Environmental Archaeology in Southern Scandinavia

Kurt J. Gron and Peter Rowley-Conwy

1 Introduction

In this contribution we examine environmental archaeology in southern Scandinavia, the part of Europe in which it was first developed. Our perspective will be that ever since the dawn of prehistoric archaeology, environmental archaeology has been central to it – not an ancillary ‘scientific’ subdiscipline. Some of the most prominent theoretical positions held by ‘conventional’ archaeologists over the past century have in fact been based on the findings of environmental archaeology. Furthermore, findings and theories promulgated by practitioners in southern Scandinavia have been extrapolated to other areas of Europe and the wider world.

This runs counter to the perspective taken in many histories of archaeology; but such histories are usually written by ‘conventional’, not environmental, archaeologists. We will however demonstrate that most information on ‘what life was like’ in the past comes from environmental work. The major conflicting views on such issues as whether agriculture appeared due to indigenous adoption or immigration derive largely from the findings of environmental archaeology. Those who argue that theoretical posturing sets the archaeological agenda need to accept that environmental archaeology just as often sets the theoretical agenda.

We define ‘environmental archaeology’ broadly. It comprises not just the classic palaeoeconomic studies of animal bones (zooarchaeology) and plant remains (archaeobotany). Vegetation history and palynology have been of central importance since the earliest days of the discipline, and geoarchaeology has also had a major impact. Recent decades have seen the appearance of three major new methodologies: the study of DNA, both ancient and modern; of isotopic analysis of organic materials, including human and animal bones; and of lipid residues in

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ceramics. Since these all provide information regarding human modification of the landscape, subsistence practices, and economic changes, we class them all as environmental archaeology.

We will start with environmental archaeology's origins as a discipline in a southern Scandinavian perspective. We will then narrow our focus to encompass its methods as applied to the question of agricultural origins in the region at ca. 4000 B.C. The methodological approaches described, of course, have been applied to numerous and disparate archaeological questions, but the 'why', 'how', and 'who' questions regarding farming's start have proven the basis for arguably the most coherent, persistent, and long-term debate for which there is still no consensus opinion. As such, the discourse and applied environmental archaeological methods have been intricately linked from the start.

We stress that what follows is a personal viewpoint. We are prehistoric archaeologists, and we recognise that we emphasise work in the earlier chronological periods while glossing over much that has been done on the archaeology of the more recent periods. This is not because we consider the later periods unimportant, but it simply reflects the twin constraints of space and lack of expertise. Others are more competent than we are to remedy this deficiency.

2 The Early Development of Environmental Archaeology: 1842–1970

2.1 1842–1851: The Creation of Environmental Archaeology

Environmental archaeology began in the early 1840s. Some related work had begun earlier – the Swedish zoologist Sven Nilsson, based in Lund, identified a pig canine tooth from a passage grave excavated in 1819 (Nilsson 1822), and some years later he argued that people in the Stone Age defined by C.J. Thomsen (1836) were hunter-gatherers (Nilsson 1835). But the first hands-on environmental archaeologist was J.S.S. Steenstrup (1813–1897).

Japetus Steenstrup was a natural historian with broad interests. His first venture was into the stratigraphy of peat bogs. During his formative years, the dominant figure in Danish geology was Georg Forchhammer, a catastrophist of the old school who believed that the earth had gone through repeated convulsions in the relatively recent past. What we now recognise as glacial moraine underlay the Danish peat bogs, and Forchhammer believed it had originated in a catastrophic flood emanating from Sweden that had swept over Denmark (Forchhammer 1835). Another huge flood wave engulfed Denmark in later times, felling numerous trees, some of which survived in peat bogs with their trunks all aligned in the direction of the wave (Forchhammer 1844).

Steenstrup's achievement was to use detailed observations to demonstrate that Forchhammer was wrong. In so doing, he laid the foundations for all subsequent

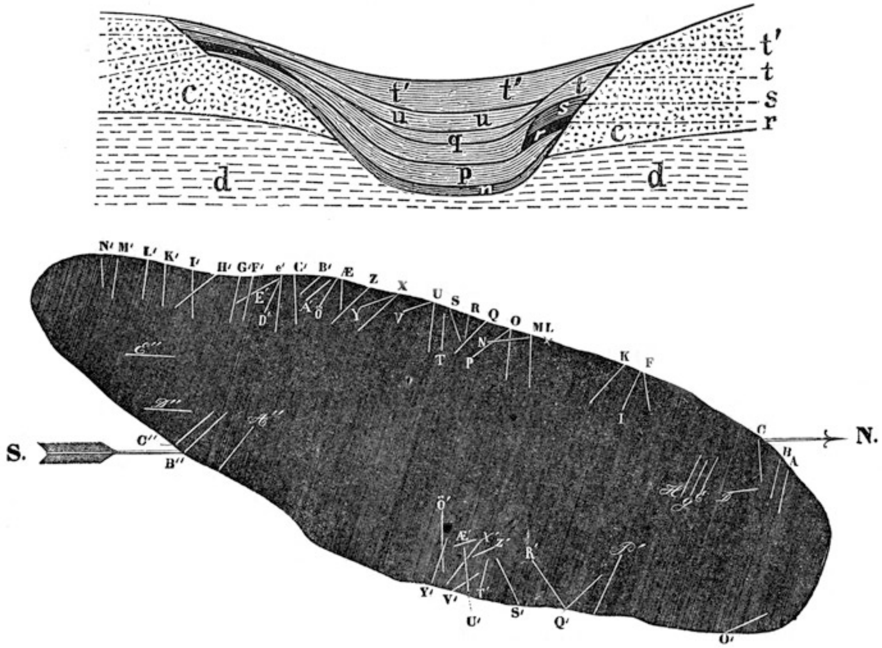

Fig. 1 Top: Steenstrup's section through Lillemose bog, showing the forest layers (From Steenstrup 1842: Fig. VII). c: gravel with boulders; d: gravel layer, the base of the bog; r, s, t: edge deposits formed by trees falling into the bog; r: layer of pine fragments; s: layer of oak fragments; t: layer of alder fragments; n: the aspen layer; p: the pine layer; q: the oak layer; u: layer of *Hypnum proliferum*; t': the alder layer. Bottom: Steenstrup's plan of the fallen pine trees in Sneglekjær bog, showing their alignment towards the centre. This small bog measured only some 140 m along its longest axis (From Steenstrup 1842: Fig. VIII)

palynological studies. The Royal Danish Academy of Sciences and Letters had offered a prize for the best essay on why there were remains of pine trees (not native to Denmark) in Danish peat bogs, then being dug out for fuel. Steenstrup examined the Vidnesdam and Lillemose bogs north of Copenhagen, and his prize-winning essay was published in 1842 (Steenstrup 1842). He observed two vital things. First, the pine trees occurred in a discrete layer quite low down in the bogs. Below the pine layer was a layer of aspen. Above the pines was a layer of oak, above them again a layer of alder (Fig. 1 top). Beech trees dominated the nineteenth-century Denmark, but were rarely found in peat bogs. Steenstrup had identified what we now recognise as the postglacial forest succession – although it was not yet understood that glaciers had once covered Denmark. Second, the trees preserved in peat bogs did *not*, as Forchhammer had claimed, all point in the same direction: their crowns pointed towards the centre of the bogs, demonstrating that they had fallen naturally, presumably at different times (Fig. 1 bottom). The process was therefore gradual, not catastrophic, involving the same processes that are at work today. This is the essence of geological uniformitarianism.

Steenstrup estimated that each of his five forest stages – aspen, pine, oak, alder, beech – spanned at least one or two millennia, thus giving a time depth of up to 10,000 years. This was remarkable, because in Vidnesdam bog he found a human-made artefact in the oak layer (Steenstrup 1842, Fig. 3). Soon after, he found evidence that pine trees in the layer below had been deliberately felled and burnt by people (Steenstrup 1848a [1851, 25]). This pushed the human presence in Denmark back to perhaps 8000 years, far longer than the Biblically derived chronology could admit. This was the first 'long' chronology proposed for humankind based on any reliable scientific evidence.

Shell middens were recognised as human settlements in 1850, as the result of work by the 'Lejre Committee', or (retrospectively) the 'First Kitchen Midden Commission', formed in 1848. This comprised Steenstrup, Forchhammer, and the youthful archaeologist J.J.A. Worsaae. Twentieth-century histories of what happened usually present Worsaae as the leading light; Steenstrup (if mentioned at all) is described as the specialist zoologist who assisted Worsaae (e.g. Gräslund 1987, 34–5; Klindt-Jensen 1975, 71–2; Schnapp 1996, 302–3). This however tells us more about the structure of later twentieth-century archaeological projects than about what the Lejre Committee did. It was undoubtedly Worsaae who first came fully to the conclusion that the middens were waste discarded after consumption by people – kitchen middens or *køkkenmøddinger* (Petersen 1938) – but most of the supporting evidence and the subsequent ideas came from Steenstrup.

In 1848, shell heaps on land were expected to be natural banks, now above sea level because the land had risen. The great Linnæus himself had in 1746 examined the huge shell banks at Uddevalla on the west coast of Sweden, which accumulated without any human involvement (Linnæus 1747 [1928, 218–223]). Steenstrup had however found Stone Age flint blades in a shell midden as early as 1837, which placed the middens (like the oak and pine layers in the peat bogs) within the period of human occupation of Denmark (Steenstrup 1848b). In early 1851 Steenstrup presented the joint results of the 1850 fieldwork to the Academy (Worsaae could not do this because he was not yet a member). Worsaae had worked at Mejlgaard, Steenstrup at Havelse and Bilidt; their results were identical, Worsaae's idea causing everything to fall into place. Bivalves such as oysters lay with their halves separated, but their edges were not worn, so they had not been washed up onto dry land by huge storms. Furthermore, they lay intermingled with ash, charcoal, fishbones, heated stones, etc. There were numerous stone tools and animal bones. Steenstrup noted that the bones were sharp-edged, not rolled; they were smashed for their marrow; some had been burnt, but *after* they had been broken; and many antlers showed signs of cutting. The animals were deer and wild boar, with no domesticates; some bones were dog-gnawed, so dogs were the only domestic animal (Steenstrup 1851).

Steenstrup even sketched out the methods he would use to examine settlement seasonality (Steenstrup 1851). In 1869 he gave a lecture demonstrating that the shell middens were occupied all year. Red and roe deer antlers were in all stages of growth, and some were shed; bird bones of both winter and summer migrants were found; but most tellingly he had procured a collection of modern pig mandibles of precisely known ages, slaughtered at monthly intervals up to 14 months of age:

> If we now compare these with the jaws of the wild boar that the ancient inhabitants consumed, we find that at one and the same place wild boar piglets were eaten aged 1 month, 2 months, 3 months etc all through the year; thus the people also stayed in one and the same place all through the year. (Steenstrup 1870, 15, translated by PR-C)

Steenstrup's work dealt with human behaviour which he had elucidated, in a landscape which he had reconstructed. This identifies him as the first practicing environmental archaeologist in Europe.

2.2 1900–1916: Placing People in Time and the Landscape

These years saw the earliest Danish settlement evidence pushed back into Steenstrup's pine period and also saw some shell middens brought into the later era of farming. Both these developments were as the result of classic environmental archaeological studies.

The Second Kitchen Midden Commission was established in 1893, under the leadership of Sophus Müller. It excavated eight shell middens, the results being published in 1900 (Madsen et al. 1900). The largest excavations were at Ertebølle, which has become the eponymous type-site of the Late Mesolithic period. The work of the Commission was characterised by careful excavation: finds were recorded by square metre and 20 cm excavation spit, and ceramic conjoins between squares were plotted to show the surface of the midden at particular points in time (Müller, in Madsen et al. 1900, 72–75). The conclusions of Worsaae and Steenstrup were confirmed and extended: the middens were dwelling places occupied throughout the year, based on the seasonality determinations of the zooarchaeologist Herluf Winge.

Perhaps the most notable achievement was the Commission's demonstration that only five of their middens were Mesolithic – the other three were Neolithic (though they did not use those terms but rather 'Older Stone Age' and 'Younger Stone Age'). A few polished stone axes and decorated ceramics turned up on the surface of the Mesolithic middens, but were found throughout the Neolithic ones. Very few of these were illustrated; however, the publication laid greater stress on the animals and plants. In the Neolithic middens, Winge identified mainly domestic cattle, pigs, and sheep, contrasting with the deer and wild boar in the Mesolithic ones. He distinguished between wild boar and domestic pig on size: lower third molar displayed hardly any metrical overlap (Fig. 2 top). Neolithic people also cultivated cereals. At all three Neolithic middens, Georg Sarauw identified impressions of wheat and barley in the ceramics, and the Leire Aa midden yielded a sample of 48 charred grains of barley, probably six-row (mentioned by Neergaard, in Madsen et al. 1900, 144, 157, 171). This realisation that some shell middens were of Neolithic date was to have far-reaching ramifications through the twentieth century.

The middens produced other charcoal as well. The project's botanist, Emil Rostrup, identified many to species. He identified 295 fragments from Ertebølle, of which 218 were oak; no pine was found (Rostrup, in Madsen et al. 1900, 90) (Fig. 2 bottom). This established a chronological link between the shell middens, which

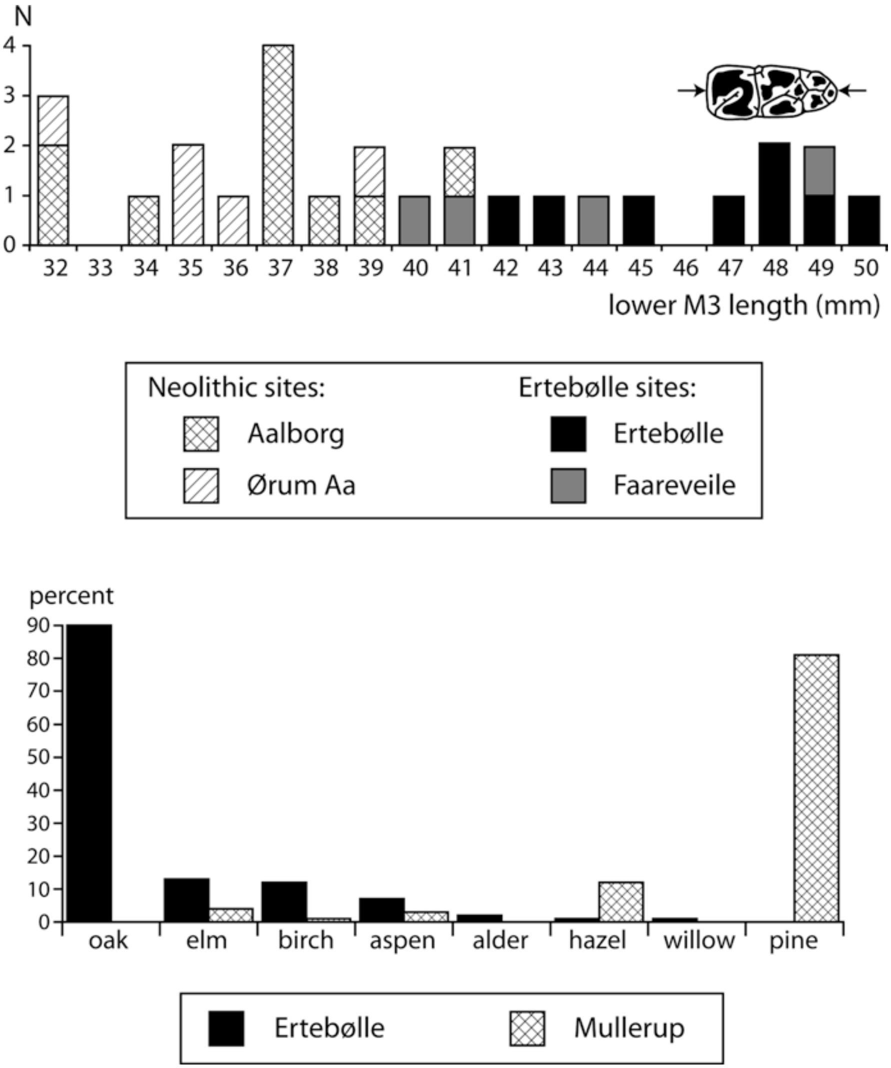

Fig. 2 Top: measurements of *Sus* lower M3, showing the size difference between wild boar and domestic pigs from the Mesolithic and Neolithic shell middens excavated by the Second Kitchen Midden Commission (from Winge, in Madsen et al. 1900, 87, 122, 145 and 160). Bottom: frequencies of identified charcoal at Late Mesolithic Ertebølle (from Rostrup, in Madsen et al. 1900, 90) and Early Mesolithic Mullerup (from Rostrup, in Sarauw 1903, 188). Rostrup's Ertebølle figures are the percentage of the 560 square metres excavated in which the species was found; the Mullerup figures are the percentages of the 1033 identified fragments of charcoal

were on the raised beaches of the maximum postglacial marine transgression, called (then and now) the Littorina Sea, and Steenstrup's oak forest period.

When the Second Kitchen Midden Commission's volume went to press, the Mesolithic shell middens were the oldest sites known in Denmark. In 1900 however Georg Sarauw excavated Mullerup in the Maglemose bog ('Maglemose' means simply 'large bog' in Danish). Mullerup produced three classic environmental archaeological studies, concerning, respectively, its date, its geomorphology, and its landscape context.

The dating of the site proved that Steenstrup had been right in 1848 when he claimed that some pine trees had been felled by humans. Sarauw (1903) rapidly concluded that Mullerup was older than Ertebølle. The absence of pottery suggested a very early date (ceramics were common in the Ertebølle middens). 1033 fragments of waterlogged wood and bark were collected during the excavation, and Rostrup identified them: 835 were pine, 120 were hazel, and 45 were elm; not one was of oak (Rostrup, in Sarauw 1903, 188) – completely different from the proportions at Ertebølle (Fig. 2 bottom). Recent work in Sweden had demonstrated that the first hazel and elm appeared late in the pine period, so Sarauw concluded that Mullerup dated to late in the pine period (op. cit., 289). A freshwater lake, the 'Ancylus Lake' (Munthe 1892), had preceded the Littorina Sea, and most trees dredged up from the submerged Ancylus forests were indeed pine. This agreed with the animal bones: Herluf Winge identified black woodpecker (*Dryocopus martius*), a species characteristic of pine woodland (Winge, in Sarauw 1903, 195). Among the mammals, elk and aurochs were common, and these had previously been found at other Ancylus period sites. Sarauw believed that the elk was extinct in Denmark by the end of the pine period (op. cit., 291); it is now known to have survived on the Jutland peninsula, but he was correct that it had disappeared from Zealand (Aaris-Sørensen 1980). Mullerup thus dated to the pine period, corresponding to the Ancylus Lake.

Mullerup's local geomorphology was unravelled by a multidisciplinary team. Organic items were spectacularly well preserved in the waterlogged peat. All the specialists concurred that the peat had formed in an ancient lake. Above the basal moraine was a layer of blue clay, identified by the geologist Nikolai Hartz as probably late glacial (Hartz, in Sarauw 1903, 158). Above this came a layer of mud, identified by the limnologist Carl Wesenberg-Lund as forming in shallow lake water (Wesenberg-Lund, in Sarauw 1903, 159–160). The upper part of this mud contained numerous snail shells, which Valdemar Nordmann identified as inhabiting lake water a metre or two deep (Nordmann, in Sarauw 1903, 160). Above the mud came the peat. Sarauw concluded that the lower part of the peat, which contained the artefacts, formed in open water because it contained open-water plants like waterlilies. Above this were the matted roots of the common reed (*Phragmites communis*), which grows in marshy lake edges. And above this the peat was full of the roots of sedges. This sequence clearly showed that the ancient 'Lake Maglemose' was filling with dead vegetation, turning from open lake to bog (Sarauw 1903,162).

Mullerup's landscape context was however a problem for Sarauw: how could a settlement be in peat laid down in open water? The peat did not dry out even seasonally, because the waterlilies required continuous submergence. He considered various options (op. cit.: 175–85). The first was that he had found a lake dwelling like those in Switzerland, believed to be villages built on piles over open water (Keller 1854). Such a village required some 50,000 wooden piles to support it; but no such piles were present in the Maglemose, and there were no post holes in the lake bed. The next possibility was an artificial island or crannog, like those in Scotland (Munro 1882) and Ireland (Wood-Martin 1886), but once again the mass of stone and timber that would have been piled on the lakebed should have survived. Finally, Sarauw speculated that people had camped on the ice during winter, so the cultural debris sank to the lake bed when the ice melted in spring – but this did not work either because Winge's zoological study showed that Mullerup was occupied in *summer*. Some species were summer visitors – in particular red kite (*Milvus milvus*) and crane (*Grus grus*). There were also bones of ducklings so young that they were summer fledglings. Sarauw knew that these bones might occur naturally in the lake sediments and not be an indicator of settlement seasonality, but since one of the duckling bones bore cut marks made with a stone tool, this could be ruled out (op. cit.: 177, n. 1). Sarauw was forced into the conclusion that people lived on a floating raft and dropped artefacts into the water. He admitted that there was no evidence for such a raft, but he was unable to explain the site in any other way (op. cit.: 177–8).

Sarauw's problem was soon solved, through the earliest scientific reconstruction of a non-coastal prehistoric hunter-gatherer landscape. This was the work of one of the most significant figures in the history of Danish environmental archaeology: the palynologist and botanist Knud Jessen.

In 1903 Carl Neergaard excavated another settlement at Mullerup, just over 100 metres from the one Sarauw had excavated. The geologist Lauge Koch undertook a major landscape study in 1915, with assistance from Knud Jessen (Koch 1916). Koch excavated a trench next to Neergaard's and took cores along two transects across the bog (Fig. 3). The sites were not in open water, but on the flanks of two barely discernable small islets or holms, now known as 'Sarauw's holm' and 'Neergaard's holm', respectively. These were low rises in a morainic ridge projecting out into the contemporary lake. Jessen cut a trench to the west from Koch's excavation, and this was crucial in placing the site into its landscape context. On the top of Neergaard's holm, the peat layer dwindled to just a couple of centimetres in thickness, and the archaeological finds were more tightly packed (Fig. 3 middle). A couple of preserved tree stumps were found there, indicating tree growth on the top of the holm; stone tools occurred among their roots (Koch 1916, 7–8). Jessen's trench traced the peat layer out into the former lake. On top of the holm, it was forest peat, indicating rather soggy dry land. This metamorphosed into sedge and reed peat, which would have grown on the waterlogged lake shore, and then into lake peat, indicating open water (Koch 1916; Jessen 1935a, b, 5–13). Jessen placed the contemporary lake shore at about the 4 m contour, allowing the landforms to be plotted accurately (Fig. 3 top). This demonstrated that parts of both sites had lain on moderately dry land. Jessen also recovered artefacts from the lake (Fig. 3 bottom). Jessen and Koch concluded that people had actually lived on the tops of the holms, where their excavation had found traces of hearths. The material in the deeper peat was rubbish dumped off the edge of the settlement, into the lake (Koch 1916, 11). Sarauw's floating raft was no longer required; the holms were the actual living sites.

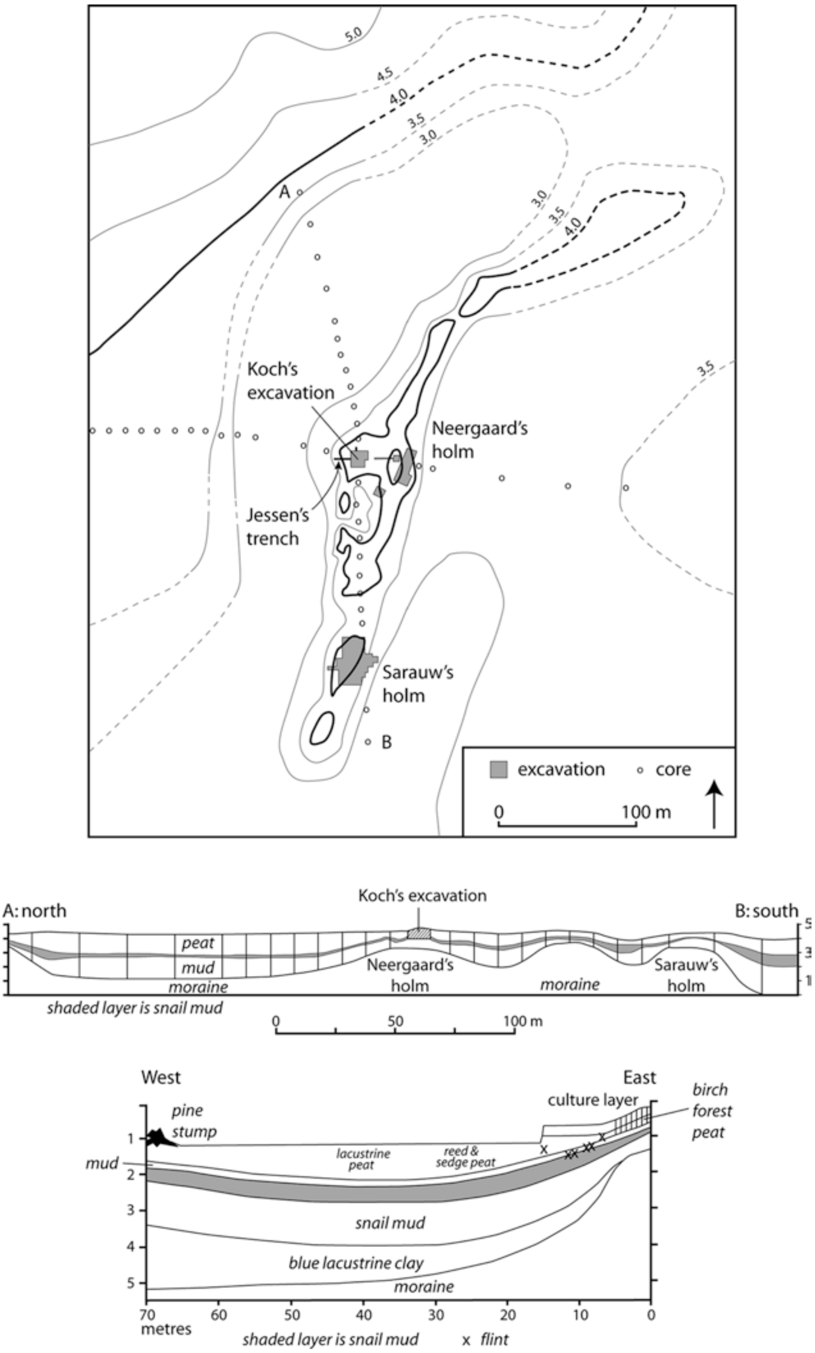

Fig. 3 Top: contour map of the Mullerup region of the Maglemose bog, showing the excavations, coring locations, and the contour lines above present sea level that this established. The emphasised 4 m contour was identified by Jessen as the lake shore at the time of occupation (Redrawn and modified from Koch 1916: Fig. 1). Middle: profile established by the core line A–B, showing the two holms or islets in the prehistoric lake (Redrawn and modified from Koch 1916: Fig. 2). Bottom: profile from Jessen's trench, measured by him in 1915 but not published until later (Redrawn and modified from Jessen 1935a: Fig. 1)

This work by Jessen and Koch marked a spectacular departure in environmental archaeology. For the first time, a settlement site in the interior was placed in its landscape context. Jessen's lake-edge model saw considerable refinement in the 1920s (see Rowley-Conwy 2010) but has stood the test of time and still forms the basis for our understanding of the landscape context of such sites.

2.3 1916–1937: Developing the Environmental Chronology

Work continued on Steenstrup's forest epochs. The Norwegian Axel Blytt had proposed that the four main phases represented alternating periods of dry and wet climate: the Boreal, a dry phase, corresponding to Steenstrup's pine period; the Atlantic, a moist phase with oak and other deciduous trees; the Sub-Boreal, drier and warmer, seeing a forest recession; and the Sub-Atlantic, humid and cool (Blytt 1876). Initially greeted with scepticism, this scheme was taken up by the Swede Rutger Sernander, who demonstrated its correctness in a series of peat bogs in Sweden, Denmark, and Northern Germany (Sernander 1908, 1909). This came to be known as the 'Blytt-Sernander' scheme (see Iversen 1973, 13–14). This zonation worked well where the stratigraphy was clear; a case in Sweden where it was *not* clear led the Swede Lennart von Post to develop pollen analysis.

Von Post (1916) faced a problem in Lerbäck bog. In its NE part, he identified all four Blytt-Sernander phases using conventional macroscopic remains. But the SW part of the bog comprised *Sphagnum* peat, which could not be assigned to phase. Von Post used pollen analysis to date this part of the bog, stating that he developed the technique himself for this precise purpose (von Post 1916, 262). Figure 4 (top) shows (right) von Post's pollen diagram confirming his attribution of the NW sequence in the Blytt-Sernander scheme and (left) his diagram (his Fig. 9) in the *Sphagnum* peat area. He argued that the major rise in pine at the top of the left diagram was not visible in the right diagram. Sample 1 in the right diagram corresponded to between samples 3 and 4 in the left diagram. The bottom of the left diagram corresponded to samples 2 and 3 in the right diagram. This neat technique allowed von Post to date the formation of the two parts of Lerbäck bog and show that they did not overlap much in time.

Pollen analysis was rapidly adopted in Denmark. Knud Jessen (1920) used it to confirm his layer attributions in Sækkedam bog. He subsequently developed the full numerical scheme that remains in place today, in which the late glacial phases I, II, and III refer to the Early Dryas, the Allerød, and the Younger Dryas, respectively, followed in the postglacial by IV (the Pre-Boreal), V and VI (the Boreal, with pine trees), VII (the Atlantic, with mixed oak forest), VIII (the Sub-Boreal, with a recession in mixed oak forest), and IX (the Sub-Atlantic, seeing an increase in beech and sometimes pine) (Jessen 1935b). Jessen's first diagram using these phases came from Brøndum bog and spanned the entire lateglacial and postglacial (Fig. 4 bottom). He used the precision of his scheme to date archaeological items found in

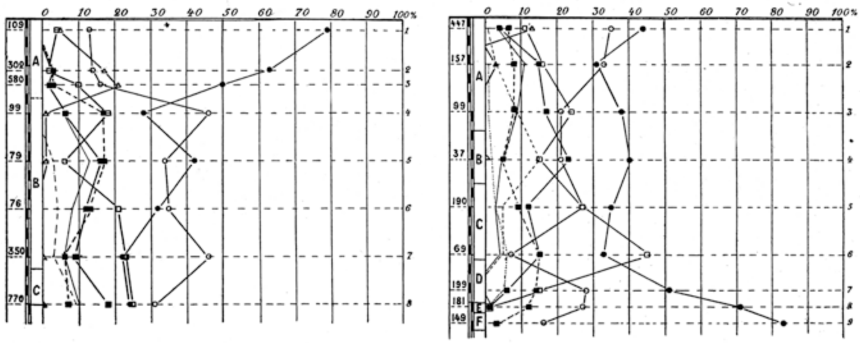

Fig. 10. Das Lerbäcker Moor. Pollendiagramm m 274.

A. Jüngerer Sphagnumtorf.
B. Älterer Sphagnumtorf.
C. Bruchwaldtorf.

Fig. 11. Das Lerbäcker Moor. Pollendiagramm m 1002.

A. Bruchwaldtorf.
B. Sandiger Torf der Bachrinne.
C. Bruchwaldtorf.
D. Seedy.
E. Mjäla.
F. Detritusgyttja.

—○— *Betula* —●— *Pinus* —□— *Alnus* —■— *Eichenmischwald* (······ *Ulmus* - - - - *Tilia* —— *Quercus*)
—▲— *Fagus* —△— *Picea* - - -■- - - *Corylus.*

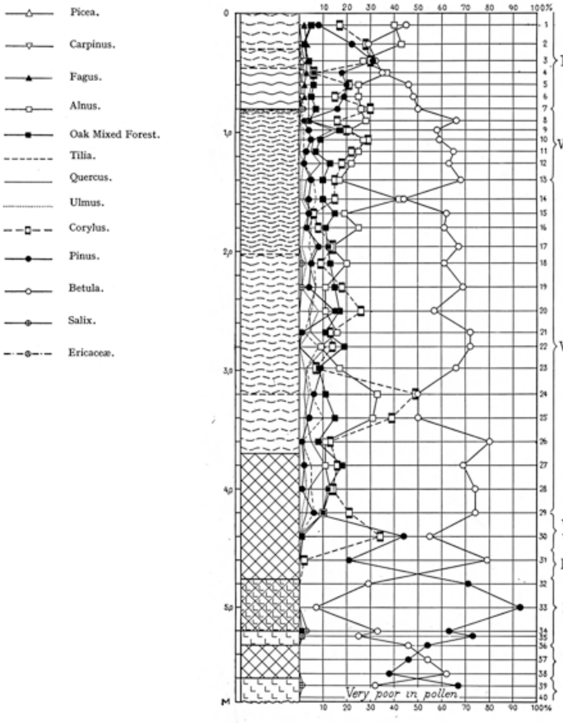

Fig. 4 Top: the first pollen diagrams ever published, from Lerbäck bog in Sweden (Reproduced from von Post 1916, Figs. 10 and 11). The numbers down the left side of each give the number of pollen grains counted. See text for discussion. Bottom: the first pollen diagram to be numerically zoned in the method now used, from Brøndum bog in Denmark (Reproduced from Jessen 1935b, Fig. 3, by kind permission of *Acta Archaeologica*)

bogs, showing, for example, that the Bronze Age fell into upper zone VIII (Jessen op. cit.).

The Littorina marine transgression, to which the shell middens were linked (see above), was also being subdivided. Otto Rydbeck (1928) argued that the Järavallen raised beach in western Sweden showed that the Littorina Sea had two maxima, the second dating to the Neolithic. This was developed in Denmark by Johannes Iversen (1937), whose work at Søborg revealed no fewer than four successive transgression maxima, all falling towards the end of Jessen's zone VII, the Atlantic period (it should be noted that in 1937 the Atlantic to Sub-Boreal transition was placed at the start of the major recession in the mixed oak forest curve (Jessen 1935b, 188); only in 1941 was it moved to its current position at the elm decline, as discussed below).

This new precision in the pollen and marine transgression chronologies immediately had theoretical consequences that Northwest European archaeologists live with to this day.

2.4 1937–1947: Environmental Chronology and the Forager-Farmer Overlap

These developments in the marine and pollen chronologies led to a flurry of archaeological dating activity, which apparently demonstrated that some Ertebølle sites were contemporary with the Neolithic. This led to immigration becoming the accepted understanding for the appearance of farming (the situation by 1942 is shown in Fig. 5 left).

The Finnish archaeologist Carl Axel Nordman was the first to argue that the Ertebølle was a *periferikultur*, contemporary with Neolithic farmers in central Europe. Cultural impulses such as ceramics spread from the farmers to the foragers (Nordman 1927, 31–2). Rydbeck's (1928) study of sea levels at Järavallen (see above) led him to conclude that the two cultures existed contemporaneously even within southern Scandinavia. He pointed out that many Danish Ertebølle shell middens had produced a few Neolithic artefacts. This suggested that the Ertebølle continued parallel with the Neolithic Passage Grave Period, although people kept to their coastal foraging lifestyle (Rydbeck 1928, 67–73).

Jørgen Troels-Smith published three papers in 1937 alone, all dating Ertebølle sites: Alstrup III was on a beach he equated with Jessen's fourth marine transgression (1937a); Brabrand, a major settlement, he pollen-dated to zone VIII (1937b); and Amager III and IV were on beaches he dated to Jessen's fourth transgression (1937c). In the same year, Jessen placed the Klintesø shell midden (published by the Second Kitchen Midden Commission in 1900) early in zone VIII using marine transgressions (Jessen 1937). The forager-farmer overlap was also confirmed by artefactual means. C.J. Becker found some Neolithic items in the Ertebølle site at Ordrup Næs. He dated this site to the latest part of the Ertebølle, contemporary with the Passage Grave Period, and regarded the Neolithic items as imports acquired from the farmers (Becker 1939). Therkel Mathiassen argued that a similar admixture in Mesolithic Strandegaard showed that this site was contemporary with the

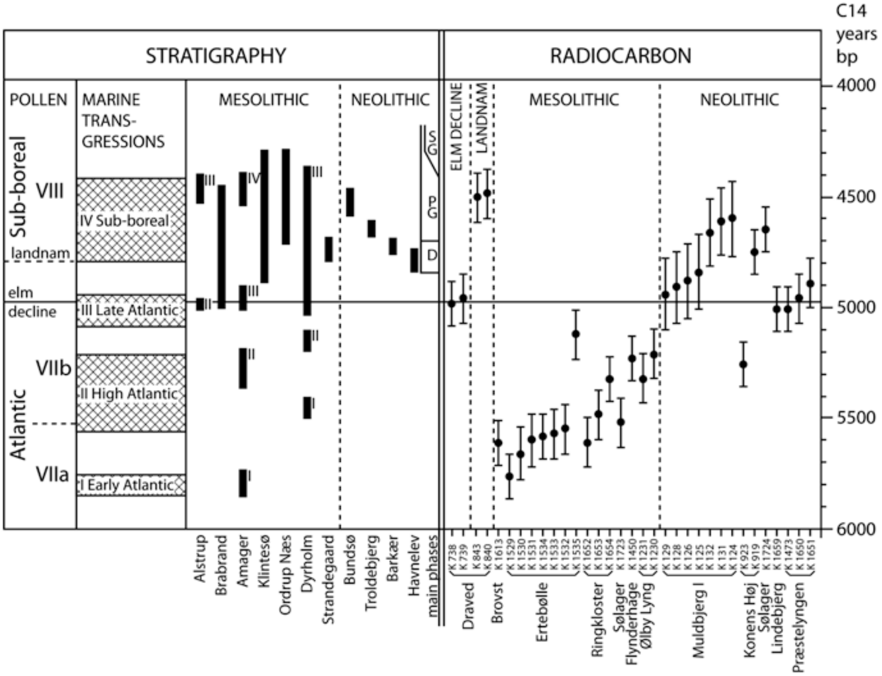

Fig. 5 Chronological relationships between Mesolithic and Neolithic as understood by environmental archaeology in 1942 (left, partly based on Troels-Smith 1942, Fig. 5) and by radiocarbon dating in 1970 (right). Pollen zones follow Jessen (1935b), except that the zone VII–VIII boundary is placed at the elm decline, not at the 'landnam' decline in deciduous forest (following Iversen 1941, 21–2). The marine transgressions are those distinguished at Søborg (Iversen 1937), named as proposed by Troels-Smith (1942, 168). Neolithic phases indicated by D (Dolmen Period), PG (Passage Grave Period), and SG (Single Grave or Corded Ware) – the last two partially overlapping in time. Radiocarbon dates selected from Tauber (1956, 1960, 1966, 1968, 1970). Note that the radiocarbon scale applies only to the right side of the figure; the only chronological marker common to both parts is the elm decline. The pollen and transgressions columns on the left cover substantially more time than the radiocarbon scale on the right (see relative positions of the landnam)

nearby Neolithic site of Havnelev (Mathiassen 1940). The Third Kitchen Midden Commission was set up to examine this and excavated the Ertebølle site of Dyrholm; layer III of this site was also dated to zone VIII (Troels-Smith 1942).

All these Ertebølle sites were thus contemporary with the Neolithic. At that time the Dolmen Period was believed to be the first Neolithic phase in Denmark, the Passage Grave Period coming next. Jessen (1938) pollen-dated the Neolithic site of Troldebjerg, artefactually belonging to the early Passage Grave Period, to zone VIII, noting that Bundsø was a little younger. Havnelev belonged to the Dolmen Period (Mathiassen 1940), which Iversen (1941) demonstrated was also in zone VIII. Mathiassen (1940, 38) noted that Neolithic Barkær was also Dolmen Period, but a little younger than Havnelev.

These dated sites are all plotted in Fig. 5 (left). The importance of this chronological overlap can hardly be overstated, because it led to general agreement that the Neolithic farmers were immigrants (e.g. Mathiassen 1940, 35–36; Iversen 1941, 43; Becker 1939, 272–280; Troels-Smith 1942, 175) – it could hardly be otherwise, with foragers continuing to live largely on coastal resources just a few kilometres away from people with a full farming economy. Environmental archaeology thus provided the archaeological/anthropological explanation for the appearance of farming in southern Scandinavia.

The cultural and economic gulf between immigrant farmers and indigenous foragers was underlined by Iversen's epoch-making realisation that farming practice was visible in the pollen diagrams. Gudmund Hatt (1937, 134) had suggested that the earliest farmers would employ swidden cultivation. This involved forest clearance, burning the felled vegetation, a brief episode of cultivation, soil exhaustion due to lack of manuring, and settlement movements followed by another clearance. These extensive clearances were what Iversen detected in his pollen diagrams (Iversen 1941). Forest stage VIII in the Blytt-Sernander scheme, the Sub-Boreal, had long been seen as a period of forest recession due to drought. Iversen argued that people, not drought, were the cause. He termed the clearances the 'landnam' phase, an archaic Scandinavian term meaning 'land occupation', which has now entered the international vocabulary. Since the date of a landnam episode might vary from place to place, Iversen argued that the boundary between VII and VIII should be moved to the elm decline, a natural climatic event (op. cit., 21–22).

Figure 6 shows selected taxa from Iversen's classic diagram from Korup (from Iversen 1941, Fig. 3). The elm decline starts at analysis 3, marking Iversen's new transition between zones VII and VIII. The arrival of farmers, marked by 'Neol.', is at analysis 6. There was thus a chronological gap between the zone boundary and the start of farming. Iversen distinguished between regional and local farming impacts. By analysis 7, oak forest was declining, indicating clearance some way away from the pollen site. This was accompanied by the first trace of *Plantago lanceolata*, "the 'trail' of the Neolithic farmer in the pollen diagram" (Iversen 1941, 27). At analysis 11 oak forest fell abruptly, accompanied by a sharp rise in herbs and cereals; this was the local landnam phase of clearance and burning. The Korup pollen site is right next to the settlement of Barkær, which Mathiassen (1940) dated artefactually to the Dolmen Period (see above). Analysis 11 was evidently the precise time that Barkær was established and people cleared the forest. Analysis 12 saw the abandonment of the clearing, marked by the increase in recolonising birch, followed by hazel.

This environmental tour de force had a huge impact on archaeological interpretation. In 1947 C.J. Becker subdivided the Early Neolithic into three phases, A, B, and C. The archaeological record revealed little about phase A, but the environmental work described above nevertheless allowed Becker to come to a clear conclusion:

> From an ordinary ethnological viewpoint the problem can be put rather more clearly than the archaeological material by itself would allow…. Although the purely archaeological material may not show signs of such a clear break at the very first appearance of Neolithic culture that one could conclude from this that there was a new immigration, a straightforward invasion of considerable size, one need not hesitate in drawing the line sharply.

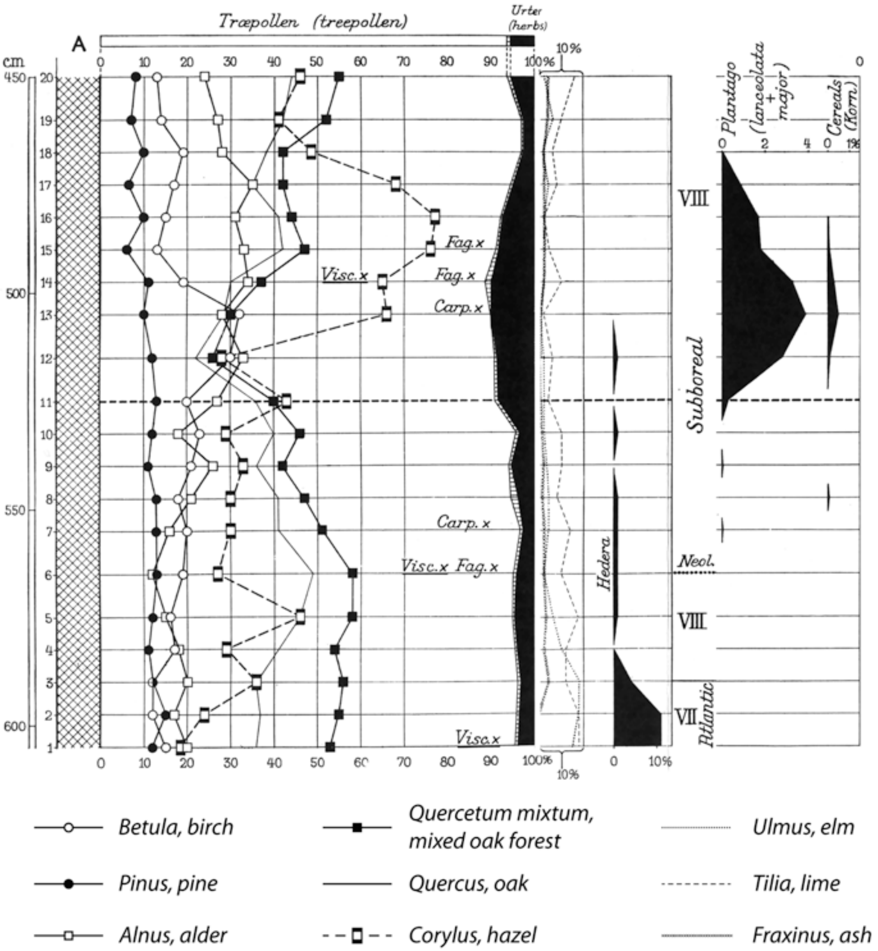

Fig. 6 Selected taxa from the pollen diagram from Korup (From Iversen 1941, Tavle IV). The boundary between pollen zones VII and VIII, marked by the start of the elm decline, is at the level of analysis 3. See text for further discussion. (Reproduced by kind permission of GEUS, the Geological Survey of Denmark and Greenland)

> Although the Neolithic A-group proposed here is so far as badly known as any Danish Stone Age group, its position at the start of the farming cultures by itself makes it certain that we are dealing with a complete cultural entity, and not with a number of new ceramic forms and other individual cultural traits which, spread through cultural transmission, came to characterise a particular phase of the old foraging culture…. (Becker 1947, 286, translated by PR-C)

This clear statement shows how environmental dating and understanding dominated archaeological interpretations. In the next few years, this was developed in an unexpected way.

2.5 1947–1966: Nuances of Overlap, the Debate Between Becker and Troels-Smith

World War II saw a resurgence of peat digging for fuel in Danish bogs, leading to many new finds. Many deliberate depositions of Early Neolithic beakers were uncovered, and these were the ones that Becker (1947) divided into his phases A, B, and C. Becker's interests were mainly typological, and his finds were not pollen-dated, but he did suggest that his earliest phase, with A-beakers and pointed-butted axes, was earlier than the Dolmen Period with its B- and C-beakers and thin-butted axes (Becker 1947, 121).

Troels-Smith meanwhile had been working on numerous sites in the great bog of Aamosen. In 1953 he published a highly influential paper coming to very different conclusions from Becker. In Aamosen too, many Early Neolithic beakers had turned up, and Troels-Smith dated some by pollen analysis. He concurred with Becker's A-B-C sequence and also that the A-beakers preceded Iversen's landnam phase. There were however two crucial differences: first, Troels-Smith argued that the elm decline was *not* a natural phenomenon as Iversen had supposed, but resulted from the pollarding of elm trees so that their leaves could be fed to stalled cattle and, second, that this was done by people of the Ertebølle culture, who were also the makers of the A-beakers. Only after this phase did the makers of the B-beakers immigrate and cause the landnam clearances.

It was the site of Muldbjerg I that convinced Troels-Smith that the A-beakers were an integral part of the Ertebølle culture. This site had a largely Ertebølle artefactual assemblage except that most of the ceramics were A-beakers. Most of the animals were wild, but there were a few domestic cattle. Troels-Smith later (1960a) developed this scenario, arguing that the absence of undergrowth pollen meant that the uncleared oak forest was a hostile place containing few ungulates and fewer people: the pre-Ertebølle population of Denmark was limited to the coasts and numbered as few as 30 people (Troels-Smith 1960a, 102). Cattle could not feed themselves in this forest but had to be permanently stalled – hence the feeding with elm leaves. Muldbjerg I was a summer hunting camp; the cattle and cereal plots were elsewhere, probably at coastal sites (Troels-Smith 1960b). Four cattle teeth from Dyrholm I were smaller than aurochs, closer to later domestic animals in size, and might have been domestic (Degerbøl 1963, Figs. 14 and 15). A Neolithic building at Weier in Switzerland yielded a deposit of preserved cowdung containing many twig and leaf fragments, offering support to the leaf foddering hypothesis (Troels-Smith 1955).

Troels-Smith's classic pollen diagram is reproduced in simplified and annotated form in Fig. 7. The chronological markers on the right are as originally published in Danish (Troels-Smith 1953, Fig. 2; also 1960a, Fig. 2) and later in English translation (Troels-Smith 1960b, Fig. 8). The italic descriptions on the left are additions. Elm is in the left column, the elm decline occurring at the first horizontal line. Iversen's landnam starts at the dated appearance of the B-beakers, followed by the successive regeneration of birch, hazel, and oak forest. The upper peak of plantain and grasses marks the establishment of permanent fields and grazings.

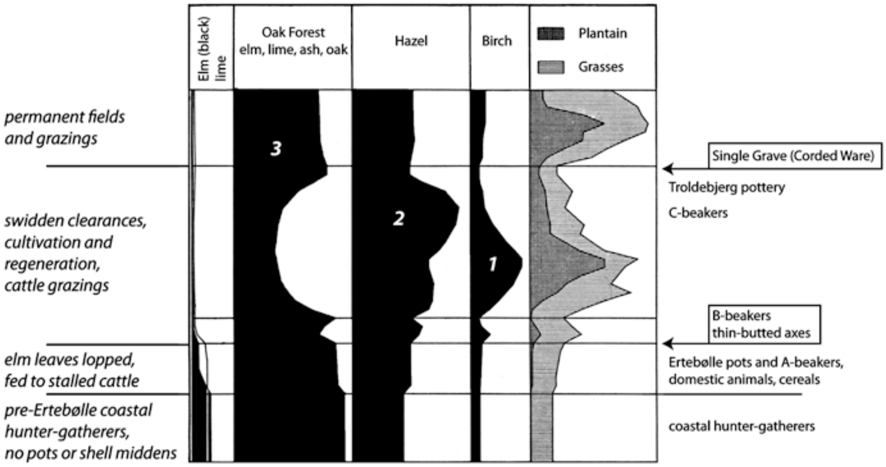

Fig. 7 Selected taxa from Troels-Smith's diagram from Aamosen (From Troels-Smith 1953, Fig. 2, by kind permission of Det Kongelige Nordiske Oldskriftselskab). Annotations on right translated from the Danish (cf Troels-Smith 1960b, Fig. 8); italicised explanations on left and numbered stages on pollen curves are added

This diagram was massively influential; but in retrospect we can see major problems with it. It is in fact not one diagram in itself, but is 'the simplified sum of a large number of pollen diagrams, which are in turn based on a very large number of statistically certain individual analyses. In all this diagram is based on the counting of over one million pollen grains' (Troels-Smith 1953, 11–13, translated by PR-C). The upper section was added from a diagram from Dyrholm in Jutland (op. cit., 13). Troels-Smith stated that the landnam phase reflected not one clearing, but many separate ones that could not be separated out (op. cit., 13). But if this were the case, the successive birch – hazel – oak forest regeneration (marked 1, 2 and 3 in Fig. 7) should be more long drawn out and contemporaneous as different clearings went through their regeneration stages at different times. The Aamosen pollen diagram is evidently a highly idealised 'mind's eye' rendering by Troels-Smith, in which there is a conflict between the local and the regional scales.

Troels-Smith's time scale was also problematic. For the Ertebølle and the A-beakers to be part of one and the same culture, the entire Ertebølle, complete with all the shell middens and pointed-base ceramics, had to be placed at or after the elm decline, and that is where Troels-Smith placed it (Troels-Smith 1953, 41–43; 1960a, 103–105; 1960b). This explicitly referred to the classical Ertebølle culture at sites such as Dyrholm II (Troels-Smith 1953, 60, n 37). As late as 1966, he was stating that 'Dyrholm II is pollen-analytically dated to the time about the elm fall' (Troels-Smith 1966, 516). This is however in clear contradiction with his original publication of Dyrholm: phase III at that site started *before* the elm decline, and phase II was earlier still (see Fig. 5, in which the position of the Dyrholm is taken from Troels-Smith 1942, Fig. 5). There is in fact a clear 30 cm gap in the Dyrholm dia-

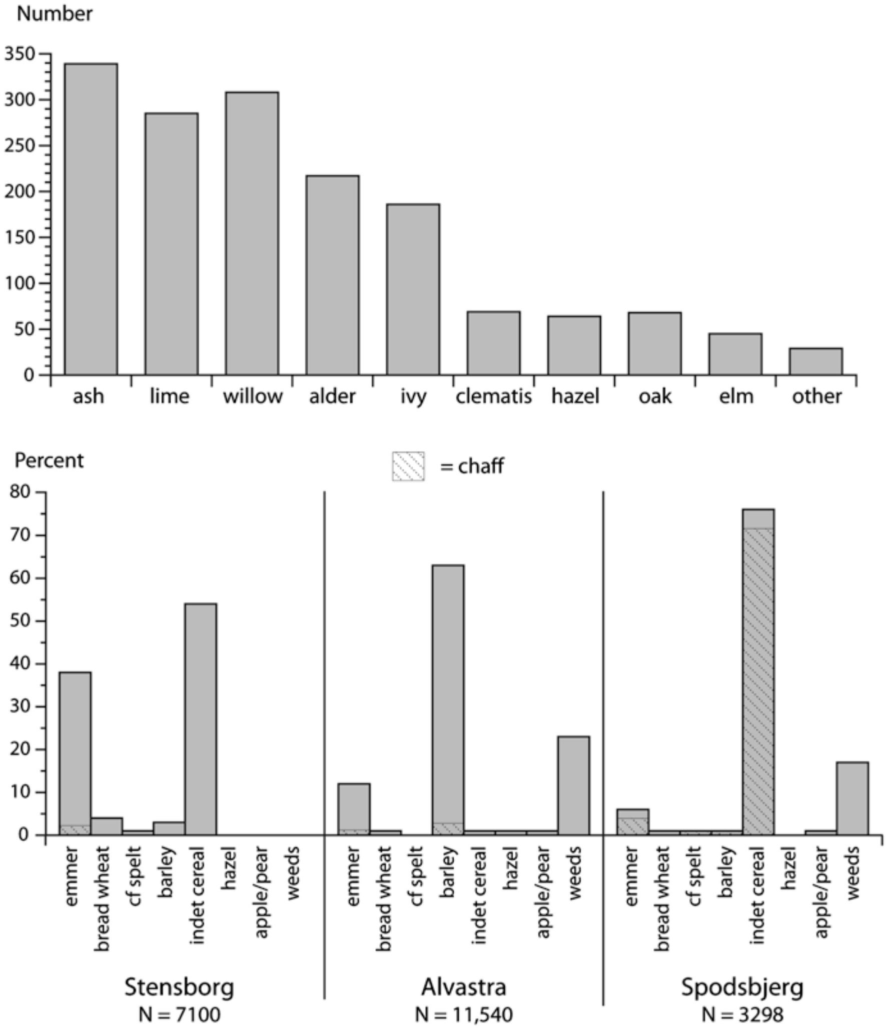

Fig. 8 Top: number of identified twig and leaf fragments in the Neolithic cow dung from Weier, Switzerland. (Data from Rasmussen 1989, Table 2). Bottom: macrobotanical assemblages from Stensborg (Early Neolithic), Alvastra, and Spodsbjerg (Middle Neolithic). (From Larsson and Broström 2011, Table 1; Göransson 1995, Tables 3, 4, and 5; and Robinson 1998, Table 1, respectively)

gram between the end of Dyrholm II and the elm decline (Troels-Smith 1942, 191 and Tavle V).

Becker was not slow to point out the chronological issues. He published some pits from Store Valby, which contained pure A-beakers with no hint of Ertebølle; A-beakers were thus not part of the Ertebølle. The classic Ertebølle, he argued, was a pure forager culture that predated the elm decline (Becker 1954, 157); later Ertebølle sites continued alongside the immigrant farmers and acquired A-beakers and other cultural elements from them (op. cit., 160). All the cereal impressions at Muldbjerg I were on A-beakers, not Ertebølle pots, so even the post-elm decline Ertebølle was a pure foraging culture (op. cit., 166). Becker's relative dating of Ertebølle sites was backed up by a clear typological change in axe typology, from core to flake axes (Becker 1939, 236–237). But Troels-Smith did not accept this and continued to argue that the classic Ertebølle of the Dyrholm II stage dated to the elm decline (1966, 516). He did however point out that several Ertebølle sites purportedly overlapping the Neolithic were not well dated: this went for most of those plotted in Fig. 5 (Troels-Smith 1966, 520–521).

The key point in the 1950s and earlier 1960s was that both Becker and Troels-Smith were arguing for a chronological overlap between farmers and foragers, which thus implied that the farmers had to be immigrants (even though in the Troels-Smith scenario the Ertebølle/A-group had acquired a little farming before the immigration). This neatly backed up the prevailing theoretical ideas in European archaeology, which saw Neolithic farmers as incomers stemming ultimately from the Near East. Major changes were however afoot: radiocarbon dating was about to render these views obsolete.

2.6 1966–1972: Radiocarbon and the Demise of the Forager-Farmer Overlap

The Copenhagen radiocarbon laboratory was one of the first to be set up in Europe, its first dates being run in 1952 (Anderson et al. 1953). One of the first sites dated was Muldbjerg I (Tauber 1956), which after correction produced an average based on nine samples of 4770 ± 80 bp (Tauber 1960). For a few years Muldbjerg I floated in time, but from 1966 the Ertebølle and the Early Neolithic rapidly fell into place.

Figure 5 (right) shows the important early determinations. The elm decline and the landnam were early targets at the well-stratified Draved bog (Tauber 1966). Muldbjerg I fell, as expected, between the two. So, soon, did a variety of other Early Neolithic sites. The Ertebølle, however, did *not* overlap with the Neolithic: a series of dates from the preserved section from Ertebølle, and a variety of other sites being excavated at the time, all fell before about 5200 bp. One of the Ertebølle dates looked anomalously late, one of the pair from Neolithic Konens Høj anomalously early; without these, the two periods fell neatly end-to-end.

Tauber presented this in the mainstream archaeological journal *Antiquity* in 1972 (Tauber 1972). The end-to-end pattern raised the remarkable possibility that no Neolithic immigration was required at all; the foraging Mesolithic could evolve indigenously into the farming Neolithic. The impact of this was profound. It came in the same year as Colin Renfrew's *Before Civilization*, which used radiocarbon dating to demonstrate, for example, that the British Early Bronze Age was far too early to have resulted from traders coming from the early civilisations in the Eastern Mediterranean. Indigenous development was the only possible cause (Renfrew 1972). By demolishing the forager-farmer overlap, Tauber's results opened up the possibility that even agriculture could have a largely indigenous origin – just as theoretical perspectives were ready to receive this idea. In Britain, Higgs and Jarman (1969) argued that there was no hard division between 'wild' and 'domestic' animals. Wild cattle and pig were indigenous to NW Europe and could have been locally domesticated in the later Mesolithic (e.g. Smith 1970), a suggestion that meshed with Degerbøl's (1963) identification of some cattle at Dyrholm I as possibly domestic (see above). Indigenism remained the generally accepted explanation for the origins of agriculture in the region for some decades (e.g. Dennell 1983; Barker 1985; Zvelebil 1995; Price 1996).

3 Development and Diversification Since 1970

3.1 Regional Studies

In the last 30 years, the initiation and execution of large interdisciplinary regional studies have yielded a wealth of new information regarding the Neolithisation process. This is because even the most spectacular sites cannot be placed in a landscape, and therefore a system, without a broader perspective, chronological, disciplinary, geographic, and otherwise. These studies have involved a wide range of methodologies and have generated a wealth of results that far outstrip the pioneering studies described above. In particular, investigations in advance of large infrastructure projects have provided a wealth of information mostly owing to the simple reason that otherwise extensive and well-funded exposure and investigation would not have occurred at these localities. Furthermore, such large-scale projects often result in a compendium of results or monograph, tying together broad datasets as a coherent story. Since the 1990s, the finds and results from these projects have been no less than astonishing and have radically expanded upon the available data regarding agricultural origins.

One of the earliest examples involved the building of the fixed link bridge between Zealand and Fyn in Denmark, across the Great Belt or Storebælt (Pedersen et al. 1997). In preparation of construction, several coastal areas were excavated, including the island Sprogø, located almost directly between the two larger Danish islands, near coastal waters and coastal areas on either side, and through the depths of the Storebælt. Underwater preservation, coupled with a comprehensive picture of sea-level change, dendrochronological dating of submerged trees, and variation through time allowed a reconstruction of the coastal settlement system on either side of the transition to agriculture in the region in context with the local environments (Pedersen et al. 1997). Importantly, the discovery of preserved stationary fish weirs from the Neolithic offered a complimentary perspective on the role of aquatic resources in the Neolithic (Pedersen 1997), and the Early Neolithic occupations on Sprogø reinforced the limited impact on the local environment and continuing role of hunting in the Early Neolithic (Nielsen 1997).

In the early 2000s, an infrastructure development project aimed at improving the rail link between Scania and eastern Denmark uncovered a series of Early Neolithic sites near what is today Malmö (see Rudebeck 2010). One of these, Almhov, yielded a series of pits dating to the earliest ENI and the largest recovered faunal assemblage to date from the incipient Neolithic (Rudebeck 2010). Stemming from these larger sample sizes, it has become possible to directly address previously restricted population-based questions such as for what purposes were cattle being raised and were they moved across the landscape in the earliest Neolithic (Gron et al. 2015, 2016).

Another example, while not strictly an application of environmental archaeology, was Magnus Andersson's work on the Early and Middle Neolithic landscape in western Scania (Andersson 2004). Drawing its source material from excavations in advance of the building of a new rail line along the west coast of the region, new perspectives upon the distribution of settlement and change through the earliest Neolithic became possible.

More is to be expected. Current excavations in advance of the building of a fixed link between the southern Danish island Lolland and the northern German coastal island Fehmarn (the Fehmarn Belt Project) have revealed outstanding conditions of preservation and some truly remarkable finds. These include hafted flint axes, transverse points still in their shafts, and in situ organic remains (Mortensen et al. 2015). Only time will tell regarding the impact of this ongoing project, but it is fair to say that our understanding of Neolithisation can only be increased by evidence from this hitherto under-investigated region as already substantial evidence of Neolithic stationary fishing weirs has emerged.

It is not only infrastructure projects offering regional perspectives of course. The Ystad project in Scania was undertaken from ca. 1982–1990 and aimed to integrate landscape and societal change from the Mesolithic to historical times in a specific area of southern Scania (Berglund 1991). This ambitious project tied together researchers from paleoecology, plant ecology, archaeology, and human geography in order to tell a coherent story of the human impact and environmental interaction in the *longue durée*.

Research on Bornholm regarding landscape, environmental impact, and changing subsistence strategies has been ongoing on an island-wide scale for a number of years now. The scientific results are forthcoming (Nielsen and Nielsen 2017) and will offer a complimentary view on the Neolithisation process in mainland areas of southern Scandinavia from a local and landscape-wide scale.

Lastly, but certainly not least, shell midden excavations in eastern Jutland, Denmark, have been ongoing for many years under the direction of Søren H. Andersen (see Andersen 1991, 1993a, 2004, 2007, 2008a; and many more). By focusing on the stratified shell middens and scientific analyses of their Mesolithic and Neolithic occupations, these investigations have resulted in an unparalleled view of change and continuity across the transition to agriculture. Most strikingly, they have illustrated that at places like Bjørnsholm (Andersen 1993a; Bratlund 1993), Visborg (Enghoff 2011), Havnø (Andersen 2008b), and Norsminde (Andersen 1991), the earliest centuries of the Neolithic were characterised by remarkable continuity with the Mesolithic.

In aggregate these regional studies have offered a new, landscape-wide view of processes leading to and after the transition to agriculture. More than anything, they have served to A) greatly expand the available dataset useful for addressing the relationship between humans and their environments, B) introduce an understanding of the variability in the Neolithisation process across the landscape, and C) have underscored the complexity of the transition.

3.2 Archaeological Chemistry

Starting in 1981 with perhaps *the* seminal paper in the archaeological sciences regarding agricultural origins in southern Scandinavia, Henrik Tauber presented data demonstrating a profound shift in diets between Danish Mesolithic and Neolithic populations: marine foods were predominant in the Ertebølle, terrestrial foods in the Neolithic (Tauber 1981). Since, a number of isotopic studies detailing human (including using proxies) have largely reinforced this view (Fischer et al. 2007; Richards et al. 2003) but are not without conflicting perspectives (Lidén et al. 2004; Milner et al. 2004). The meaning of this massive shift in human diets is unfortunately less than clear. The reason for this is that the chronological timing of the dietary shift and the relationship of human diets to available subsistence resources do not necessarily neatly correspond to the start of the Neolithic. This primarily owes to the need for a marine reservoir correction on radiocarbon dates on individuals with marine-dominated diets directly at the transition. Within this uncertainty it does appear that at or about the introduction of farming, there are some individuals eating marine foods and some individuals eating terrestrial foods on the landscape at the same time (see Fischer et al. 2007). Furthermore, there is evidence for a continuation of the exploitation of marine resources in the form of continuing occupation at the shell middens (Andersen 2008a) as well as stationary fish traps (Mortensen et al. 2015; Pedersen 1997). In aggregate, this means that some ambiguity remains with regard to how to interpret the dietary isotopes in context.

While some analyses of animals have been presented as baselines relating to human dietary studies (Fischer et al. 2007), in the context of new methodological applications (Craig et al. 2006), to isotopically characterise certain taxa (Robson et al. 2016), or as secondary to traditional zooarchaeological analyses (Richter and Noe-Nygaard 2003; Ritchie et al. 2013; Magnussen 2007; Hede 2005), several studies have focused specifically on fauna with regard to understanding the Mesolithic-Neolithic transition. Broadly, this work has aimed to reconstruct past feeding environments and any potential change in animal populations, habitats, and diets between the Mesolithic and Neolithic, as well as to investigate animal husbandry strategies in the earliest years of the Neolithic.

Early work included carbon isotope analyses of various classes of fauna from the Store Åmose bog system on Zealand (Noe-Nygaard 1995), which demonstrated the utility of such applications in documenting environmental change and differences in the landscape. Later work was built on this application (Noe-Nygaard et al. 2005), comparing domestic and wild cattle values with deer baselines and documenting a closure of the forest through the Atlantic and Sub-Boreal and arguing that cattle were being kept in open environments. Building on this, we have recently published a broader, landscape-wide view of variation in deer diets in order to place cattle in the landscape (Gron and Rowley-Conwy 2017). Perhaps not surprisingly, with a broader perspective on geographic variation and the addition of nitrogen isotope analyses, we were able to determine that cattle were being raised in small areas cleared by humans in the earliest Neolithic.

The application of other isotopic techniques has been much less common. Strontium isotope work has been hampered by two main factors: (1) the geology across southern Scandinavia is largely homogenous, resulting in limited potential for answering many research questions, and (2) the general lack of baseline values. The former cannot be avoided as it is simply the geological reality, but fortuitously, in a series of recent studies, the latter has largely been rectified (Frei and Frei 2011; Frei and Price 2012; Price et al. 2012a, b, 2017). As such, it has become possible to start addressing basic but simple questions regarding the earliest Neolithic, about which little is known regarding the actual practice of farming. One example is our recent paper (Gron et al. 2016) which demonstrates the movement of cattle by boat across the Øresund in the earliest Neolithic using strontium isotope proveniencing.

Very little other isotope work has been completed specifically addressing questions pertaining to the transition. Initial analyses of oxygen isotopes, for example, on materials from somewhat later in the Neolithic (Sjögren and Price 2013) demonstrated that seasonal variation in $\delta\ ^{18}O$ is recorded in hypsodont Scandinavian cattle teeth. However, the only application directly relevant to the understanding of agricultural origins to date is our study of birth seasonality of cattle in the earliest Neolithic from the aforementioned site Almhov, in Scania (Gron et al. 2015). In that study, we demonstrated multiple birth seasons for the cattle in the sample, which we interpreted as evidence of dairying in the earliest Neolithic. Other applications are rarer still. Only recently has the manuring of crops during the Early Neolithic been demonstrated through elevated charred cereal $\delta^{15}N$ values (Gron et al. 2017). Similarly, sulphur isotopes have only really been applied once to Scandinavian materials about the transition, and then as a proof of concept (Craig et al. 2006), the conclusion of which stated limited potential awaiting future research.

Another approach has been to analyse ceramics directly to determine the composition of food crusts and therefore what was being prepared in the pots. A number of studies have taken this approach, looking at both the stable isotopic composition of bulk food crusts and more detailed analysis of lipids within those crusts (see Heron et al. 2013; Craig et al. 2007, 2011; Isaksson and Hallgren 2012). The earliest applications capitalised upon excellent underwater organic preservation (Andersen and Malmros 1984), while in the recent years more detailed and specific approaches have become more common, attempting to parse specific components of what was being cooked (Craig et al. 2007, 2011; Heron and Craig 2015; Isaksson and Hallgren 2012). Other approaches have looked at what was being used as fuel in the so-called blubber lamps (Heron et al. 2013).

3.3 Ancient DNA

In the last few decades, a series of genetic studies have started to address the question of agricultural origins in northern Europe. On a basic level, three lines of inquiry have been explored, including asking who were the people involved in the transition and were they related, what were their characteristics, and lastly what can genetic analyses of non-human species tell us. For the most part, the focus has been on other Neolithisation events and not strictly on Scandinavia (Bramanti et al. 2009; Haak et al. 2010; Soares et al. 2010).

Only a few studies have addressed Scandinavian material directly. Skoglund et al. (2012) found a marked genetic discontinuity between TRB farmers and hunter-gatherers. However, this study did little to address the start of farming in the region because of the simple fact that the hunter-gatherer individuals were from the Pitted Ware Culture (PWC), Neolithic hunter-gatherers much later than the last Mesolithic foragers. Another study, based on a broader sample both culturally and chronologically, including modern samples postulated a replacement of Mesolithic Danes by incoming Neolithic groups (Melchior et al. 2010). Further genetic work has also addressed the relationship between members of the PWC and contemporary farmers (Malmström et al. 2009), but again the crucial question regarding relationships between the last foragers and the first farmers remains unaddressed (Malmström et al. 2015). However, when local Mesolithic hunter-gatherers are taken in comparison with TRB individuals, at least in some capacity, it becomes clear that hunter-gatherers intermixed with the first farmers (Skoglund et al. 2014). As such, any simple conclusions regarding agricultural origins can no longer be drawn.

Perhaps of more import for understanding the transition is investigating the presence of lactase persistence in Late Mesolithic and Early Neolithic populations. In at least one study (Malmström et al. 2010), the percentage in a Neolithic population of Pitted Ware Culture (PWC) hunter-gatherers who could digest lactose was vanishingly small compared to modern proportions of the Scandinavian population. While seemingly this demonstrates that perhaps the Neolithic population of Scandinavia was largely unable to digest milk, as always there are limitations when it comes to understanding agricultural origins. For example, if processed correctly, milk products can be consumed by those without lactase persistence, and therefore the presence or absence of lactase persistence does not say much about how or if dairy was consumed.

The genetics of the domesticated species themselves have lent a complimentary view of the transition. One approach to the question looked at the adaptive processes of crop plants themselves to different climates as possible players in the timing and spread of agriculture to Scandinavia and elsewhere (Jones et al. 2012). The genetics provided a plausible explanation for the delay in the spread of agriculture to the region, although again causality is hard to demonstrate. A different approach aimed to rectify some conflicting information regarding unexpectedly small *Bos* sp. specimens from the latest Mesolithic site Rosenhof, Germany (Scheu et al. 2008). In this case, the genetic data showed that in fact there was no evidence for local or early domestication at the site and that the earliest domesticates were associated with the widespread adoption at or around 4000 cal BC (Scheu et al. 2008). Perhaps the most contentious claim proposed is that Ertebølle hunter-gatherers possessed domestic pigs (Krause-Kyora et al. 2013) based on mtDNA in pig remains from Ertebølle sites. Quickly rebutted (Rowley-Conwy and Zeder 2014) on the basis of basic zooarchaeology as well as domestic and wild pig behavioural ecology, this study probably best represents the limitations of genetic analyses.

3.4 Archaeobotany

A steady, if not geographically inconsistent, series of palynological studies has been completed in the last decades relating to the latest Mesolithic and earliest Neolithic (Andersen 1992, 1993b; Berglund 1985, 1991; Göransson 1988; Lagerås 2008; Rasmussen 2005; Regnell and Sjögren 2006; Regnell et al. 1995; Schrøder et al. 2004; Skog and Regnéll 1995). In general, these studies have, through a series of palynological sequences from across the region, demonstrated a series of disparate vegetation changes from the late Atlantic into the Sub-Boreal, an increase in secondary successive species and evidence of disturbance (Andersen 1998; Berglund 1969; Lagerås 2008), and the presence of heat-deformed pollen interpreted as being the result of burning for slash-and-burn agriculture (Andersen 1992). In some cases, no discernable anthropogenic effects on the environment are seen in the ENI at all (Regnell and Sjögren 2006).

Various lines of environmental archaeology have focused on the elm decline, with the result that this vegetational change is now regarded as probably not due to human activity after all. The earliest farmers would not have been very numerous. Later calculations suggested that to reduce elm by the amount they did, they would have been pollarding impossibly large numbers of elm trees (Rackham 1980, 266) and feeding impossibly large numbers of cattle (Rowley-Conwy 1982). The twigs and leaves in the cow dung from Weier, argued by Troels-Smith (1955) to be support for the leaf foddering hypothesis, were identified by Peter Rasmussen, who showed that they came from a wide variety of species (Fig. 8 top); only 3% of them were in fact elm (Rasmussen 1989, Table 2). It has become increasingly clear that the elm decline occurred all over Europe and beyond and at the same time regardless of the local cultural and economic situation. The possibility that the elm decline was caused by disease was reinforced by a new epidemic decimating Europe's elm trees in the 1980s (Perry and Moore 1987), and the *Scolytus* beetle, the vector in the 1980s outbreak, was identified in deposits dated to the elm decline (Girling and Greig 1985).

Palynology in general is beset with several fundamental limitations, including the need for the use of proxy species, difficulties and variability regarding the size of catchments for pollen cores, and the interplay with local processes of which some have nothing to do with human activities (Berglund 1985). With regard to the transition to agriculture, there are two key issues: first, the pollen of domestic cereals simply does not travel very far (Berglund 1985); and second, there are major problems in distinguishing cereal pollen from that of some native wild grasses (Behre 2007; Lahtinen and Rowley-Conwy 2013). Basic palynological analyses by themselves are therefore much better at demonstrating large-scale human impacts on existing environments (e.g. deforestation, increases of species that thrive in open areas, or demonstrating heating) than at detecting the earliest traces of agriculture in a region. It is in the context of these limitations therefore that the palynological record at present is interpreted to show little noticeable human impact on the floral composition of southern Scandinavia in the first centuries of the Neolithic, with widespread clearance only visible by the ENII, or around half a millennium after the introduction of domesticated plants and animals (Gron and Rowley-Conwy 2017).

Plant macrofossils offer complimentary and more concrete evidence of the presence of agriculture on a landscape. However, in order to be preserved (and therefore identified), a very certain series of conditions must be met, including that the grains must have been burned, they must be specifically sought using soil flotation, and lastly they must be identifiable (see Sørensen 2014). Flotation has been patchily employed in Southern Scandinavia and rarely on a large scale, which necessarily limits the conclusions. Conversely, cereal impressions in ceramics may also be used to document the presence of domestic cereals (Sørensen and Karg 2014). It is generally agreed upon that several forms of wheat and barley are present as domestic grains in the earliest part of the Neolithic in southern Scandinavia (Sørensen and Karg 2014) although the rarity of samples from the Early Neolithic has hindered our understanding of agriculture in this crucial period. The Middle Neolithic is better understood. Figure 8 (bottom) presents the major assemblages from Alvastra and Spodsbjerg (Göransson 1995; Robinson 1998). One major Early Neolithic sample comes from Stensborg (also in Fig. 8), and directly dated cereal grains from the unpublished assemblage from Almhov also date to the Early Neolithic (Nilsson and Rudebeck 2010). Plant frequencies in archaeobotanical assemblages cannot be simply be read at face value in the way that animal bones can: animal bone assemblages accumulate over a period of time and are probably representative of the economy as a whole, while an archaeobotanical assemblage may be charred as a single event and thus represents only one particular activity at one precise moment in time (Rowley-Conwy and Legge 2015, 431). Such chance factors probably account for the variability between sites in Fig. 8.

Within the limits of our ability to date cereal finds, the transition to agriculture looks increasingly like an abrupt switch to a cereal-based economy. There is no good evidence for the cultivation of cereals in the Late Mesolithic (Sørensen 2014, I, 60). Two claimed direct dates are in fact on items of uncertain provenience and/or identification, while a third stems from a misprint in a table (Nilsson and Rudebeck 2010, 117). For the Early Neolithic, the evidence from Stensborg in Fig. 8 is at least as compelling as that from the Middle Neolithic sites and pushes evidence for the major importance of cereal agriculture back to near the start of the Neolithic.

Recently, however, archaeobotanical research has expanded into the identification of microfossil crust inclusions for the identification plant species using starches (Saul et al. 2012) and phytoliths (Saul et al. 2013). The results of these studies have indicated that food was being spiced in some cases using species of little nutritional value and that a complete replacement of wild resources by domesticated species does not seem to be in evidence in the earliest Neolithic.

3.5 Zooarchaeology

Many zooarchaeological methods were developed early on, for example, the distinction between wild and domestic pigs (see above and Fig. 2). This continued through the mid-twentieth century: Magnus Degerbøl routinely separated small domestic pigs from large wild boar, for example, at Neolithic Bundsø and Mesolithic Dyrholm II (Degerbøl 1939, 1942 – see Rowley-Conwy et al. 2012, Fig. 3). The separation between wild and domestic cattle is more complex because cattle are sexually dimorphic. As noted above, Degerbøl (1963) identified a few Late Mesolithic cattle from Dyrholm II as domestic. He soon amended this: as more of the smaller female aurochs became available, the aurochs size range broadened to overlap more with male domestic cattle. The Dyrholm II specimens fell in this overlap zone and could therefore no longer be definitely classified as domestic (Degerbøl and Fredskild 1970). A few specimens at Late Mesolithic Rosenhof were also identified as domestic (Nobis 1975), but they too fall in the metrically intermediate zone (Rowley-Conwy 2013). These are the specimens subsequently identified as aurochs through aDNA (Scheu et al. 2008, discussed above). The most recent synthesis suggests that there were no domestic cattle in the Late Mesolithic (Sørensen 2014, I, 86–89). Domestic pigs were claimed from the same site on the basis of aDNA, but these remain problematic (see above).

Current dating methods allow us only to say that the first domestic animals appeared somewhere close to the Mesolithic/Neolithic boundary. Smakkerup Huse provides a clear illustration of the problems (Price and Gebauer 2005). The animal bone assemblage is classically Mesolithic comprising wild animals, birds, and fish, with a few domestic dogs – except that four domestic cattle bones were also recovered (Hede 2005). The site is on the island of Zealand, where Mesolithic hunters had exterminated the local aurochs two millennia before the arrival of farming (Aaris-Sørensen 1999), so misidentified aurochs can be ruled out. Figure 9 shows the calibrated dates. Most dates fall before 4000 cal BC, but the two dated cow bones fall after this. They could thus be intrusive Neolithic cattle. They were found together with other faunal items, however, and there were no Neolithic cultural items, so it is possible that they might fall into terminal Mesolithic times (Price and Gebauer 2005, 124). This example shows how vital it is that problematic specimens be directly dated.

Some Early Neolithic sites however are largely dominated by wild animals – while others have mostly domestic ones. Figure 10 shows a selection. Muldbjerg I is dominated by red deer and Anneberg by seal, while domestic animals dominate at Almhov and Skumparberget. The difference is underlined by the fact that there are very few fish at Almhov and Skumparberget, while there are some 3000 at Muldbjerg and no fewer than c. 75,000 at Anneberg. Thus in both the northern and southern

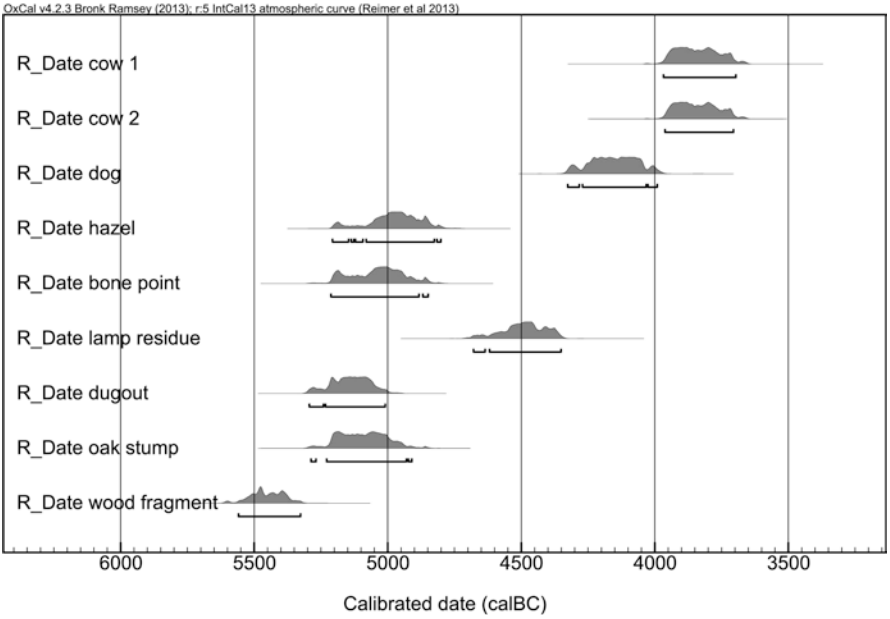

Fig. 9 Recalibrated radiocarbon dates from Smakkerup Huse. Determinations from Price and Gebauer (2005), Table 8.1, recalibrated using OxCal 4.1 with the IntCal 09 curve (Bronk Ramsey 2009)

TRB, some sites are dominated by domesticates, while others continue a largely 'Mesolithic' way of life. Thus the Mesolithic-Neolithic transition is not clear-cut – not because there are domestic animals in the Mesolithic, but because some Early Neolithic sites continue to be dominated by wild mammals.

In terms of recovery, zooarchaeology has advanced markedly. It was the first sector of archaeology in which it was realised that it is essential to sieve all deposits if smaller items and taxa are not to be differentially missed (Payne 1972). The impact of sieving is shown in Fig. 10 (bottom). There was a major increase in Late Mesolithic mammal and bird assemblage size following the introduction of the technique in the late 1960s. This is even more true of assemblage size of fish bones, which require even finer sieve mesh to recovery the numerous small fish bones (Gron and Robson 2016, Fig. 1). Fine sieving has led to a much better understanding of the importance of fish in the Ertebølle, particularly through the work of Inge Bødker Enghoff (e.g. Enghoff 1983, 1994, 2011). Only through this work has it become possible to reconcile the zooarchaeological record with the marine diet documented by stable isotope analysis (see above); without the small fish, terrestrial mammals dominate the picture.

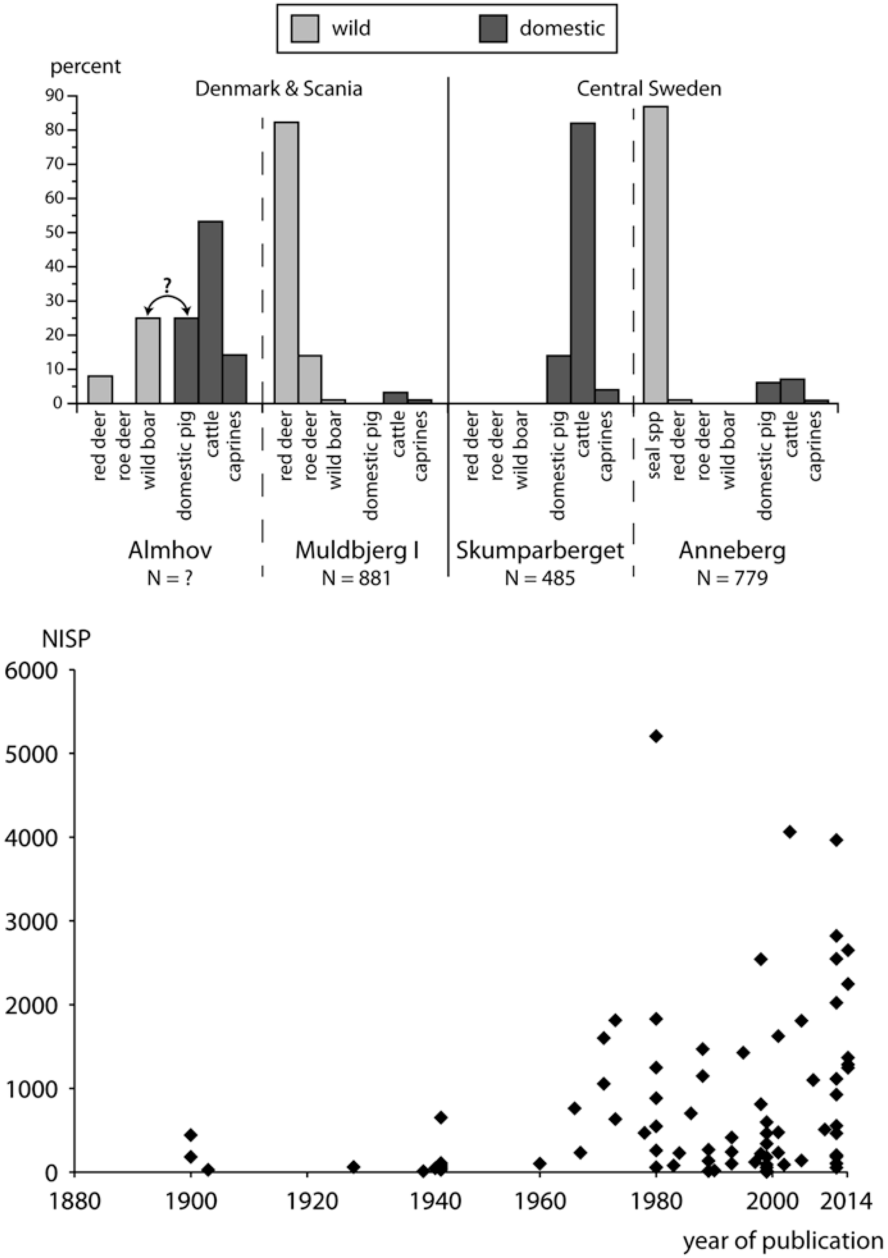

Fig. 10 Top: some Early Neolithic faunas. Muldbjerg I from Noe-Nygaard (1995), Table 6; Almhov figures estimated from Nilsson and Rudebeck (2010), Fig. 7 (wild and domestic pigs are not separated, so the percentage is shown in both columns); Skumparberget from Bäckström (1996), Table 15; Anneberg from Segerberg (1999), Table 100. Bottom: size of Late Mesolithic faunas correlated with date of publication. (Modified from Gron and Robson 2016, Fig. 1)

3.6 *Ecosystem Modelling*

In the late 1970s and 1980s, a series of papers addressed EBK economy and settlement system from the standpoint of what was essentially a human behavioural ecology (HBE) approach. These papers aimed to establish a basis for understanding the observed site distribution within EBK settlement systems through calculating various aspects of local productivity. One of the present authors applied such an approach in a series of papers (Rowley-Conwy 1983, 1984) which endeavoured to explain the context of the complex foraging adaptations observed in EBK society, as well as calculate the effect of changes in resource availability on societies resulting in the transition to agriculture. This approach then assigned a most likely scenario for the transition to agriculture resulting from the reduction in a single cornerstone resource – the oyster – owing to changes in ocean salinity (Rowley-Conwy 1984). This approach can be criticised because it applied only to those areas of Denmark where oysters were available and could not directly account for the transition in the rest of southern Scandinavia or indeed Britain and Ireland, which all saw the appearance of agriculture at the same time (Schulting 2010).

Another approach was to take a regional view of resource availability to establish the types and degrees of change that would be required in order to upset the EBK subsistence system and presumably usher in agriculture (Paludan-Müller 1978). While useful for understanding the environmental and economic underpinnings of EBK subsistence, the above studies largely assigned human actors a passive role in culture change, as well as implicitly considering agricultural origins in the region the result of local individuals changing their subsistence strategy.

3.7 *Ongoing Fundamental Research*

Despite new methodological applications outlined above, it is easy to forget the value and necessity of fundamental and traditional methods. Since the year 2000, for example, essential zooarchaeological analyses have been performed from the vital early farming sites Almhov (Magnell 2015), Saxtorp (Nilsson and Nilsson 2003), and Hunneberget (Magnell 2007) giving for the first time a more complete view of resource exploitation during the early years of the Neolithic. Additionally, a series of similar analyses of Ertebølle localities (Enghoff 2011; Hede 2005; Magnussen 2007; Richter and Noe-Nygaard 2003; Ritchie et al. 2013) have greatly expanded our understanding of regionality and variability across southern Scandinavia.

The study of molluscs also has also continued, with new developments expanding our toolbox for understanding environmental change and resource exploitation. For example, thin sectioning of molluscs has shown a reliable tool for understanding seasonality of exploitation at the shell middens (Milner 2002), and ongoing work incorporating salinity proxies from oysters and other proxies has allowed a reconsideration of the causes of the oyster decline concomitant with the start of farming (Lewis et al. 2016).

The instigation of underwater excavations have expanded the possibility for the recovery or preserved organic remains. The impact has been multifold, not least of which is the filling in of the giant black box southwest of the zero line of isostatic rebound (Christensen 1995; Mertz 1924) which was hitherto represented by very, very few Stone Age sites. Underwater excavations at Tybrind Vig (Andersen 1985; Andersen 2013), in the Storebælt (Pedersen et al. 1997), Ronæs Skov (Andersen 2009), and elsewhere (see Lübke et al. 2011) have immeasurably increased the available sample of preserved organic remains available for study while simultaneously allowing a view of regions from which very little is known.

4 Looking Forward

We are fast approaching the bicentennial of environmental archaeology as applied to southern Scandinavia and in particular to the question of agricultural origins in the region. Despite this duration of strong scholarship, a consensus opinion regarding the ultimate (or even proximate) causes of the shift from foraging to farming at around 4000 B.C. remains elusive. Dominant points of view have come and gone, but the data remain, resulting in a situation where we have perhaps the best documented transition to agriculture in the world, but one we still do not really understand.

As we stated at the beginning of this chapter, it is our impression that more often than not, it is methodological innovation which leads the theory building instead of vice versa. There are exceptions, of course, but the dominant paradigmatic shifts have followed in the wake of the major methodological developments (C14 dating, stable isotopic geochemistry, aDNA, or further back zooarchaeology and palynology) or simply large projects which have yielded new data in previously under-investigated geographic locations. Nonetheless, old ideas have cycled back and are sure to go out of vogue with time. This underscores the larger and simplest of problems that our samples are, in general, far too small. We do not have enough Early Neolithic sites, large enough faunal assemblages, enough burials from the latest Mesolithic and earliest Neolithic, etc. to which we can apply our substantial environmental archaeological analytical toolkit.

It should go without saying that any one method, extant or future, will not ‘solve’ the question of agricultural origins in southern Scandinavia. If anything, the suite of methods has revealed significant, and probably substantial, variation within the Neolithisation process across the landscape. The true story is probably a combination of reasons, and our best attempts at accessing its underpinnings are probably through a combination of methods. If the long history of environmental archaeology in the region has taught us one lesson, it is that there is no substitute for fundamentals and that an integrated approach to research led by environmental archaeologists comfortable with interdisciplinary engagement is the only safe way forward.

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