical analysis for understanding everyday activities in past societies through pottery use.

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Documenta Praehistorica XXIX

Changes in the production and use of pottery from the Early Neolithic to the 'secondary products revolution': some evidence from LN Makriyalos, Northern Greece

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ABSTRACT – *Recent developments in pottery studies have altered the way archaeologists handle and interpret prehistoric pottery. The technology and use of pottery, the symbolic and social meaning of the pot are considered as anthropological phenomena, the products of human action. Excavations at Late Neolithic Makriyalos offered the opportunity to explore from a new perspective several aspects of neolithic society in Greece in terms of the use, function, distribution and discard of pottery.*

IZVLEČEK – *Sodoben razvoj preučevanja keramike je spremenil način arheološke obravnave in interpretacije prazgodovinske keramike. Tehnologijo in uporabo keramike, simboličen in družbeni pomen posod smatramo za antropološki fenomen, za proizvod človekove dejavnosti. Izkopavanja poznoneolitskega Makriyalosa so omogočila nove poglede na neolitsko družbo v Grčiji z vidika uporabnosti, namenskosti, distribucije in zavrženosti lončenine.*

KEY WORDS – *Neolithic; Thessaly; pottery use; production; function; discard*

LATE NEOLITHIC MAKRIYALOS: A CASE STUDY

In 1992 a rescue excavation in Pieria, Northern Greece, near the modern village of Makriyalos, revealed a prehistoric site with archaeological finds dated to the Late Neolithic period (Fig. 1). The site covers approximately 50 ha, of which 6 ha was intensively investigated (*Pappa and Besios 1999.179*). The excavation of the site offered valuable information about the character of the flat-extended type of Neolithic site, which is relatively unknown for Greece in comparison with other regions of Europe and the Balkans, where flat-extended settlements are fairly well known. The main characteristics of these settlements are the horizontally shifting occupation, interspersed with open spaces, presumably cultivated land and fields, and, finally, their great extent which may exceed 50 ha (*Andreou, Fotiadis and Kotsakis 1996.578*).

The excavation revealed, according to pottery finds, two different occupation episodes, Makriyalos I and II (Fig. 2), which refer respectively to the early and late Late Neolithic. Makriyalos I is dated no earlier than 5400 BC, while Makriyalos II yielded a great amount of pottery that has close relations with decorative motifs from pottery assemblages of Thessaly, those of the so called 'Classical Dimini' pottery style (*Theocharis 1973; 1993*) (Figs. 3, 4). These two different occupation episodes appear on opposite slopes of the hill. Only a few sherds of Makriyalos II were found in deposits of Makriyalos I, leading to the conclusion that Makriyalos I was completely abandoned before the establishment of Makriyalos II.

During Makriyalos I, the entire settlement was encircled by two curved, parallel ditches, ditch Alpha and ditch Beta, while a third one, ditch Gamma, was revealed inside the settlement. Makriyalos II is rather different. Spatial overlap with Makriyalos I is minimal and Makriyalos II is possibly smaller in extent than Makriyalos I. In this occupational phase,

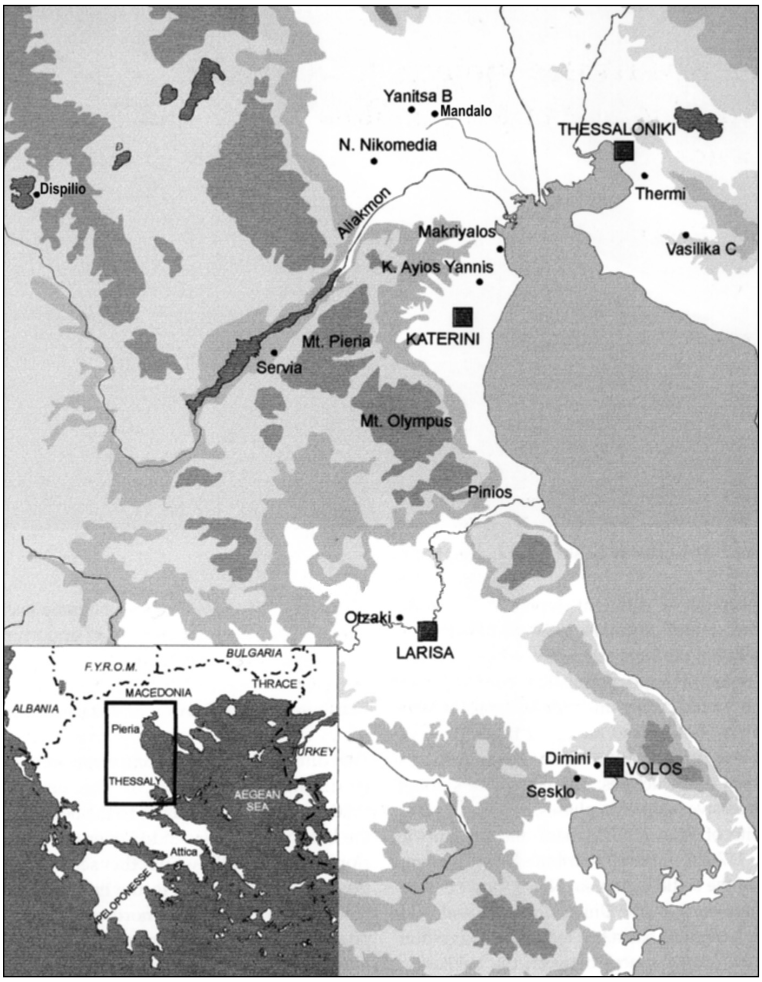

*Fig. 1. Map of Pieria and Thessaly, showing sites mentioned in the text (***after Pappa and Besios 1999***).*

ditches were also present, but their character is unclear, because they lie outside the excavated area. As in Makriyalos I, the ditches are comprised of a chain of pits forming a linear boundary to the settlement. At the intra-site level, habitation is denser in Makriyalos II with almost no open spaces between the dwellings. According to the excavators, two habitation subphases were distinguished, an earlier subphase of pit dwellings and a later subphase of apsidal structures (*Pappa and Besios 1999.180*). Hearths and ovens were situated outside the houses in small clusters of three or four, while a number of pits around the dwellings were recognised as storage pits, refuse pits and possible working areas.

MAKRIYALOS IN PERSPECTIVE: THE POTTERY

Understanding of the Greek Neolithic is still dominated by the results of excavations in the early 20th century at Sesklo and Dimini (*Tsountas 1908*), in Thessaly. Apart from these two sites, adequate published information is scarce for settlements of this period and the same is true for pottery. Indeed, one of the major problems of Greek Neolithic studies is the restricted extent of later 20th century excavation programmes, mostly by German and Greek groups (*Gallis 1979*) and, as a result, the limited potential for reliable archaeological inferences. Furthermore, most sites in Thessaly are tell-villages that were densely inhabited, long-lived and restricted in extent, and so not representative of the newly recognised category of flat-extended settlements.

Until recently the chronological framework for the Greek Neolithic and the culture histories of different regions within Greece were based on typological differences between pottery groups, analysed at an inter-site level and treating date as the only significant source of variability at an intra-site level (*Milojčić 1960; Milojčić et al. 1976; Hauptmann 1981*). This framework now seems fragile and the mere observation and description of typological differences inadequate. Makriyalos offers the opportunity to investigate spatial variability in archaeological material on a large scale and, thereby, to explore human activity within an early farming community with a high degree of confidence.

Among the wealth of finds from Late Neolithic Makriyalos the pottery from Makriyalos II amounts to approximately 12 tons. Information on production of the Makriyalos II pottery and the exchange of this material over long distances will be available in short time from Elli Hitsiou's study, based on thin section petrography, of certain technological aspects and provenance. The objectives of the study were to trace the social and functional role of the Makriyalos II pottery, by exploring its use and the spatial distribution of discard. In addition, it was hoped that ceramic analysis would help to refine the chronological framework of the site.

The preliminary results presented here are based on 8-months of systematic work dealing with approximately 2 tons of pottery. Sampling of material for study has focussed on the 'closed' excavation units,

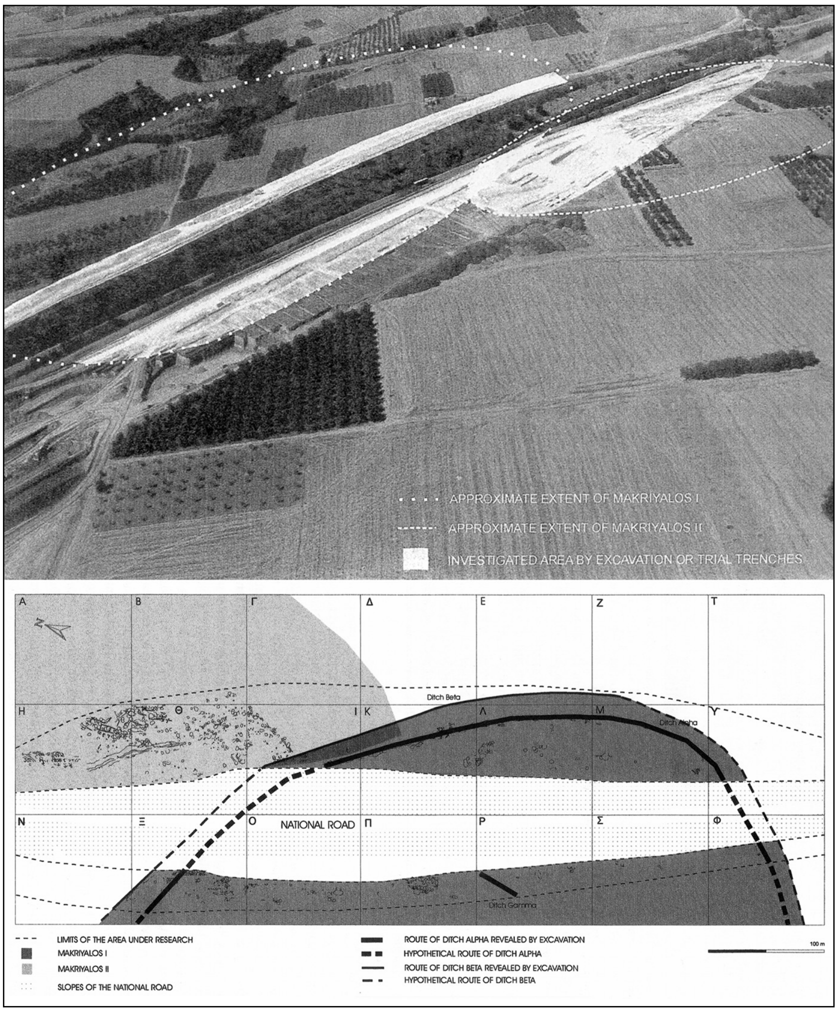

Fig. 2. Aerial view and sketch plan of Makriyalos I and II.

the pits, which, with the exception of the two or three apsidal buildings, were the basic architectural units of this phase. Almost all the material from the Makriyalos II pits was examined and recorded. In addition, some of the overlying surface layer was examined to investigate its relationship with the pits and to explore postdepositional factors that may have affected the way pottery was distributed in the archaeological record. Finally, particular attention was paid to an area in excavation sector Eta (H), on the northern edge of the settlement, where the excavators had noted an exceptional abundance of ceramics: this area, although only one tenth of the excavated Makriyalos II habitation area, yielded nearly one quarter of the total pottery assemblage for this phase.

The most common shapes in Makriyalos II are (Figs. 5, 6): a) for tableware shallow flat-based bowls, straight-sided open bowls, carinated bowls, fruit-stands and cups; b) for serving, storing and transferring liquids jugs and jars with vertical handles; c) for long-term storage pithoi and other small storage pots; and, finally, d) for cooking pots with traces of repeated use on fire. Spatial distribution within the settlement, however, suggests variability in the use of space and/or date.

Most striking is the distribution of the so-called 'Classical Dimini' pottery style (Dimini brown-on-cream, Otzaki black-on-red, polychrome decoration and incised patterns). Almost 90% of this type of pottery comes from the ceramic-rich area in sector Eta on the northern edge of the settlement, discussed above, and ca. 10% from pit 24, which was recognised by the excavators as a clear example of a subterranean dwelling (Fig. 7). In addition, one pit outside the ditch produced a significant amount of this kind of pottery, but otherwise only a few sherds were found inside and outside the remaining pits.

The excavators describe the ceramic-rich area in sector Eta as a 'borrow pit' and have suggested that this was subsequently filled with pottery eroded from the slope above the pit (*Pappa and Besios 1999. 188*). In support of this interpretation, the stratigraphy in this area shows a series of deposits of, sometimes, very distinctive pottery, which are separated by thin layers of soil. Beneath these deposits, were discovered some pits with small amounts of pottery and a few traces of minor ditches. If the overlying material had been deposited by erosion, however, relatively intense abrasion and fragmentation of sherds might be expected, whereas in fact the pottery is mostly well preserved and the size of sherds is remarkably large compared to other areas of the settlement.

Furthermore, as already noted, tableware in this area is overwhelmingly of 'Classical Dimini' type. Shallow flat-based bowls and straight-sided open bowls are dominant and decorated with the characteristic 'Classical Dimini' motifs, as are the fruit-stands (Fig. 8).

Fig. 3. 'Classical Dimini' pottery from Thessalian sites.

Some incised jars are also present. Pottery with different decorative motifs is scarce, as is undecorated tableware like cups or carinated bowls. The unusual nature of the assemblage from this area suggests that it represents the primary locus of discard from a particular human activity, rather than the result of postdepositional erosion.

Further support for this view comes from the evidence for cooking vessels in the Makriyalos II settlement. Overall, very few sherds could be associated with cooking and in most cases they were situated near cooking facilities, such as hearths. Both inside and outside the pits, sherds that could be assigned to cooking vessels or that seemed to have traces of repeated use on fire are almost absent and the few exceptions belong to fragmentary 'dish-like' vessels with rough surface, which are very shallow and have a large rim diameter. In the sector Eta 'borrow pit', however, numerous cooking vessels and pots with clear traces of fire were recognised and almost all of these have fabrics rich in shell inclusions. A very large number of storage pots were found in this particular area. Thus it seems clear that this area was the location of a distinctive type of activity or at least discard. The almost complete absence of decorated pottery and particularly of 'Classical Dimini' pottery elsewhere

Fig. 4. Pottery with polychrome decoration.

Fig. 5. Common shapes from Makriyalos II.

high. The fill consists of sherds ascribed to small storage pots and almost complete absence of tableware or decorated pottery, except for some incised pots, as in the case of most pits at the habitation area. It seems that the pits which constituted the ditch filled with material exposed for a long time before incorporation in the ditch or in some cases with refuse discarded from the settlement itself.

The apsidal buildings (Fig. 11), assigned by the excavators to a separate habitation episode, show clear evidence of a distinctive use, even if there is heavy erosion in this area and it is very difficult to explore and interpret them. Their internal organisation, including one or two separate rooms and an apsidal end with many fragments of storage pots, reflects a different and more elaborate perception of the use of space from that of the simple pit dwellings. However, inside the rooms differences from the pit dwellings in the composition of pottery is minimal.

The subterranean dwelling, Pit 24, is the only pit that presents stratigraphic differences (Fig. 12). This pit is unusual in its depth, its diameter, the entrance identified by the excavators and the discovery of three holes marking the position of storage pots on the floor, 2 m below the present surface. The sherds of these storage pots were found in the floor deposit. The excavators suggest that the bottom of the pit could have been used as a cellar. The pottery of the pit exhibits a clear stratigraphic sequence. 'Classical

in the settlement and the quantity of this pottery in this 'borrow pit,' completed with the abundance in this pit of pottery related to cooking, suggest that this distinctive group of material should be interpreted in terms of patterns of activity or discard rather than chronological variation.

In the Makriyalos II habitation area, no stratigraphic distinctions are evident within pits (Fig. 9), but many pits contain small quantities of pottery and share a common, but limited 'repertoire' of ceramic categories. This 'repertoire' consists of a small number of impressed and incised tableware vessels such as carinated bowls (Fig. 10), but other tableware is undecorated and could be related to the consumption of food or liquids, as in the case of cups. Pottery for storage needs, like pithoi and small storage vessels, and for the transfer of liquids, like jars, was dominant inside the pits. Very few sherds could be ascribed to a cooking vessel, with a preference to the shallow 'dish-like' vessels. More cooking vessels were recognised in areas near hearths, but the number is still low compared to the number of cooking vessels that was found in the 'borrow pit' in sector Eta. A pit in the eastern part of the settlement yielded remarkable quantities of incised pottery, but it was excavated in a trial trench and so its spatial relationship to other pits remains unclear.

In the southern part of the excavated area, the quantity of pottery from the boundary ditch is very small, the degree of preservation extremely low and the fragmentation of sherds very

Fig. 6. Pottery from Makriyalos II.

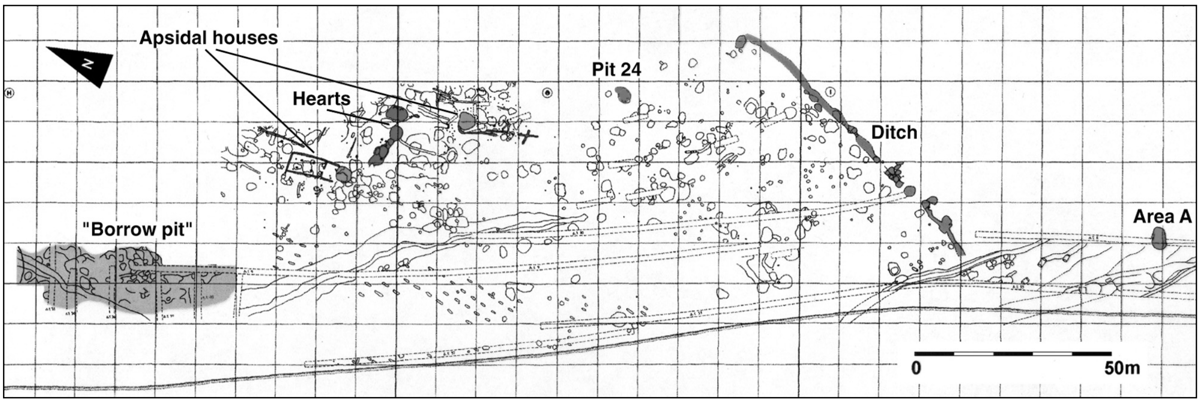

Fig. 7. Plan of Makriyalos II marking places of interest as mentioned in the text.

Dimini' pottery is dominant in the upper layers along with many big storage pots. In the lower levels, the amount of 'Classical Dimini' pottery decreases and other decorative motifs are present, albeit in small quantities, while the frequency of storage pots increases. Whether this difference in the composition of the pottery from successive levels in this particular pit reflects changes in the use of space, as suggested by the excavators, chronological differences, or both, demands further examination in the future.

CONCLUSIONS

In recent years, pottery studies in archaeology have moved beyond the traditional dichotomy between technology-use and social-symbolic (*Pritchard and van der Leeuw 1984; Stark 1998*). The technology and use of pottery and the symbolic and social meaning the pot itself carries, are now regarded from a more anthropological perspective as parts of the same sequence of actions that begin with the manufacture and production of a pot and includes its various uses and, ultimately, its discard (*Lemonnier 1993; Skibo 1999*). Of course, people are the main participants in these actions. They understand and even change the social meaning of pottery through time, organising the production of a pot not only to meet basic biological needs, but also to represent certain perceptions of dietary traditions or as a means of changing them.

As for Makriyalos II, the history of research in Macedonia and Thessaly shows that, in the later Late Neolithic, stylistic regions are smaller and there is a variety of 'wares' and decorative motifs (*Demoule and Perlès 1993.392–393; Perlès and Vitelli 1999. 98*). Certain wares are evident over very large geographical areas, as in case of the 'Classical Dimini' pottery, distribution of which reaches Albania, but seems uneven as is indicated by the absence of 'Classical Dimini' pottery at Mandalo and Dispilio. In the case of Makriyalos, the quantity and quality of this particular ceramic category is high. The origin of this

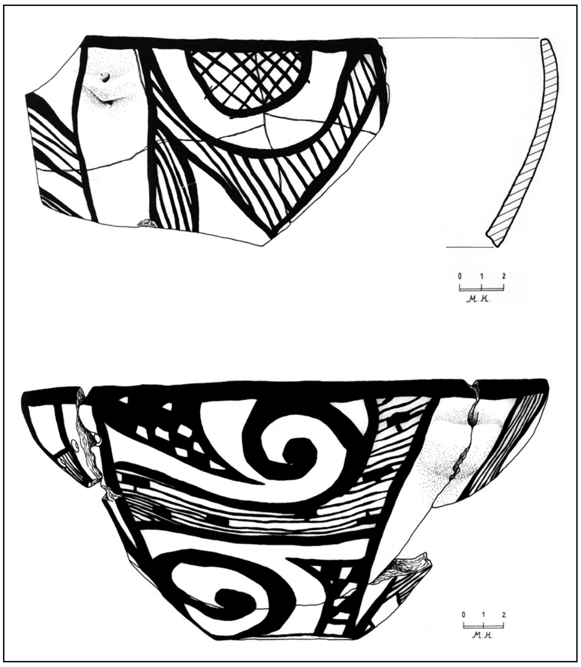

Fig. 8. 'Classical Dimini' pottery from Makriyalos II.

Fig. 9. Pit-dwellings.

pottery is still unclear and whether pots were imported and so represent products that were exchanged widely, as in the case of obsidian, or were produced locally, is still uncertain. On the other hand, Makriyalos lacks the variety of 'wares' and decoration evident elsewhere in Macedonia, as at Servia (*Ridley and Wardle 1979.213–217*) or Giannitsa B (*Chrysostomou 1996.165*), where 'Classical Dimini' pottery is only a part of the decorated pottery assemblage. Decorated pottery at Makriyalos II is dominated by the 'Classical Dimini' styles and only a few other decorative styles occur, such as the incised carinated bowls and some incised pots, but the number of these pots or sherds is limited. The possibility that this is a result of differences in chronological sequence, yet undetected, inside the settlement demands further examination.

In the later Late Neolithic, coarse wares and pottery shapes that could be related to cooking and pottery with traces of repeated use on fire make up a large part of the ceramic assemblage. This perhaps reflects increasing use of pottery in the domestic sphere (*Perlès and Vitelli 1999.98*). At Late Neolithic Makriyalos II, the preparation of food in particular areas, where there is a concentration of hearths and cooking vessels, seems to be an activity that engaged several individuals or more than one family. On the other hand, the consumption of that food may have been more individualised as the number of cups and some undecorated shallow bowls inside the pits shows. This dual pattern of collective production and individual consumption might suggest that relations between inhabitants were negotiated in everyday life through food. It has been previously been argued that the consumption of food and drink, and of the tableware, played such a role in negotiating social relations in neolithic Greece, particularly between different 'household' groups (*Halstead 1995; Andreou, Fotiadis and Kotsakis 1996*). Makriyalos

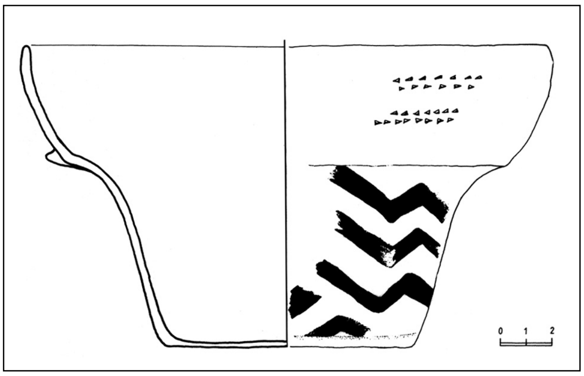

Fig. 10. Incised carinated bowl with painted decoration at the lower part.

II offers the opportunity to explore this role in the rather different social context of a site dominated architecturally by small pit dwellings, suitable for housing only restricted numbers of people.

Finally, while the study of Late Neolithic ceramics has begun in recent years to move beyond the mere concern for chronology, it is clear that little progress has been made in the basic source of the archaeological record, excavation. The extensive excavation at Makriyalos is rare, in terms of Greek archaeology, and more work on this scale is needed to clarify the spatial organization and possible symbolic uses of ceramics and ultimately to treat pottery as an anthropological phenomenon, as a product of human action.

ACKNOWLEDGEMENTS

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Fig. 11. The apsidal building.

Fig. 12. Pit 24.

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Documenta Praehistorica XXIX

Neolithic pottery at Polgar-10 (Hungary): measuring the habitus

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ABSTRACT – *It is self-evidently true that ceramics form the largest component of the artefact assemblages of the Neolithic and Copper Age of Central and Eastern Europe, yet we are still poorly informed about the final stage of the life of most vessels – their ultimate disposal. In this paper, I wish to consider the ways in which pottery can be studied with respect to disposal and deposition. An assessment of ten different kinds of pottery analysis is made, using site single contexts as the main unit of analysis. I propose that these analyses constitute ways of measuring Bourdieu's term "habitus". This contextual analysis is based on examples taken from the Neolithic settlement of Polgar-10, in North East Hungary, excavated by the Upper Tisza Project in 1994.*

IZVLEČEK – *Več kot očitno je, da med najdbami neolitika in bakrene dobe v Srednji in Vzhodni Evropi močno prevladuje keramika. Kljub temu še vedno malo vemo o končnih stopnjah življenja večine posod – ko so jih dokončno zavrgli. V članku obravnavam načine, kako lahko preučujemo keramiko glede na te končne stopnje (odlaganje in deponiranje). Ocenim deset različnih vrst analiz keramike in kot merilo analiz uporabim kontekst enega najdišča. Predlagam, da bi bile te analize podlaga za merjenje Bourdieujevega izraza "habitus". Vsebinske analize temeljijo na primerih iz neolitske naselbine Polgar-10 na severovzhodnem Madžarskem, ki so ga izkopali leta 1994 v okviru projekta Zgornja Tisa.*

KEY WORDS – *Neolithic; Hungary; ceramic analyses; disposal; deposition*

INTRODUCTION

Two of the characteristics of Neolithic and Copper Age archaeology in Central & Eastern Europe are the predominance of settlement sites and the often extraordinarily large and diverse artefact assemblages generated by the excavation of these sites. These two characteristics have often been noted and usually been taken for granted apart from acting as good reasons for excavating these rich sites. But the presence of so many settlements and such masses of finds on them is not at all typical of Eurasian prehistory as a whole and raises the question of why this should have been so.

One way to approach this question is to consider the nature of the material remains which archaeologists study. Barrett (*1988; 1994*) has proposed that archaeological evidence comprises the surviving fragments of those recursive media through which the practices of social discourse were constructed. Hence, the aim of archaeological investigation is the identification of the social practices, which led to the deposition of particular material residues in specific places. What is the effect of this re-focussing of research aims upon the way that archaeologists classify material residues? I suggest that the results are twofold: the consideration of closer links between humans, things and places, and a more active role for material culture in social practices.

The classificatory schemes developed for types of "refuse" by Schiffer (*1975; 1987*) and Needham and Spence (*1997*) are permeated with one of the key foundation-myths of archaeology – the notion that archaeology is the science of rubbish or, as Julian

Thomas (*1991.56*) put it, 'archaeology is concerned with the rubbish of past generations'. The designation of archaeology's principal object of study as 'rubbish' is remarkably widespread and has ramifications which stretch into all areas of the discipline. Different cultural values are expressed by the term 'rubbish' in various modern states but there are two aspects of the term which are widespread and which perhaps best characterise the cultural value of the term. First, rubbish designates something, which was once active, once in use, and now is passive, of no more use. Continuation of the past use may be prevented by breakage, circumscribed by replacement or the 'active' part of the material used up, leaving the 'passive' part for disposal. Secondly, because of this first aspect of value, rubbish is a material category, which should be separated from the processes of living. Ideas of pollution, whether expressed in terms of danger to health or well-being or aesthetic dis-pleasure, lie at the heart of this second aspect of the values expressed by rubbish. Thus, archaeologists carry a set of ideological assumptions about what they take to be rubbish today and it is not hard to see that they apply these modern ideological assumptions to the past.

There are two potentially serious problems with the application of modern ideological assumptions about rubbish to the prehistoric past. The first is that these assumptions widen the 'gulf' between the dead refuse of archaeological sites and the active social life whose practices contributed to the deposition of material culture, making it harder to theorise the connections between 'dead' rubbish and 'once-living' people. Thus it is not difficult to identify archaeological traditions in which description, classification and seriation of finds is the principal, if not the only, research goal. It is my contention that it is easier for researchers working in these traditions to continue this research by continuing to assume a large gap between rubbish and people. By contrast, objects produced and utilised within the household are part of that household not only during the 'life-spans' of those objects but also when they have been deposited.

The second problem is that it drastically narrows the interpretative possibilities for understanding the contexts and meanings of the deposition of our common resource – past material culture. If most of our finds are simply 'rubbish', we can hardly be expected to come to any sophisticated conclusions about the behaviour of the people who threw them away, nor can that behaviour be deemed to be anything but unproblematic.

I believe that there are grounds for demonstrating that one of the core assumptions of our discipline is false. I maintain that archaeology is not about rubbish as much as about deposition, generally of the structured variety. Thomas also maintains that the two modern ideological assumptions about the value of rubbish are also inappropriate for a study of prehistoric artefacts. Not only have many objects been deposited according to cultural rules underpinning categorical distinctions concerning disorder and order, purity and pollution, but also many of them have been broken deliberately before deposition. This applies not only to pottery, which fragments relatively easily, but also to a wide range of other, rarer objects such as altar-lamps, figurines and miniature furniture. It applies not only to items made of fired clay but also those manufactured out of harder materials such as bone, antler and even stone and metal. In short, object fragmentation is as fundamental to the Balkan Neolithic and Copper Age as is structured deposition (*Chapman 2000*).

If structured deposition of often deliberately broken objects is to be considered as a potential alternative to refuse disposal in the Balkan Neolithic and Copper Age, it is important to define the contexts in which such deposition takes place. In previous papers, I have considered three classes of site context found in Balkan NCA sites: above-ground features, such as roundels; cultural levels; and below-ground features, such as pits, shafts and wells (*Chapman 2000a; 2000b*). Three general points emerged from these reviews of depositional practices:

❶ The concentration of discarded material close to the home marks an important principle of dwelling in both tells and flat sites – a basic practice of settled life in which the identity of people, the things and the place are mutually reinforcing and reproduced in constant relation to the ancestors.

❷ Far from being nothing but a neutral means of disposing of unwanted 'refuse', digging pits, wells and shafts can be seen as an exchange with the ancestors – of new material for old – when the features are dug into earlier 'cultural layers'. This notion of digging into the past is especially germane to tell settlements, which are based upon the principle of living where one's ancestors have lived.

❸ The rejection of the 20th century notion of refuse, with its twin correlates of the uselessness of 'dead' artefacts compared to 'functioning' living humans and the spatial separation of polluted artefacts from active, living humans, opens up a wide range of possibilities for the re-interpretation of the principal forms of deposit on settlement sites. The main impact is to raise the analytical potential for the identification of the active use of cultural material in everyday social practices and ritual occasions.

In my recent research on deposition in Central and Eastern Europe, I have focussed on special examples of deposition from a range of different sites and monuments. In this paper, I wish to narrow the scope of the investigation to a single site, at the same time seeking to explore more deeply the contextual links between pottery deposition and intra-site spatial variability.

The notion of *habitus* (*Bourdieu 1977*) refers to habitual behaviour, which has an unspoken basis of embodied tradition. Since sherd deposition near or in settlement features was a basic aspect of the Neolithic *habitus* in this region, my expectation is that many of the contexts will show signs of specific structuring in material deposition. In the first group of analyses, concerned with the ceramics themselves, I make use of the statistical concept of the "site norm" – often a calculation based upon the total pottery sample from Polgar-10 (e.g., the sherd size profile from all measured sherds). The "site norm" may be used as the standard against which to compare and contrast individual contexts. In this way, the site norm is the product of a range of different depositional practices which, when found frequently enough, may be taken to represent the *habitus* in a general sense. Variations from the site norm will be considered not as exceptions to the *habitus* but rather as pointers to specific cultural preferences which would probably indicate some kind of structured practice.

THE NEOLITHIC SITE OF POLGAR-10

Fieldwork and subsequent excavation at Polgar-10 arose out of a motorway rescue programme led by Dr. Pal Raczky, on behalf of the Eotvos Lorand University Institute of Archaeological Sciences and the Deri Muzeum Debrecen. The Hungarian side fieldwalked the line of the motorway in 1993 and invited the Upper Tisza Project to excavate Polgar-10 in September 1994. Polgar-10 proved to be an extremely rich example of a Neolithic site with the likelihood of one major, and several minor, flood episodes, sandwiched between Middle Neolithic deposits (*Chapman 1995; Chapman et al. 1995*) (Fig. 1). A sampling strategy was evolved which enabled the hand excavation of a reasonable number of contexts from each of the five occupation phases. Dry sieving and froth flotation of soil samples from each context provided the basis for the recovery of small ecofacts and objects. The excavation of the threatened part of the site was completed by the end of September 1994, prior to the planned start of motorway construction. The excavation report (*Chapman et al., in prep.*) attempts to interpret each individual context and then use the results in a series of three combinations – Phases, Zones and Context Types, to understand the processes of discard and deposition.

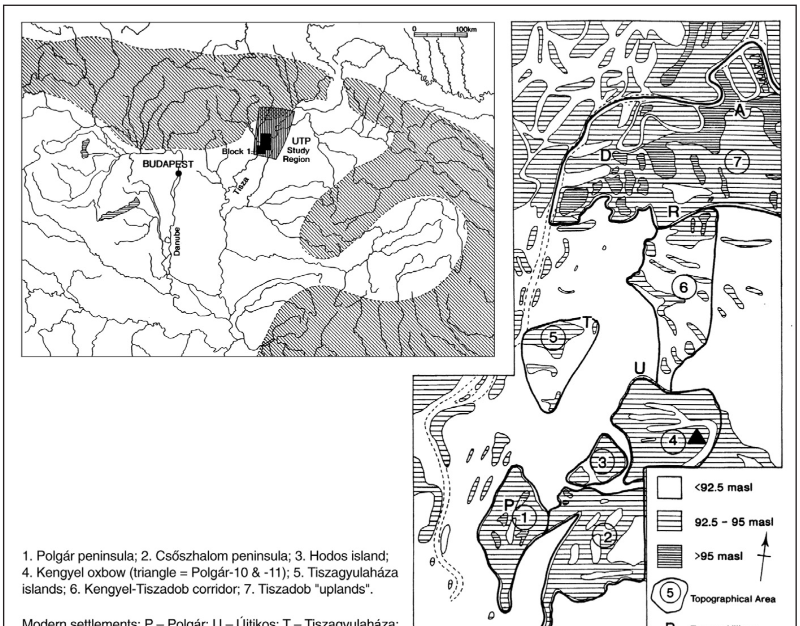

Fig. 1. Location map of Polgar-10.

The site area threatened by the motorway was divided into three unequal sectors: the Central sector, the small Northern sector and the much larger Southern sector (Fig. 2). These sectors acted as a loose framework for the stratification of the sampling. The results of the first two test pits showed that there were two major stratigraphic units on the Central sector – a light grey silty soil, overlying a much darker blocky clay, which in turn overlay the dirty loess earlier identified at Polgar-11. Further investigation

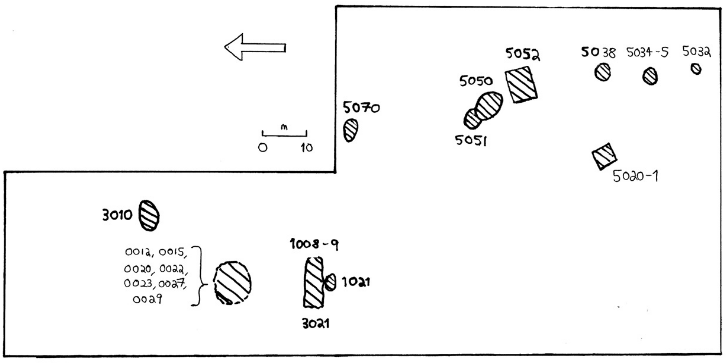

Fig. 2. Site plan, Polgar-10.

of the light grey silty sediment led to the hypothesis that it was a flood loam laid down in a single episode or a series of short-lived floods. The "flood deposit" was found in all of the test pits and, subsequently, in all of the excavation boxes. Ranging in depth between 0.25 m and 0.35 m, it marked a convenient division of the deposits into three units: pre- flood, flood and post-flood. The pre-flood dark soil was identified as what is discussed above as a "cultural layer". Without careful excavation, it was impossible to predict how many occupation horizons were contained within the pre-flood "cultural layer". The post-flood deposits were generally quite thin (maximum depth – 0.10 m). Thus, a framework for sampling the site deposits was constructed at an early stage (Fig. 3).

The extra boxes in the Central sector were designed to give a wide spatial exposure to the post-flood features, as well as to test the homogeneity of the "flood deposit". They revealed a major "natural" feature which was presumably of significance to the early inhabitants – a channel running East – West through the site. The soil fill of this feature indicated that a low probability of running water moving through the channel, so the site stream became the site "boggy hollow". Much of the boggy hollow was filled in with "flood deposit".

As time moved on, it was clearly important to sample parts of the site outside the relatively small Central sector. Auguring and test pits in both the North and the South sectors enabled the validation of the overall sequence of sediments. Time constraints forced some serious decisions: the machining-off of the "flood deposit" and the pre-flood cultural layer in the North sector, in order to identify early features cut into the loess. The "flood deposit" was also removed by machine in the South sector but the cultural layer was left for excavation of selected features – many of which showed up immediately after the removal of the "flood deposit". After excavation of the most striking features in the South sector, further limited removal of sediment by machine revealed further features cut into the dirty loess; this enabled the recovery of a reasonable number of contexts from the earliest part of the site occupation. In summary, the sampling strategy enabled excavation of a range of different contexts from each of the five Phases and from all of the three Zones.

The stratigraphic sequence at Polgar-10 consists of four cycles of fills and cuts. The sequence begins with the deposition of sterile, yellow aeolian loess at some stage of the Late Pleistocene. At the top of the yellow loess is a 10–15 cm thick deposit termed "dirty loess" – a lighter aeolian loess mixed with organic staining, flecks of charcoal and occasional Neolithic pottery. Whether this stratum represents the disturbance of the uppermost loess horizon by the earliest Neolithic occupation or a phase of early – middle Holocene pedogenesis, which incorporated early, but scanty artefact deposition is not yet clear.

Phase 1
The first phase of cuts into the aeolian loess is composed of a series of archaeological features cut into and through the surface of the "dirty" loess. All of these features contained Middle Neolithic pottery in the Szatmar II style.

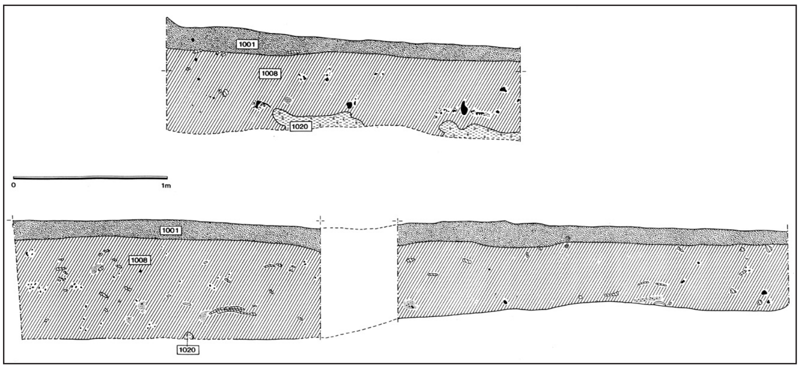

Fig. 3. North Sections, Trench AJ19B and AJ19C.

Phase 2
The second phase of fills concerns the gradual accumulation of what is termed in Hungarian archaeology a "cultural layer" or "occupation horizon" – viz., an organic-rich layer containing often high densities of ceramics

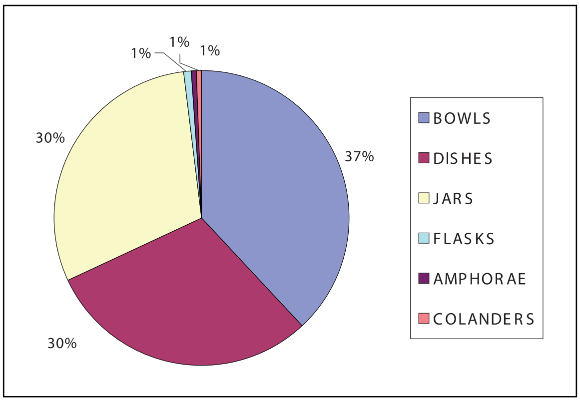

Fig. 4. Frequency of Shape types, total sample, Polgar-10.

and animal bones. The explanation for such accumulations is not entirely clear; at Polgar-10, the introduction of material through flooding and the inwashing of clay from wattle-and-daub constructions outside the excavated area are two plausible means by which 15–30 cm of deposit built up within the Middle Neolithic period. Admixture of materials discarded or deposited by people on their living surface with the flood deposits and the house remains probably accounts for the density of finds in this horizon.

Phase 3

The second phase of cuts is represented by the cutting of archaeological features into the top of the "cultural layer". Their finds comprise no pottery but Middle Neolithic material.

Phase 4

The third suite of fill comprises the inwashed material from one single large, or a series of smaller, flood episodes. The occurrence of features lying on an active surface within the flood loam makes the latter explanation seem more probable. A certain amount of ceramics was incorporated into the flood loam, suggesting that active living surfaces were close at hand. Since no material later than the Middle Neolithic was found in the flood loam, it may be concluded that we have represented here a set of Neolithic floods.

Phase 5

The third phase of cut features is represented by a group of features cut into the uppermost surface of the flood loam. While a relatively small quantity of pottery, and even fewer animal bones, were preserved in these features, no material datable to a period later than the Middle Neolithic has been recovered.

The fourth and final cycle of fills and cuts can be dated to the post-Neolithic period. The infilled materials consist of post-Neolithic flood loams and erosion deposits, which accumulated over the longue duree and apparently undisturbed by later prehistoric and historic occupation.

A series of five AMS radiocarbon dates places the Neolithic deposits firmly in the late sixth – early fifth Millennia CAL BC (Tab. 1) (p.c., T. Higham).

In terms of the context types at Polgar-10, the basic contrast has already been made between fills and cuts. However, four more specific Context Types have been defined, leaving a fifth category for "Other" types: cultural layers, fill deposits, flood deposits and pits.

The contexts defined as "cultural layers" have in common a fairly high to high organic content and a moderate to high density of artefacts. Fourteen such features are identified at Polgar-10, all in Phase 2. These units are highly variable in terms of size and range and quantity of finds.

Fill deposits are found in every Phase except Phase 4 – defined as a special kind of fill – flood deposits. Their defining trait lies in the negative nature of their deposition – they do not have a high organic content nor high densities of finds, nor are they features cut into another matrix. Fourteen such contexts make up this potentially disparate Context Type, whose range and quantity of artefacts is just as variable as in the cultural layers.

The six examples of flood deposits are, by definition, restricted to Phase 4. The diversity and quantity of finds in some of these contexts indicates that often surprisingly large quantities of material have been washed into these deposits.

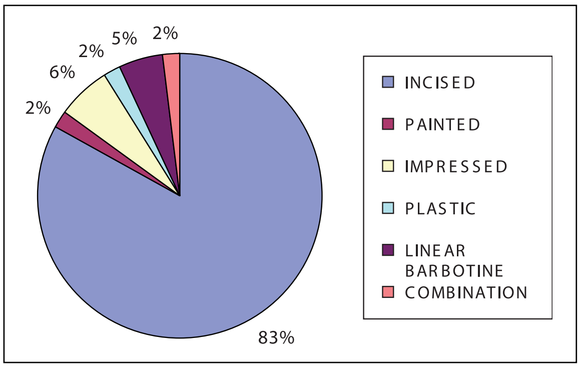

Fig. 5. Frequency of Decorative techniques, total sample, Polgar-10.

Lab No.	Phase	Date	Calib Date Range (2 σ)	Associated Pottery
OxA–9633	I	6440 +/- 60 BP	5480-5320	Szatmar II
OxA–9634	I	6365 +/- 50 BP	5475-5255	Szatmar II
OxA–9635	I	6245 +/- 45 BP	5310-5190	Szatmar II
OxA–9675	II	6190 +/- 90 BP	5325-4900	Tiszadob
OxA–9637	IV	6290 +/- 45 BP	5365-5205	Late Tiszadob

Tab. 1. A series of five AMS radiocarbon dates.

The fourth specific Context Type comprises Pits. The size of these features has been recorded in such a way that it is possible to assess the density of finds in a quantitative way. In two cases, the pits are just large enough to hold a single vessel (the so-called pot-pits); otherwise the pits can range up to 8.2 m^3 in volume. The finds density can range from no finds at all up to over 1000 sherds and many animal bones.

The final Context Type is the most variable, including as it does a few examples of a diverse range of contexts with little to unite them. The most numerous examples include burials and pottery and/or daub concentrations but occasional examples of burnt floors and a single hearth complete the group.

In summary, Polgar-10 is a multi-phase Neolithic settlement with a medium-sized ceramic assemblage recorded in single contexts, each located within one of three zones. Total occupation is likely to be discontinuous, spanning several hundred years.

OUTLINE CHARACTERISTICS OF THE CERAMIC ASSEMBLAGE

The Neolithic pottery deposited at Polgar-10 constitutes an assemblage of cca. 25 000 sherds, including over 2700 rims and over 3300 decorated sherds. Initial categorisation of rims and decorated sherds was completed by Rhodri Jones and Jerome Edwards as their dissertation topics at the University of Newcastle upon Tyne (*Jones 1996; Edwards 1996*); since then, further studies have been made by the author.

The basic characteristics of the assemblage are an overall domination of coarse wares over fine wares (a ratio of 3:2). A total of seven fabrics have been defined: four for the coarse wares and three for the fine wares (Tab. 2).

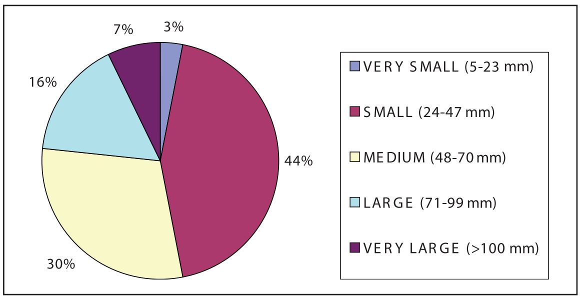

Fig. 6. Frequency of Size categories of total sample of Polgar-10 sherds.

The assemblage comprises six overall shape types: three common types – bowls (38%), dishes (30%) and jars (31%) – and three rare types – flasks (1%), amphorae (<1%) and colanders (<1%)(Fig. 4). Decoration is dominated by the Incised technique (83%), with minor contributions from five other techniques: Painted (2%), Impressed (6%), Plastic (2%), Linear Barbotine (5%) and a combination of these techniques (2%) (Fig. 5). The Incised decorative motifs have been sub-divided into five motif groups: wavy lines (5%), curvilinear (10%), rectilinear (42%), deep, simple incision (8%) and a combination of these motifs (18%). Such summary statistics provide basic yardsticks against which to measure single-context **difference** – as we shall see, an important tool for the assessment of various modes of discard.

It is not the aim of the paper to present a Phase-by-Phase account of the history of settlement at Polgar-10. Rather, I shall seek to discuss examples of context types in terms of the ceramic evidence.

CERAMIC ANALYSES: SEARCHING FOR STRUCTURE IN THE DISCARD DATA

We are now in a position to explore some individual contexts from Polgar-10 to assess their ceramic contents against the mode(s) of deposition used. Ten types of analysis have been performed on the Polgar-10 contexts and their ceramic inventories. The first five analyses focus on the characteristics of the ceramics themselves: (1) a fragmentation analysis of sherd size, following Buko; (2) an erosion analysis of the sherds, following Buko; (3) an analysis of the vessel parts represented; (4) an analysis of the fabrics of the context group; (5) an analysis of the decorational intensity. The next five analyses are devoted to spatial – contextual aspects of deposition: (6) the location of whole vessels in specific locations; (7) the concentration of sherds in a small

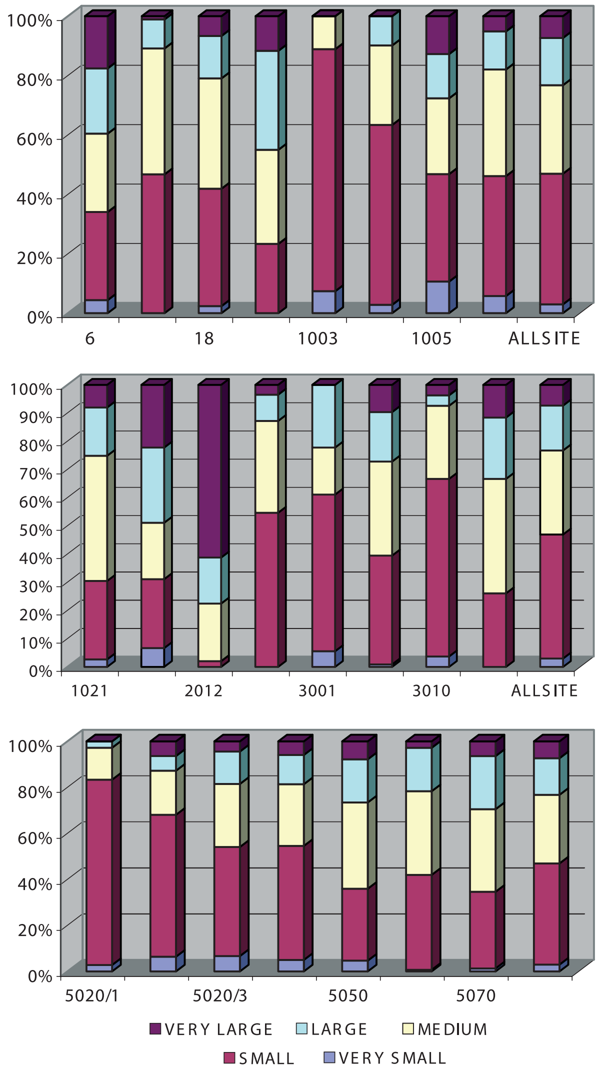

Fig. 7. Sherd size profiles by context, Polgar-10.

area; (8) the concentration of sherds in a specific phase of a context's "life-history"; (9) the association of pottery with other classes of finds deposited in a structured way; and (10) the juxtaposition of differing finds densities in adjacent contexts. Clearly, the multiple occurrence of ceramic characteristics supportive of an interpretation of structured deposition for the same context would strengthen such an interpretation.

Sherd size

The notion that sherd size is an important primary characteristic of a ceramic assemblage has been recognised for some time, particularly in the work of the Polish Medieval potter specialist, Andrzej Buko. Buko (*1987; 1990*) has devised a range of indices for the measurement of Medieval pottery (see below, pp. 134–136, for erosion), which allow him to compare and contrast individual contexts or context groups according to the values of these indices. An example is the way in which Buko has demonstrated that the ceramics in the fill of the first and second fortification ditches in the Medieval town of Sandomierz were derived from different places because of their differing size characteristics (*Buko 1987*).

This approach was followed for the Polgar-10 pottery, with one major difference. The specific technique used to measure Medieval vessel size was the number of vessel parts included in the sherds (e.g., *Buko 1987.Fig. 5*). Since the profiles of the majority of Neolithic vessels are not so highly developed, a simple size measurement was preferred – viz. the largest measurement across the surface of the sherd. Plotting these measurements on a histogram indicated several size peaks, which enabled the identification of five size categories on the basis of the interquartile ranges of the sherd sizes in each category: Very Small, Small, Medium, Large and Very Large (Fig. 6) (*cf. Buko 1990.Ryc. 2*). The only problematic aspect of this technique was discovered empirically: the inclusion of only two or three very large sherds in a sample of 20–30 sherds led to a distortion of the results. Removal of these sherds from the analysis led to a second set of results, which could be compared to the first – and often produced a more satisfactory result.

A total of 2262 sherds in 21 separate contexts was analysed for sherd size by Mr David Brookshaw in the 1999 laboratory season in Budapest. The sample derived from 11 pits, 2 "fill" contexts, 2 flood contexts, 3 cultural layers and 3 Other. The overall picture shows a strong predominance of Small sherds (44%), followed by Medium sherds (30%) (Fig. 7). In those contexts with such high frequencies of Small and Medium sherds, it may be suggested that the processes of deposition were characteristic for the site

Coarse Ware Fabrics	
1	large, thick-walled, very coarse and large grit temper
2	medium wall thickness, gritty surface, mineral temper
3	thin – medium-thick walled, coarse surface with some signs of smoothing
4	fairly thin-walled, gritty surface, mineral temper
Fine Ware Fabrics	
5	medium-thick walled, burnished inside and out
6	thick-walled but burnished surface
7	thin-walled, highly burnished surface

Tab. 2. Fabric types for the total assemblage, Polgar-10.

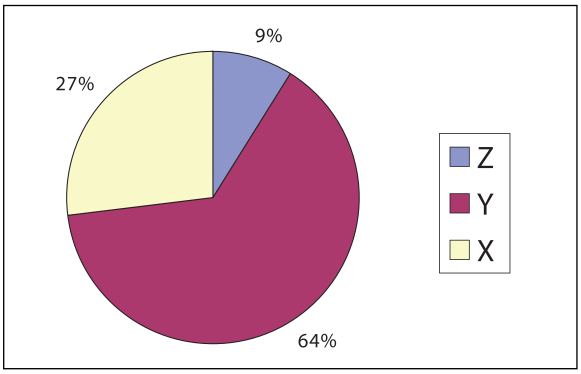

Fig. 8. Frequency of Erosion categories of total sample of Polgar-10 sherds.

habitus, in that the overall sum of factors contributing to such a sherd size profile was typical for moderate rates of pottery fragmentation and a reasonably small distance over which the sherds may well have moved. Any context in which the sherd size profile deviates markedly from this site norm may well indicate the operation of different discard processes.

The majority of contexts (n = 13) show sherd size profiles broadly comparable to that of the site norm. However, there is a strong emphasis on Very Large sherds in three contexts:

- 0006 sherd concentration on the surface of a shallow pit
- 2001 surface pottery and daub concentration
- 2012 pot-pit, with many large sherds belonging to a single vessel

It would indeed be extraordinary if the proportion of Very Large sherds was not exceptionally high in the case of the pot-pit 2012. However, the two other contexts stand out through the sherd size range from other similar surface concentrations.

There are a further five contexts which differ from the site norm through the extremely high frequency of Small sherds:

- 1003 shallow scoop with much pottery in a small feature
- 1004 long, narrow, flat-bottomed pit
- 3010 sandy fill into which material appears to have been washed
- 5020/1 clayey fill cut into the loess
- 5020/2 lowest part of the cultural layer

In the cases of 3010, the high fragmentation rate appears to be linked to inwash of material culture from adjacent deposits during a flood. However, a plausible alternative explanation for the high fragmentation of the other four contexts is deliberate smashing of pottery into small pieces ("Scherbenmachen" *pace Makkay 1983*). The high densities of pottery in 1003 are another feature worth noting in the context of structured deposition. It should, however, be noted that three of these contexts have small sample sizes of fewer than 40 sherds (1003, 3010 and 5020/1).

In summary, one aspect of pottery fragmentation of widespread applicability in contextual studies is the sherd size profile. While there may well be general expectations of such profiles, in practice such expectations should be calibrated against each site's fragmentation data, in order to identify a well-founded norm. The second stage is the identification and explanation of cases diverging from that norm. At Polgar-10, high frequencies of Very Large sherds occur in three contexts – one with strong circumstantial evidence for structured deposition of a single pot in a pit, while five contexts are dominated even more than usual by Small sherds – perhaps in some cases an indication of deliberate pottery-smashing.

Sherd Erosion

The study of the erosion of sherd fractures is a second field of research highly developed by Andrzej Buko (*1987; 1990*). Buko has defined four typical stages of erosion on Medieval glazed sherds, rang-

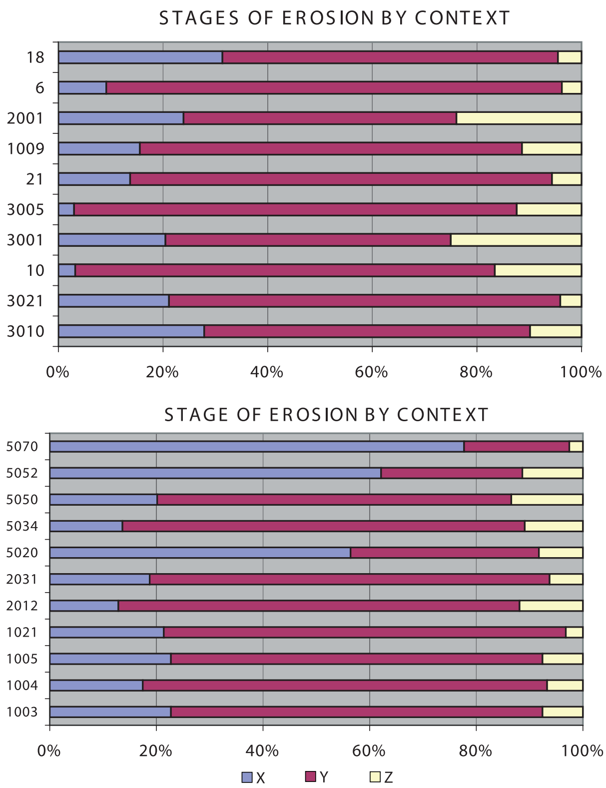

Fig. 9. Sherd erosion profiles by context, Polgar-10.

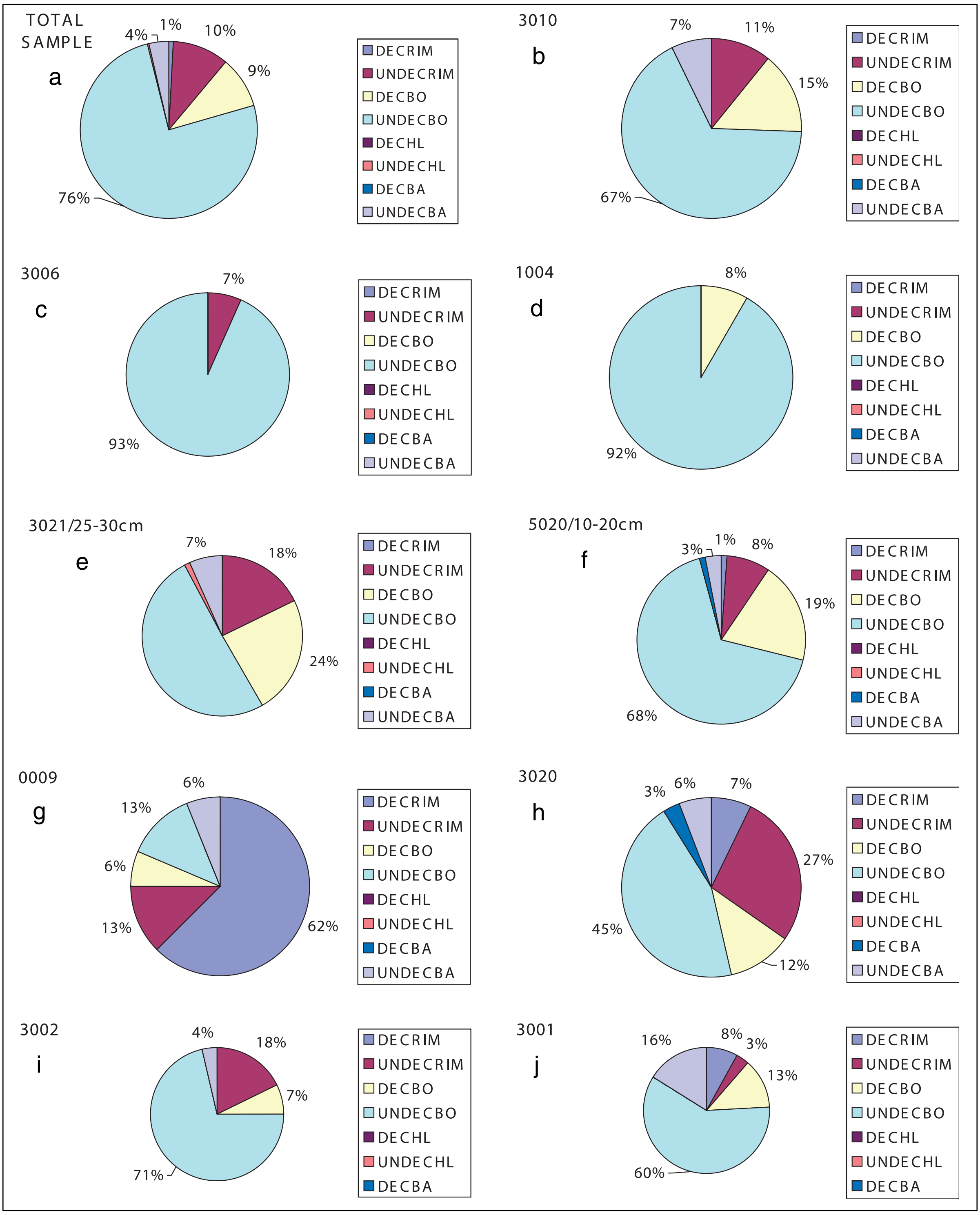

Fig. 10. Potpart distribution by context, Polgar-10.

ing from uneroded sherds with glaze intact or locally worn to sherds with well-rounded sherds with the original shape uncertain (*Buko 1990.Ryc. 1*). As with sherd size, Buko (*1990*) uses sherd erosion profiles to define deposition patterns at the site of Storvagan, in the Lofoten Islands. The Basic logic is the more eroded the sherd, the longer it has been on an active living surface, with abrasion and comminution from the elements and cumulative damage from other cultural practices. Conversely, the more rapidly the sherd is incorporated into a context of preservation, such as a pit, the less likely the sherd would suffer high-level erosion.

In the case of the Polgar-10 sample, three erosion stages were defined by Mr David Brookshaw in his

1999 analysis, in which Buko's "uneroded" stage 0 was omitted as not relevant: Stage X: sherd has sharp, well-defined edges; Stage Y: sherd is becoming rounded, with local wear on body surface; and Stage Z: well-rounded sherds with the original shape uncertain. There were no major technical problems with the application of the method to the sample sherds, which amounted to 2111, again discovered in 21 contexts.

The overall site picture shows a strong preponderance of medium-level sherd erosion (64%), with rather more low-level than high-level sherd erosion (Fig. 8). This would suggest that, at the most general level, the pottery assemblage at Polgar-10 was not exposed greatly to either natural or cultural elements of transformation but that, for the most part, sherds were incorporated reasonably quickly into sub-surface features or buried on once-active surfaces.

The key question is the degree of fit of sherd erosion profiles from individual contexts to the site norm. The context-based erosion profiles are presented by context type (Fig. 9). There is a much higher proportion of contexts with variance from the site norm with the erosional data than with the pottery fragmentation information. Three pit contexts (5020, 5052 and 5070) share a far high percentage of low-level erosion than is the norm, ranging from 60–80%. This would suggest that the ceramics in these pits were incorporated rather faster than usual – an interpretation consistent with structured deposition. The opposite case – a higher-than-usual incidence of high-level erosion – is also attested in two contexts:

- 2001 surface pot and daub concentration
- 3001 cultural layer

The suggestion here is that these sherds had been on the active living surface of the settlement for a relatively long time before they were discarded into their respective contexts. The third and final variance is quite common, occurring in nine contexts – five pits (1004, 1021, 2012, 2031 and 5034), two cultural layers (0010 and 3005), one flood deposit (0006) and a surface sherd concentration (0021). These contexts share a higher-than-average frequency of medium-level erosion, varying from 77%–87% and marking an extreme dominance of the norm. The common occurrence of such sherd erosion profiles does not necessarily mean that the possibility of structured deposition is excluded from these contexts, since pottery fragmentation and deposition would seem to be part of the settlement's habitus. Yet it is in the distinctive erosion profiles that a sense of structuring is more readily grasped.

In summary, the sherd erosion profiles of a sizeable sample of Polgar-10 contexts show a strong emphasis on medium-level erosion, suggesting that material culture remained on the living surface for a reasonable amount of time before final deposition. However, a small number of contexts indicate much more rapid deposition and a slightly larger group suggests long exposure to natural and cultural processes of transformation.

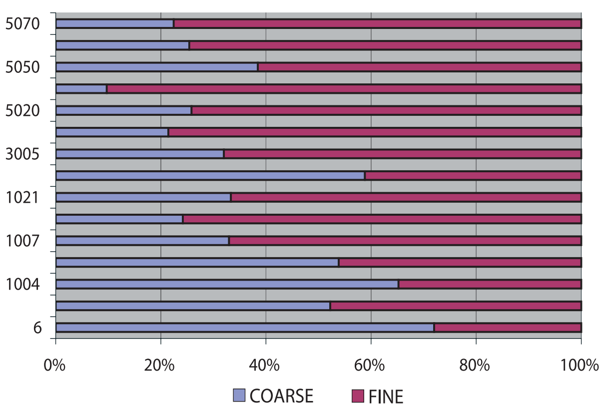

Fig. 11. Fabric distribution of rim sherds by context, Polgar-10.

Potpart analysis

The analysis of Pot Parts is based on the number of vessel parts found in each context, in comparison with the standard site norm of all the potparts. Each sherds has been classified by vessel part in eight standard categories: decorated and undecorated variants on rims, body sherds, handles/lugs and bases. For the purpose of this analysis, the very small number of unidentifiable sherds has been omitted.

The results of the analysis are presented as a series of pie-charts of sherd counts; sherd weight statistics are omitted here for the sake of brevity (Fig. 10). The site norm indicates that, as with most site assemblages, the most frequent element is the Undecorated Body sherd (overall – 76% by number), with similar frequencies of Undecorated Rims and Decorated Body sherds (Fig. 10a). Base sherds and Decorated Rims are rare, while handles and lugs fall below 1% of the sample. A total of 52 contexts or sub-contexts (mostly layers in a pit) contained sherd samples large enough for analysis. All but eight of the 52 contexts were dominated by Undecorated Body sherds (e.g., 3010: Fig. 10b). The eight contexts will be briefly discussed to examine the claim

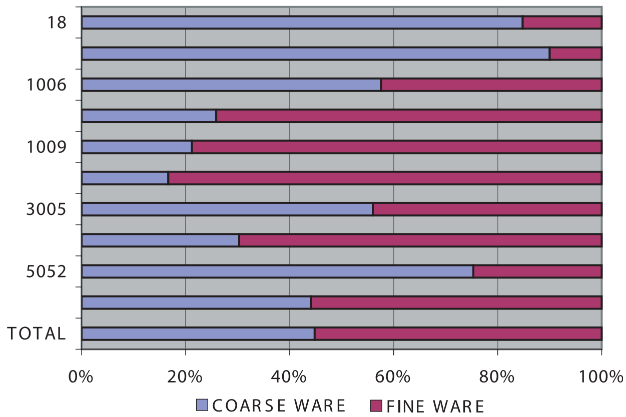

Fig. 12. Fabric distribution of decorated sherds by context, Polgar-10.

of structured deposition. Although three of the eight unusual contexts have small sample sizes (< 30 sherds), their potpart profiles remain interesting examples of unusual deposition.

Some contexts stand out for their absence of specific potparts. The part of the cultural layer excavated as Context 3006 (n = 61) was remarkable for its total absence of decorated sherds (Fig. 10c); a similar case occurs in the small sample (n = 14) from the adjacent Context 3007 – the only two site contexts without decorated sherds. A related profile comes from Context 1004 (n = 24), the only site context containing nothing but Body sherds, for the most part undecorated (Fig. 10d). While the 1004 sample is small, the unusual potpart profile raises questions of deliberate cultural selection.

By contrast, other contexts have unusually high rates of feature sherd deposition. Context 3021 – part of the fill of the boggy hollow in the centre of the excavated area – is typical of all boggy hollow fill deposits in its higher-than-average proportion of feature sherds (over 40% in sub-context 25–30 cm: Fig. 10e). This suggests that the boggy hollow is a special place for artifact deposition, marked by positive selection of decorated and other feature sherds. A similar selection occurs in Context 5020, part of the cultural layer in the Southern Zone, where Decorated Body sherds receive preferential deposition (Fig. 10f). The context with the lowest proportion of Undecorated Body sherds on site is the fill Context 0009 (Fig. 10g), with one such sherd in a small assemblage of 16 sherds. In comparison to 5–25% on most other contexts, the percentage of Rim sherds – 70% or 11 sherds – indicates strong selection, a view supported by the fact that most of the rim sherds derive from at least three, and possibly as many as five, different vessels. A similar preference in a much larger assemblage derives from the flood deposit Context 3020 (n = 432), with very high ratios of rims (34%) and Decorated Body sherds (12%) (Fig. 10h). Equally, the small sample from the cultural layer Context 3002 (n = 24) favours Undecorated Rims (18% or 4 sherds deriving from at least three vessels) (Fig. 10i). The final unusual context – the cultural layer 3001 – indicates a strong selection of Base sherds (11 examples, or 16% rather than the normal 1%) (Fig. 10j).

The general background point relating to the interpretation of the potpart data concerns vessel fragmentation (*Chapman 2000*), where a mass of data is presented on deliberate breakage of vessels and the deposition of the resulting fragments in graves and pits. Additional data supports the absence of large parts of those vessels represented by rim sherds at sites such as Nea Nikomedeia (*Pyke & Yiouni 1996*) and Wyszogrod (*Kobylinski & Moszczinski 1992*). Thus, one of the most important questions for a study of fragmentation, viz., "where are the missing parts ?", applies with equal force to the potpart profiles for any settlement context. This is a large question and we cannot expect the emergence of a satisfactory answer from the Polgar-10 data. However, even in this small-scale investigation, two cases have been recognised of preferential deposition of rims from several vessels, with one or maximum two rim sherds per vessel (Contexts 0009 and 3020). A further example concerns the pot-pit Context 2021, where nothing but the rim sherds from two or three vessels were found together with most of a storage-jar placed in the pit. A parallel case concerns the eleven Base sherds from Context 3001, representing five or six vessels with fewer than a handful of non-Base sherds found in that area. Equally, the higher-than-usual deposition of feature sherds in the boggy hollow is a sign of the structuring of material discard.

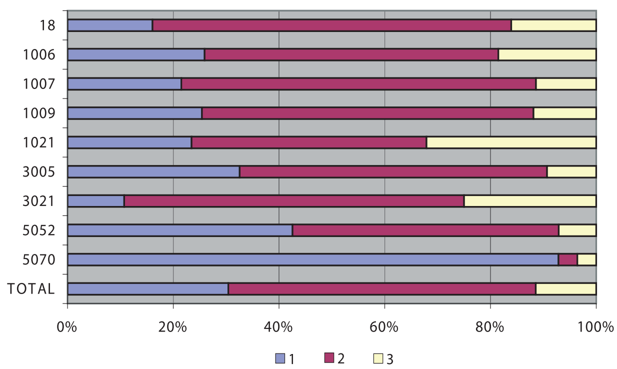

Fig. 13. Distribution of decorational intensity by context, Polgar-10.

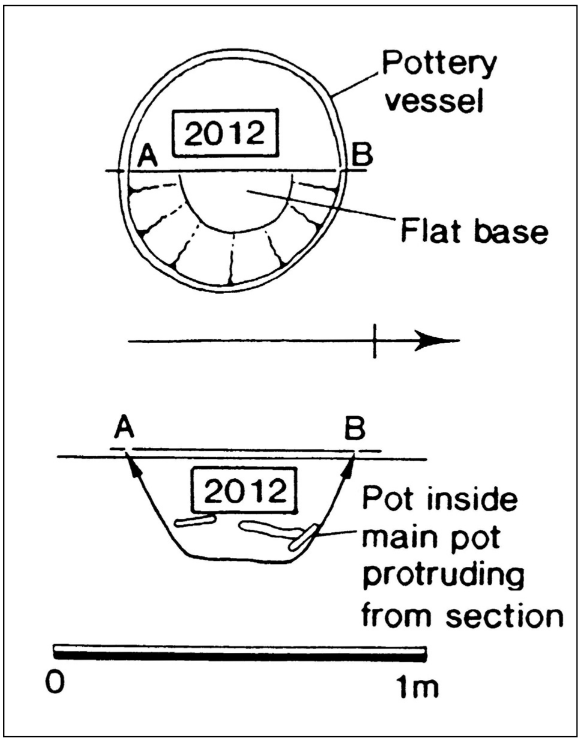

Fig. 14. Plan and section of pot-pit, Context 2012.

The principle of *pars pro toto* may be invoked here, with sherds symbolising the complete vessel and all that the vessel itself stands for in the network of social relations mediated by material culture. The absence of so much pottery from any given vessel is taken as a sign that deliberate fragmentation often preceded selection of cultural material for deposition. Potpart analysis does not yet confirm that structured deposition occurs in every context with normal selection of ceramic elements but the small number of exceptional contexts would appear to mark the strong preference for certain types of material culture consonant with structured deposition.

Fabric analysis

It has already been stated (p. 132, Tab. 2) that seven fabric categories have been identified for the rim sherds in the Polgar-10 assemblage. However, these fabric categories are too detailed for an analysis of fabric variability by context, which is, in any case, possible for only 15 contexts for rim sherds and 10 context for decorated sherds. The fabric analysis is therefore based upon the most general distinction between fine wares and coarse wares. Once again, the underlying principle is that the site norm is a representation of the *habitus* for the cultural material deposited at Polgar-10 and that variations from that norm presuppose deliberate cultural selection. The site total of decorated and/or rim sherds comprises 2412 sherds, of which 59% are fine ware sherds. In comparison with the rim sherds, 64% of which are fine wares, there is a smaller percentage of fine ware sherds amongst the decorated wares (56%).

The breakdown of rim sherds into fine and coarse fabrics is presented below (Fig. 11). There is a level of fine wares substantially higher than that of the site norm in six contexts, ranging from 74% to 92%. The small pit Context 5034 contains such a high percentage of fine ware rims that deliberate selection of this cultural material is highly probable. Equally, coarse ware rims occur much more frequently than normally in five contexts, including the shallow pit Context 0006, with 60% coarse wares. This suggests that the concept of "site norm" is not particularly useful here and that, instead, there is a bimodal distribution of contexts where either coarse or fine ware rim sherds are favoured.

In the case of decorated sherd fabrics (Fig. 12), only one context has a fabric distribution similar to that of what may be, in this case inaccurately, termed the "site norm". The decorated ware fabric profiles resemble not so much a site norm as a bimodal distribution of contexts: high concentrations of fine wares (70–83%), contrasted with contexts with high concentrations of coarse wares (57–91%). The surface sherd concentration Context 0021 has the highest proportion of coarse ware, at 91%.

What is intriguing is that fabric peaks for rims do not match those for decorated sherds in four cases (Contexts 1007, 1021, 3005 and 5070), although only one context with a high fine ware rim count is also characterised by a high coarse ware decorated sherd count (pit 5052). These mismatches support the notion of specific choices of fabrics whereby cultural messages are mediated by ceramic deposition.

In summary, the fabric choices in specific contexts present an exception to the previously robust concept of the site norm, with bimodal preferences for coarse and fine wares in different contexts. The selection of high frequencies of either fabric suggest something more structured in depositional practices.

Decorational complexity analysis

The analysis of decorational complexity seeks to measure the quantity of decoration on the surface of a pot. The analysis is a response to the proposition that the Alfold Linear Pottery group is characterised by an increase in decorational complexity through time (*Tringham 1971.128–133*). The initial data for the analysis was gathered by Jerome Edwards (*1996. 26–27, 38 & Fig. 12*).

Three classes of decorational complexity have been defined by Edwards: Intensity Level 1: very low-level density; Intensity Level 2: medium-level density; and Intensity Level 3: high-level density. The total sample of decorated sherds (n = 1128 sherds) shows a preponderance of medium-level decoration (58%), with rather more than double low-level than high-level intensity (Fig. 13). Although the results will not be presented in detail here, it should be noted that Tringham's proposition is confirmed. This means that any variations in this diachronic trend will affect individual contextual variability.

Nonetheless, at a very general level, it is possible to conclude that a higher proportion of sherds with medium-level intensity was deposited in the boggy hollow than elsewhere on site, although that was not the case with high-level intensity sherds. In the case of individual contexts, the pattern is one of considerable variability, with low-level intensity varying between 10% and 95%, medium-level intensity varying between 5% and 75% and high-level decorational intensity varying between 5% and 30%. The highest incidence of high-level intensity, well above the site norm, is found in the boggy hollow fill (Context 3021) and in the small pit 1021, while the greatest concentration of low-level intensity, again well above the site norm, is found in the Phase 1 pits 5052 and 5070.

In summary, at first sight, the diachronic trend in increasing decorational intensity would appear to make problematic any interpretation of structured deposition from these data. However, the chronological trend is a post-hoc generalisation made by archaeologists, which does not explain the quotidian practices resulting in such varied deposition. What it suggested is that the selection of low-level decoration in the early occupation at Polgar-10 was abandoned at a later date, with the development of a different set of cultural preferences. These changing preferences are best seen in those few contexts in which there are strong selections of either high- or low-intensity decorational intensity.

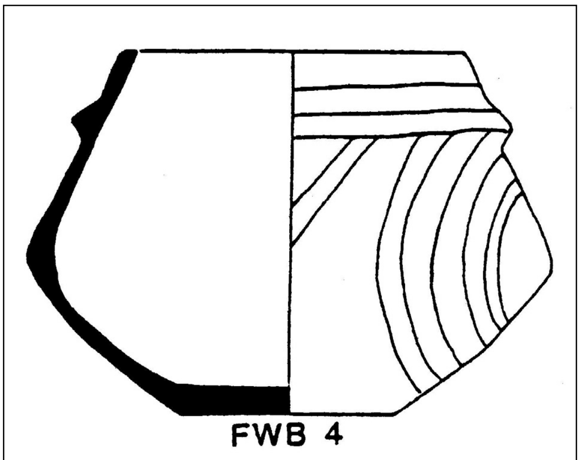

Fig. 15. Carinated bowl, placed at the base of pit Context 5021.

I now turn to the spatial and contextual aspect of the analyses, which rely not so much on statistical exploration of the *habitus* but a contextual discussion of the finds.

Deposition of whole vessels

The discovery of complete vessels in the excavated part of Polgar-10 is such a rarity that their occurrence is a sign of structured deposition. Two such vessels merit attention: the storage-jar placed in the pot-pit 2012 and the carinated dish placed in the bottom of the pit 5021.

A small pit, measuring 0.6 m in diameter and 0.4 m in depth, containing the lower part of a single vessel, with sherds from other vessels placed inside the main pot (Fig. 14). The pit has been cut into the upper surface of the flood loam and filled with the vessel. The upper part of the vessel would originally have projected above the land surface by as much as perhaps 50 cm. The large orange coarse ware Straight-Sided Jar was filled with large sherds coming from other vessels, indicating the deposition of fragmentary, partial remains of several other pots, perhaps as many as five.

Context 5021 was an irregular oval pit, containing fill varying from black to dark brown, similar to the cultural layer, measuring 1.9 m in length by 2 m in depth by 0.5 m in depth; the finds in the fill form a group of mostly undiagnostic sherds. However, on the base of the pit was placed a small carinated bowl with incised decoration (Fig. 15). This vessel, with a highly burnished surface and medium-level decorational intensity, appears to have been a foundation deposit to define the deepest deposit of the pit.

There can be little doubt that these two vessels are exceptional both in their completeness and in their contexts of deposition. They can thus be interpreted as instances of structured deposition.

Horizontal sherd concentrations

One of the most characteristic forms of deposition at Polgar-10 is the surface concentration of sherds and/ or daub. Four examples are discussed here as typical of the class of finds.

Context 0021 was a surface spread of sherds and other material, 1.2 m in length and 1m in width, resting on and slightly cut into the flood loam material of Context 0018. The context comprises the deposition of a large quantity of varied ceramics, with little else except for animal bones, where high meat values predominate for the pig bones. The relatively high values for Large and Medium sherds suggest deliberate deposition on the surface of the flood loam, an interpretation not contradicted by the erosion data. The main characteristics of the pottery are the high values for coarse wares and the variety of decorative motifs in a reasonably small sample.

Context 1003 was a shallow scoop, incompletely excavated, in the North East part of the trench AJ14P, at least 1.5 m in length and 1m in width and 0.07 m in depth. The fill consisted of fine grey sandy loess, probably re-deposited. The large quantity of finds, especially pottery, for such a small feature suggests deliberate deposition or in-washing of the finds from a surface in close proximity to the pit.

Context 2001 comprised a surface concentration of pottery and daub, measuring 5 m in length, 3.5 m in width and 0.1 m in depth. The main feature was a deliberate deposit of a fairly large quantity of ceramics and daub, with a more varied size profile than usual and a very small proportion of feature sherds. The narrow range of finds classes suggests a specialised deposit, incorporating sherds which are more eroded than usual.

Context 3008 was a small, shallow pit, with an ashy fill derived from a hearth, measuring 0.8 m in length by 0.8 m in width by 0.05 m in depth, which may have been truncated through machine excavation of the upper part of Context 3001/3004.. There is a high rate of discard, especially ceramic, for such a small pit, including a very high proportion of decorated sherds. The lack of identifiable animal bones and the absence of lithic remains suggests a rather specialised deposit, as does the incorporation of two of the largest daub fragments found on site.

These contexts share the high density of pottery and/ or daub in a confined space, with additional criteria which lend support to the idea of deliberate deposition.

Vertical sherd concentrations

There is strong evidence for the structured deposition of material culture at the beginning of a sequence of deposition (e.g., the base of a pit) and/or as the closing deposit (e.g., the very latest deposit in a pit fill) (*Chapman 2000a*). There are only a few examples of this class of deposit at Polgar-10. One example has already been mentioned – the placing of a whole carinated bowl in the very bottom of pit 5021 (see above, p. 139 and Fig. 15). Two further deposits consist of fills designed to close pits.

Part of Context 0006 comprises a concentration of potsherds in the upper fill of a shallow pit, some 2.2 m in length, 1.1 m in width and 0.15 m deep. No or very few finds at the base of the pit, in primary fill; almost all finds occur on the ground surface of the flood loam, indicating deposition at the very end of the life of this pit. Erosion is hardly likely to have occurred through significant movement of the finds into the area of the pit. Thus, the finds represent the remains of *in situ* deposition of not only pottery but also a large quantity of daub, suggesting the proximity of a structure. The sherd fragmentation data supports this interpretation, with the relatively high incidence of Very Large and Large sherds. The strong emphasis on coarse wares with low-intensity decoration, in a wide variety of pot parts, suggests that the majority of vessels were not for public display or consumption. Yet the large number of shape subtypes for a relatively small sample of rim sherds (1 new sub-type per every two rim sherds) suggests a large number of vessels was deposited here.

Part of Context 0007 consists of a concentration of potsherds at the very top of a small, shallow pit, 0.6 x 0.6 x 0.25 m in size. The pit has been truncated and contains mostly sherds from the same vessel. Although the pit was large enough for a single coarse ware vessel, this was not a pot-pit as seen elsewhere on site but, rather, many sherds from one vessel were deposited in the uppermost part of pit fill, which had itself been previously truncated, perhaps also related to site flooding. Many more sherds were also deposited, perhaps at the same time as the sherds from the same vessel, and this spread extended over a wider area than just the pit zone. When encountered at other Neolithic sites, such as Opovo, in the Vojvodina (*Russell 1994*), such examples of vertical sherd concentrations have been interpreted as the material remains of periodic rituals, possibly seasonal, which mark the beginning or the completion of the cycle of pit digging and filling.

Association of pottery with other finds in structured deposits

Since the vast majority of contexts with evidence for structured deposition at Polgar-10 involve ceramics, there are few remaining contexts to discuss.

One such is Context 1009 – a concentration of animal bones, pottery and shell, deposited on the North side of Context 1008, near the base of the fill of the boggy hollow" and directly above the carbonate loess. The concentration measures 1.5 m in length, 0.75 m in width and 0.15 m in depth. The most concentrated zone for the deposition of animal bones in the excavated part of the site, with a large number of sherds, mostly small- and medium-sized Fine wares with incised decoration, indicating the likelihood of deliberate placement of these bones, some of which were still articulated. The strong emphasis on medium-level erosion indicates that few of these sherds had been transported over a long distance, into a secondary position. The absence of lithic remains suggests that this area was specifically devoted to the disposal of bones and sherds, although the occurrence of large daub fragments suggests the presence of a structure in the vicinity.

It may be suggested that the social practice of deposition of animal bones and shells in the boggy hollow also included the placing of ceramic fragments so as to associate the different classes of material culture.

Juxtaposition of contrasting finds

There is a wide range of sites in the Balkan Neolithic and Copper Age with well-documented examples of the use of binary oppositions to make statements about human categorisation processes (*Chapman 2000a*). These contexts may involve one of several contrasts: nature: culture, upper fill: lower fill; or left side of pit: right side of pit. Another practice involves cyclical or repeated deposits of two different classes of material: at one of the Early Neolithic shafts at Endrod 119, dark black organic matter and pure yellow loess (*Makkay 1992; Chapman 2000a*).

There is only one such example excavated so far at Polgar-10: the shallow pit Context 3009, whose ashy fill, derived from a (nearby) hearth, measures 3 m in length by 1 m in width by 0.05 m in depth. In contrast to the ash-filled pit Context 3008 with a proliferation of finds (see above, p. 140), there were no finds in this pit. The juxtaposition of two small ash-filled pits – one with a high density of finds and one with no finds at all – would appear to represent an example of binary categorisation, in which different individuals or groups are associated with the multiplicity – or absence – of material culture.

DISCUSSION AND CONCLUSIONS

This article has sought to demonstrate the potential of a wide range of methodologies for the investigation of structured deposition on Neolithic settlements. The discussion will be focussed around two questions: (1) how well do these methodologies work? and (2) how can the deposits at Polgar-10 be interpreted in the light of these methods?

The methods presented and used in this study are of potentially widespread applicability for anyone who seeks to study Neolithic ceramics in these ways. The most important aspect of all the ten methods discussed here is that they require little additional data collection to the normal recording of any advanced ceramic analyst. The author has found no technical problems with any of the methods; the analyses relating to the ceramics presuppose categorisations, which could, in theory, be developed empirically for each site. My general conclusion is that any ambiguities remain at the interpretative level.

The first question concerns the statistical gloss on the concept of *habitus* – an analytical device which may not meet with Bourdieu's approval. The general issue is whether or not we are entitled to infer traditional practice from a suite of activities, which have repetitive material consequences which are measurable and quantifiable. The difficulty here is that the activities leading to material deposition may be so varied that it would be unconvincing to include all practices within the term "*habitus*". Nonetheless, it can be maintained that practices such as pottery firing and burnishing to create such and such a range of fabrics would be considered as part of the core of cultural traditions – and therefore central to the *habitus* – by students of material culture as well as ethnographers; hence, the archaeological remains do result from the core activities in the *habitus*. If the practice of deliberate fragmentation can also be demonstrated as a practice central to the *habitus* of the Neolithic and Copper Age of Central and

CONTEXT	SHERD SIZE	EROSION	POTPARTS	FABRICS	DECORATIONAL INTENSITY	WHOLE POTS	HORIZONTAL CONCENTRATION	VERTICAL CONCENTRATION	ASSOCIATIONS	CONTRASTS
6	Very Large			High CW Rims				Vertical		
7								Vertical		
9			very few Undeco-rated Bodies							
18				High CW Rims &Dec.	Medium-Intensity					
21				High CW Dec.			Horizontal			
1003	Small						Horizontal			
1004	Small		all Bodies	High CW Rims						
1006				High CW Rims & Dec.						
1007				High FW Dec.						
1009				High FW Rms and Dec.					with animal bones	
1021				High FW Dec.	High-Intensity					
2001	Very Large	High-Intensity					Horizontal			
2012	Very Large					Whole Pot				
2031				High CW Rims						
3001		High-Intensity	Base sherds							
3002			Undecorated Rims							
3005				High CW Dec.						
3006			no decorated sherds							
3007			no decorated sherds							
3008							Horizontal			contrast
3009										contrast
3010	Small									
3020			lots of Rims/ Decorated Bodies							
3021			feature sherds	High FW Rims & Dec.	High-Intensity					
5020	Small	Low-Intensity	Decorated Bodies	High FW Rims						
5021						Whole Pot		Vertical		
5034				High FW Rims						
5052				High FW Rims/CW Dec.	Low-Intensity					
5070				High FW Rims	Low-Intensity					

Tab. 3. Summary of evidence for deliberate deposition by context.

Eastern Europe, then many of the analyses relating to fragment size and erosional conditions may also represent ways of measuring the *habitus*. It will also be maintained that the spatial practices which charactise deposition at Polgar-10 are also part of the habitus of the community, indeed related to the wider cultural traditions of Alföld Linear Pottery dwelling. If the technological and depositional practices typical of Polgar-10 are accepted as portraying the *habitus* of that community, then the methods used here to analyse the variability of such practices are, *pari passu*, a preliminary and probably over-simplified way of measuring the *habitus*.

I have mentioned already that each of these methods carries with it an interpretative ambiguity; perhaps this is inevitable with prehistoric cases. An example concerns the sherd size analysis. The variable of sherd size is dependent upon many aspects of material practice, from the size of the vessel to the way it is stored/kept and any post-use practices. There will be some uncertainty over an interpretation of deliberate deposition of sherds whose size varies widely from the site norm. But if a context with such a sherd size profile shows other indications of structured deposition, the sherd size profile may well be used as supporting evidence. In terms of interpretational ambiguity, the most problematic single measure would appear to be the decorational intensity analysis, which apparently has to cope with diachronic changes in intensity. However, these chronological changes are themselves caused by variations in the *habitus* which deserve an explanation – i.e., rather more than an assertion that such decorational changes occur because of the passage of time.

I present a summary of the indices of potential structured deposition (Tab. 3). This summary demonstrates three points: (1) almost 40% of all of the excavation contexts at Polgar-10 show some signs of evidence for deliberate deposition (29/73); (2) half of the these contexts show two or more signs of deliberate deposition in their ceramic finds (14/29), with one context (5020) showing as many as four converging lines of evidence; and (3) two-thirds of the contexts show evidence relating to ceramic aspects of deliberate deposition only (19/29), with only six contexts with evidence from both ceramic *and* spatial analyses. These summary statistics demonstrate that there is potentially quite a wide occurrence of deliberate deposition on this settlement and that many of the contexts have converging lines of mutually-supportive evidence. It will be left to the reader to decide whether or not these figures support the notion that deposition of material culture is part of the broader framework of the *habitus*. But I wish to propose that the contextual evidence from this settlement lends some support to this case.

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