McDONALD INSTITUTE CONVERSATIONS

Inspired geoarchaeologies: past landscapes and social change

Essays in honour of Professor Charles A. I. French

Edited by Federica Sulas, Helen Lewis & Manuel Arroyo-Kalin

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with contributions from
Michael J. Allen, Andrea L. Balbo, Martin Bell, Nicole Boivin, Christopher Evans, David Friesem, Kasia Gdaniec, Lars Erik Gjerpe, Michael Gill, Martin Green, Ann-Maria Hart, Robyn Inglis, Martin Jones, Gabriella Kovács, Helen Lewis, Johan Linderholm, Roy Loveday, Richard I. Macphail, Caroline Malone, Wendy Matthews, Cristiano Nicosia, Bongumenzi Nxumalo, Innocent Pikirayi, Tonko Rajkovaca, Rob Scaife, Simon Stoddart, Fraser Stuart, Federica Sulas & Magdolna Vicze

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On the cover: *Hand drawn illustration by Charly French, aged around 10 years old. Courtesy of Kasia Gdaniec.*

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Mike's (BSc, PhD, MCIfA, FLS, FSA) research and geoarchaeological interest was originally based around the analysis of colluvium and land snails, including in the South Downs, Dorchester, Cranborne Chase, Stonehenge and Avebury in particular; these were the subject of both his undergraduate and PhD research. He has combined a career dominated by commercial archaeology with involvement in university research projects and as a staff lecturer at Sussex, Bournemouth and Oxford Universities. He was Environmental Manager at Wessex Archaeology for twenty years and for fifteen years has run his own geoarchaeological consultancy from a purpose-built bespoke lab, where he is involved in research designs and coordination of environmental archaeology from fieldwork to publication. Projects have been as diverse as intertidal zone research and Maltese prehistoric temples. His interests now lie principally in landscape archaeology and the development and creation of landscapes through prehistoric human intervention. He has worked with – and still is working with – Charly French in Cranborne Chase, the Stonehenge Riverside Project, and both recent Avebury landscape projects. He is vice-president of the Conchological Society, and as founding editor of the Prehistoric Society Research Papers has seen ten peer-reviewed volumes through to publication.

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Martin began a fieldwalking survey as a lad on Cranborne Chase in the latter 1960s. Following experience gained on a number of field projects, he began excavating independently in the region in 1976. He joined Richard Bradley's and John Barrett's Cranborne Chase Project the following year, contributing four site excavations to *Landscape, Monuments and Society* in 1991. He continued independent fieldwork in the early 1990s in collaboration with Mike Allen, in particular on the Fir Tree Field shaft which revealed a remarkable sequence of deposits dating from the late Mesolithic to the Beaker period, and worked with Charly French on the Upper Allen Valley Project 1998–2003, contributing four further site excavations to *Prehistoric Landscape Development and Human Impact in the Upper Allen Valley, Cranborne Chase, Dorset* (2007). Since that time, he has continued independent research, also in collaboration with Josh Pollard and Southampton University, on the Dorset Cursus, on Down Farm and in the Knowlton environs whilst continuing to increase the biodiversity on his small farm. He was made an FSA (Fellow of the Society of Antiquaries) in 2004 and received an honorary Doctor of Science degree from Reading University in 2006.

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Richard trained in geology and geography, specializing in soil science (BSc Swansea University). An MSc in pedology and soil survey (Reading University) prepared him for a soil science PhD on podzol development on heathlands (Kingston Polytechnic). An English Heritage-funded archaeological soil contract at the Institute of Archaeology (University College London) provided further training and international research opportunities were developed, including working with the Soil Survey of England and Wales and Macaulay Institute, UK, the CNRS, France, and the Soprintendenza, Italy. This led to the publication of *Soils and Micromorphology in Archaeology* (with Courty and Goldberg; Cambridge University Press 1989), the founding of the International Archaeological Soil Micromorphology Working Group, and training weeks at UCL. As a result, *Practical and Theoretical Geoarchaeology* (Blackwell 2006; Wiley 2022) and *Applied Soils and Micromorphology in Archaeology* (Cambridge University Press 2018), both with Goldberg, were written. Macphail is a recipient of the Geological Society of America's Rip Rapp Award for Archaeological Geology (2009), and is a fellow of the Geological Society of America. He is also the 2021 co-awardee (with P. Goldberg) of the International Union of Soil Sciences Tenth Kubiëna Medal for Soil Micromorphology. The paper included here also reflects more than two decades of research across Scandinavia.

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Francis has studied the archaeology of the Fens since 1971. His major excavations in the region took place near Peterborough at Fengate, Maxey and Etton. In 1982 his team's survey of fenland drainage dykes revealed the timbers of a waterlogged Bronze Age timber platform and causeway at Flag Fen, which was opened to the public in 1989. He was a member of Channel 4's long-running series *Time Team*. He has written many popular books including *Seahenge* (2001), *Britain* BC (2003), *Britain* AD (2004), *The Making of the British Landscape* (2010), *Home* (2014), *Stonehenge* (2016) and *The Fens* (2019). His most recent book is *Scenes from Prehistoric Life* (Head of Zeus 2021).

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Figures

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Chapter 15

Three wettings and a funeral: monument construction, land use history, and preservation at Skelhøj and Tobøl I round barrows, Denmark

Helen Lewis & Ann-Maria Hart

Soil micromorphology studies of Early Bronze Age round barrow sods and buried soils at Skelhøj and Tobøl I, Denmark, support proposals that specific and intentional practices were used by mound builders to create anaerobic mound cores, known elsewhere to preserve interred organic materials such as coffins and bodies. The Skelhøj barrow revealed construction procedures which may be related to the creation of a reduced (regarding iron) barrow core, including use of water and arrangement of mound sods with a variety of profiles that promoted redox conditions and the formation of iron panning around the core. These features may suggest deliberate use of and significant knowledge of soil properties on the part of the mound makers. Possible rotation of arable and pastoral land use is seen in the barrow sods; some of these land-use practices may have been part of the preparation for barrow siting and sod production for construction.

The Skelhøj and Tobøl I excavations near Ribe, Denmark (Figs. 15.1 and 15.2) investigated the soil, sediment and construction history of a round barrow type known to include preserved coffin burials dating from the Scandinavian Early Bronze Age (EBA, *c*. 1750–1100 BC; Holst 2013a, 22; Holst *et al*. 2013; Holst & Rasmussen 2013; 2015). These types of mounds are mainly found in south Jutland (Aner and Kersten 1973; Breuning-Madsen & Holst 1995; 1998; Randsborg 1996; Christenson 1998; Breuning-Madsen *et al.* 2000; 2006). Some have stunning preservation of organic remains, such as Egtved, where the partially preserved body of a woman was found in an oak coffin (Thomsen 1929). They commonly have an iron pan around the barrow core, creating a 'seal' that appears to maintain internally anaerobic conditions, leading to gleying in what are otherwise well-drained monuments constructed mainly of and upon leaching soils (Boye 1896; Broholm & Hald 1939; Holst *et al.* 1998). Plant remains found in the Egtved coffin suggested that decomposition 'stopped' soon after burial, meaning that anaerobic conditions were created quickly; this is also supported by the preservation of surface vegetation in sods in mounds such as Lejrskov (Breuning-Madsen & Holst 1998). Here we explore this phenomenon through soil micromorphology, looking at issues such as possible purposeful selection and alteration of soil materials to create anaerobic cores by EBA mound builders, and the land use history recorded in the soil used to build these monuments. This case study is part of research carried out by the authors when they were based at the McBurney Laboratory, into the geoarchaeology of earthen monument formation and conservation, and ancient land use practices (Lewis & Hart 2003; Hart 2005; 2006; Lewis 2012). Both lines of inquiry have been a major part of Charly French's research (e.g. French 2003; French *et al*. 2007; 2012); our tuition from and work with Charly on these is the foundation on which this research is built.

Several of these mounds have been studied morphologically, stratigraphically and geochemically (Gripp 1942; Breuning-Madsen & Holst 1995; 1998; Holst *et al*. 1998; Breuning-Madsen *et al.* 2000; 2003; see reviews in Holst & Rasmussen 2013; 2015). Archaeological and experimental work by Breuning-Madsen *et al*. (2001) explored how an anaerobic core was created and whether this was deliberate or not, arguing for two construction stages promoting redox processes. According to this model, the barrow core and mantle were erected in one continuous sequence. First, the core was constructed of densely packed, poorly draining soil around the burial, overlying a well-drained subsoil. The sods in the core were moist and/or may have been wetted during construction. Immediately after this, well-drained, drier sods (often from heather or grassland soils) were placed to cover the mound, creating the barrow mantle (*ibid*.).

Iron pan formation by redox processes is modelled to occur as oxygen in the barrow core would

Figure 15.1. *The location of Skelhøj and Tobøl 1 burial mounds in southwest Jutland, Denmark.*

become depleted by microorganisms, and iron in solution is suggested to travel to areas high in oxygen, such as the mantle and well-drained buried soil (Breuning-Madsen *et al*. 2001), where iron would oxidize. A build-up of iron oxides would cause mobile iron to move laterally and oxidize, forming an iron pan around the core of the mound. The iron pan, in turn, would restrict oxygen entering the core and possibly also create conditions amenable to a perched water table. Although the exact processes involved in the creation of these barrow cores are still somewhat poorly understood, the reduced conditions created are conducive to long-term preservation of organic material. If the iron pan around a core was breached, such as through later disruption, oxidization would begin to affect organic preservation (Breuning-Madsen & Holst 1995; 1998, 1104, after Gripp 1942; Breuning-Madsen *et al*. 2001; 2012; Hart 2006). Internal anaerobic conditions in these barrow cores are shown by good organic preservation, soil materials with reduced iron, and the presence of minerals such as vivianite (Holst *et al*. 1998). In contrast, in the external barrow mantles and buried soils iron is mainly ferric (oxidized), organic preservation is usually poor, and vivianite has not been noted (Breuning-Madsen & Holst 1998). At Skelhøj, for example, the formation of an anaerobic core is thought to have been nearly immediate, with redox conditions leading to the formation of iron panning layers under the mound and over the core (see below), while later disturbance of the upper mantle led to the localized

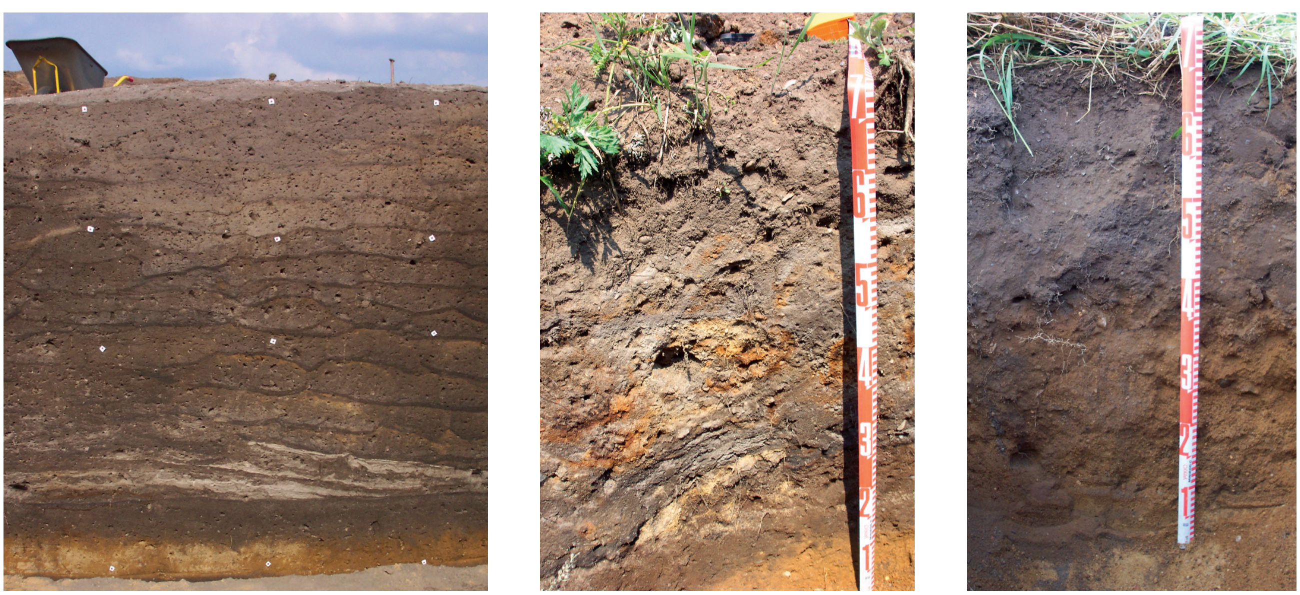


Figure 15.2. *Profile through part of the well-preserved Skelhøj mound (left), showing sods, white water-lain/water-sorted sand layers, and buried soil; the remains of the poorly preserved Tobøl I mound (centre), showing sods and buried soil; a typical profile from the area around Skelhøj, from test pit 1 (right). Images: Ann-Maria Hart.*

formation of irregular iron and manganese oxidation features (Holst *et al*. 2013).

In this study, soils and sediments were assessed for organic preservation in relation to iron oxide deposition, to better understand how redox environments in barrows were created and are maintained (Hart 2005; 2006), and for soil and land-use history, mound construction practices, and monument 'biographies' (Lewis & Hart 2003).

Methods and sites

In 2002–3 we conducted a detailed field description of exposed profiles at the Skelhøj and Tobøl I sites, and a modern comparative soil profile in a field 30 m north northeast of Skelhøj of a typical local soil. We took targeted block and bulk soil samples from the mantle, core and buried soil at Skelhøj, and from the core and buried soil at Tobøl I (Table 15.1), and field moisture

Table 15.1. *Samples taken from Skelhøj and Tobøl I Bronze Age barrow mounds (Lewis & Hart 2003; coordinates and section numbers provided by Kasper Lambert Johansen).*

Soil micromorphology (analyst)	Bulk samples (AMH)	Field description (HL and AMH)
Skelhøj X74 (HL)		'Wash' layer, gleying at vegetation zone; outermost part of first construction stage (gravel layer overlying vegetation layer)
Skelhøj X412 (HL)		'Trampling zone' at base of mound, just above buried A; similar to sods in 'wash' layers
Skelhøj X561 (HL)		Buried soil, surface horizons (L/F/Ah), K145 E503.08, N1010.22
Skelhøj X562 (HL)		Buried soil, Ap, possible ard marks, K145 E503.09, N1010.22
Skelhøj X563A-B (HL)		Buried soil, Ap-B/C; definite ard marks, K145 E502.92, N1010.21
Skelhøj X564A-B (HL & AMH)	Skelhøj X578	Sod in mound, thin turf line, mostly A, little B/C, E500.00, N990.71; site section D7
Skelhøj X565A-B (HL & AMH)	Skelhøj X579	Sod in mound, thin turf line, leached A, with B/C, E499.97, N990.50; site section D7
Skelhøj X567 (HL)		Water-lain deposits, buried soil turf, upper A, possible compaction structure, K39 & K109 E488.64, N1004.10
Skelhøj X568 (HL)		Upper & lower buried A, fragments of B in possible ard mark in lower buried A, upper B, K39 & K109 E488.64, N1004.10
Skelhøj X569A-B (HL & AMH)	Skelhøj X574-577	Lower set of water-lain deposits (lenses of sorted sands & silt), sods, turf of buried soil, Fe & Mn lenses in upper buried A, K39 E491.29, N993.43. Comparative bulk samples: X575 (between Fe pans), X576 (upper buried A), X577 (B/C); site section D145
Skelhøj X570A-B (HL)		Middle set of water-lain deposits (lenses of sorted sands & silt), sod between layers of water-lain deposits, K39 E491.75, N992.88
Skelhøj X571 (HL)		Upper set of water-lain deposits (lenses of sorted sands & silt), K39 E492.01, N992.59
Skelhøj X572 (HL)		Sod between upper & middle water-lain deposits, water-lain deposits (lenses of sorted sands & silt), K39 E492.00, N992.60
Skelhøj X573A-B (HL & AMH)	Skelhøj X580	Sod in mound, thin turf line, B/C, thin Fe pan, E494.87, N998.44; site section D8
Skelhøj X581 (AMH)	Skelhøj X582-X584	Border of 2 sods with Fe pan separating each sod; site section D8
Skelhøj X585 (HL)		Sod in mound, no turf, B horizon (no gravel); site section D10
Skelhøj X586 (HL)		Sod in upper mound, Fe pan, B/C (gravelly); site section D8
Skelhøj X587 (HL & AMH)	Skelhøj X589-X590	Modern Ap from control 1x1m test pit 30m NNE of mound, E525.50, N1041.49
Skelhøj X588 (HL & AMH)	Skelhøj X591	Modern B/C from control 1x1m test pit 30m NNE of mound, E525.50, N1041.49
Skelhøj X950/1 (AMH)	Skelhøj X954	Border of upper Fe pan of core, with sods of mantle, Fe pan, core
Skelhøj X952 (AMH)	Skelhøj X955	Core with organic material preserved
Skelhøj X953 (AMH)	Skelhøj X957	Border of lower Fe pan, with core, Fe pan, buried upper A
Tobøl I Tob A (HL & AMH)	Tob 1	Sods in lower mound
Tobøl I Tob B (HL & AMH)	Tob 2, Tob 4	Basal sod, Fe pan, 'gleyed' layer, buried upper A
Tobøl I Tob C (HL & AMH)	Tob 5	Buried lower A, upper B/C

readings at the sampled profile locations. We both conducted soil micromorphological analyses of different sample sets (Lewis & Hart 2003; Hart 2005), and Hart (2005; 2006) took bulk samples and moisture readings, and undertook a project investigating preservation conditions in comparison to experimental mound constructions, aspects of which are included here.

While Skelhøj was in excellent condition at eight metres high, Tobøl I had been significantly ploughed, and stood less than one metre. Excavation results from Tobøl I were not available to us at time of writing, but excavations at Skelhøj revealed Neolithic (Funnel Beaker) activity followed by ard ploughing episodes (undated), then soil stabilization (development of an A horizon), and then EBA monument layout, burial and mound building. The latter was interpreted as occurring in five stages, with evidence of 'rainfall episodes' both within and between them, and included the creation or development of an anaerobic barrow core, iron panning layers, an oxidized barrow mantle, monument reconfiguring, kerb and platform construction. Contemporaneous and later occupation deposits were also seen, including a Late Roman Iron Age charcoal layer at one location, later grave robbing and removal of kerb stones, and building of field boundaries (Holst *et al*. 2013; Kristiansen & Heinemeier 2013). Our research focused on the buried soils and the EBA mound sods (first to fourth 'shells'; Holst & Rasmussen 2013, 139–40).

Mammoth thin sections were prepared (after Guilloré 1985; Murphy 1986) and analysed (after Bullock *et al.* 1985) using Nikon Optiphot 2 and Leitz Laborlux 12 POL S microscopes and a Wild Photomakroskop M400. Twenty-two bulk samples saw a set of drying (oxidation) experiments (Hart 2006) and various analyses: inductively coupled plasma atomic emission spectroscopy (ICPAES) focused on total Fe and Mn among a suite of elements assessed (after Li *et al*. 1995; extraction was via ALSChemex Digestion by aqua regia); loss-on-ignition (LOI) to estimate moisture, organic and mineral content (Nelson & Sommers 1996); magnetic susceptibility (MS) by volume as an additional measure of Fe and Mn (10 cubic cm; repeated minimum on three samples averaged out) (after Aitken 1969; Longworth & Tite 1977; Lapidus 1990); particle size distribution (PSD) (Last & Smol 2001); pH (Goudie 1990); electrical conductivity (EC) as an additional measure of organic content (Courtney & Trudgill 1976; Rhoades 1996); and redox to measure the reducing-oxidizing potential of the sediments (Patrick *et al*. 1996). Moisture readings were taken in the field at 5 cm intervals down selected profiles using a TDR 300 Moisture Metre, which takes volumetric water content (VWC) measurements of percentage water in the soil. The readings were taken from the locations of specific soil micromorphology samples and were repeated three times to obtain an average reading at each sample site (see Hart 2005; aspects are summarized below).

Results

The mounds were studied micromorphologically for profile history, ancient land use, redox indicators, and other cultural indicators (Appendix, Tables A15.1–A15.7). The main mineral components for all samples examined were quartz, feldspar and amphibole grains, with granite, flint/chert, sandstone and basalt rock fragments and weathering products (the latter identifications thanks to Chris Doherty, 2006, pers. comm.).

The local modern soils are acid brown earths (after Bridges 1978, 55), some tending towards brown podzolic soils, over glacial sands and gravels (Lewis & Hart 2003). These have moder/mor and mineral A over B, B/C or Bs horizons, rich in oxidized iron (Fig. 15.2). B horizons varied in stoniness, being mainly sand with grit, sometimes with rounded and subrounded gravel (1–5 cm). The control test pit showed characteristics of leaching and bioturbation, and some charcoal additions (Appendix, Tables A15.1–A15.2). Although a known plough soil, there were few disturbance indicators typical of tilling in the topsoil (e.g. Lewis 2012; Deak *et al*. 2017), but there was mechanical inmixing of A horizon material to a depth of 6 cm into the B/C horizon.

Tobøl I

Tobøl I was flattened by agricultural land use, but some mound material and the acid brown earth buried soil were preserved. Samples were taken from a re-excavated section first exposed in 2002 (Appendix, Tables A15.1–A15.2; Lewis & Hart 2003). The overturned (grass-side down) barrow sods, with thin surface layers of oxidized iron, together formed an imperfectly sorted, leached A horizon, with less organic matter than seen in the modern A or in sods from Skelhøj (see below). Hart (2006) identified three sods in thin section, two with intact turf layers. Disturbance indicators included infillings of the main fine fabric in old pore spaces, creating a 'whole soil coating' (Fitzpatrick 1993, 189) and 'dusty', iron-stained and cracked clay coatings. Some of these features may relate to mound construction and erosion, or to pre-mound land use in the sods' original landscape locations, but many are probably the result of modern ploughing affecting this disturbed mound. Well-developed 'agric' horizons with whole soil coatings have been associated with mechanized tilling (Jongerius 1983). There were rare clean clay fragments which may have been mechanically transported into the sods from a lower horizon.

Lower in the mound, sample Tob B showed a sod with its turf layer lying upside-down on an iron pan. The turf layer became an accumulation zone for leached amorphous organic matter, and frequent iron and manganese nodules were seen throughout the sod. The underlying iron pan resembled oxidation features seen around roots, including root pseudomorphs seen in the overlying sods, but also contained frequent fine infillings related to disturbance. Immediately underlying the pan was a line of fine gravels. This pan appears to mark the base of the barrow mound, and it reflects some impermeability at the surface of the buried soil, compression or compaction related to mound construction and later disturbance, oxidation and leaching of the profile. Underneath the pan was the truncated lower A horizon of the buried soil. It was similar to the overlying mound but slightly reddish brown in colour, and was also 'agric' in nature, attesting to the strong disturbance of the site. This overlay an upper B horizon, which was similar to the B/C in the modern profile, but contained rare fragments of clean clay, and frequent pore infillings and coatings of clay, silt and very fine sand.

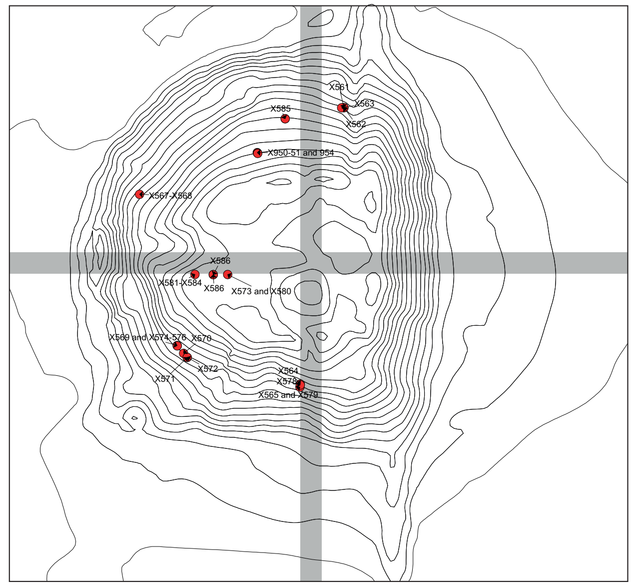


Figure 15.3. *Plan of Skelhøj showing sampling locations, except for X74, X412, X952-3, X955 and X957. The barrow is about 30 m in diameter. Image: Kasper Lambert Johansen.*

Skelhøj

Sampling locations at Skelhøj are shown in Fig. 15.3. Appendix, Tables A15.1–A15.2 include descriptions from the buried soil profile, while mound construction samples are presented in Table 15.2 and Appendix Table A15.3 (lower construction sequences), Tables A15.4–A15.6 (core samples), and Tables 15.3 and A15.7 (additional mound sod samples).

Buried soil and pre-monument land use

The buried soil was described by Breuning-Madsen and Dalsgaard (2013) in the field as Apb-Bvb-C1b-C2b, all coarse sand with subangular blocky structure. We observed a defined turf layer (3 cm thick, buried O/Ah), indicative of being left to grassland for some time before barrow construction, over one definite and one probable set of ard marks visibly cutting through the buried Ap (14 cm thick), showing at least one episode of criss-cross tilling (Fig. 15.4), and possibly two or three. The bAp overlay 10–20 cm of oxidized, iron-rich B/C, similar to that found in the control profile off-site over C (oxidized sand and gravel) (Lewis & Hart 2003).

The 'old ground surface' was marked by a turf line of brown sand with iron- and manganese-replaced roots, over panning layers of black(ened) sand, and brown or dark reddish brown loamy sand with iron-stained roots and frequent 'dusty', organic-stained clay coatings. This showed signs of disturbance and illuviation, possibly reflecting the impact of barrow construction or the tilling identified in the horizon underlying. At the base of this micro-sequence was an infilled, horizontally oriented linear void at the upper boundary of the buried ploughsoil.

In addition to the ard marks seen in the field between the buried Ap and B/C, later tilling episodes were indicated in the bAp. 'Dusty' and sandy clay coatings and infillings typical of a disturbed soil (Macphail 1987; Courty *et al.* 1989; Macphail *et al*. 1990; Gebhardt 1990; 1992; 1995; 1996) were seen, along with one definite and one possible ard mark cut, both filled with the main bAp soil. The definite ard mark cut comprised a dense line of very dark brown, strongly organic-stained clay infillings. This type of fine infilling has been identified as typical of implement mark feature cuts (Lewis 1998; 2012). An irregular, diffuse boundary divided the upper and lower parts of the buried Ap, marked by a concave line of discontinuous silty clay infillings and linear voids, and there were diagonal lenses of B/C horizon material at this level in other locations in the field (Lewis & Hart 2003). A further ard mark feature was sampled at the bAp-B/C boundary, plus one half of a possible adjacent mark. These marks were described in the field as *c*. 5 cm deep and 6–7 cm wide at the top of the exposed features. Their edges were lined with yellowish brown sand, apparently pulled up from the base into the sides of the marks. The main fill was similar to lower A horizon material, but more strongly oxidized.

Table 15.2. *Summary of samples from 'wash' layers (see Table A15.3 in this Appendix to this chapter for descriptions).*

X568-9: many distinct layers of sorted sand interspersed with possible sods over 10 cm depth: 1) 0.4 cm medium sand (water-sorted); 2) 1–2.5 cm dense, organic, brown loamy sand (sod Ah); 3) 0.5–1 cm medium sand (water-sorted); 4) Fe pan, concave; 5) 0.8 cm leached loamy sand; 6) 2–3.5 cm organic sandy loam (bAp/sod); 7) 2 cm slightly leached loamy sand; 8) 3.5–5 cm dense, sandy clay loam bAp, convoluted upper boundary.
X412: disturbed, organic-stained upper A, over lower A/A-B with Fe-oxide staining & frequent coatings, possibly disturbed through tilling &/or barrow construction. The boundary between the horizons: 3 mm thick layer of 'panning' with Fe-oxide and clay accumulation. This was not a cemented Fe pan as seen elsewhere. The location was described in the field as a 'trampling' zone, based on the compression of sods (Lewis & Hart 2003). A 2 cm-sized fragment of this fabric was seen mixed into the underlying bA.
X74: despite its field description (Table 15.1) did not show 'wash' or gleying, but was a sod profile: A over B. The A showed signs of disturbance, including 'dusty' & silty clay coatings, plus mixing of B horizon fragments into the A; although a 'turf' at time of barrow construction, this was previously a ploughsoil (Ap). There were no indications of compaction or trampling. This sample represented the outermost part of the first mound construction phase, without 'wetting', only sod laying.
X570: the second (middle) set of water-lain layers, including the base of the overlying turf sod, 'wash' layers, the entire underlying laid sod & the lowermost set of water-lain layers. The uppermost part of bA was included at the base of the sample. The sod at the top was blocky topsoil with frequent 'dusty' clay & an illuvial clay component. Under this with a sharp boundary was a layer of sorted medium sand with occasional charcoal & clay fragments from a lower horizon (Bt). This layer was leached of other fine fabric and organic matter. Under this was a 'micro-spodic' horizon: 500 μm-thick layer of amorphous organic and Fe coatings on sand grains, over 1000 μm-thick layer of well-sorted dense sand & silt infillings around sand grains, with finer later infillings. Under these layers was a compacted/compressed laid sod, with in-mixed clay fragments, likely originating from a B horizon at its original location; this appears to have seen tillage. There were also many infillings & coatings of material similar to the groundmass. Under this sod were layers of leached sand and Fe-stained sand, the latter with frequent complex coatings and cappings of organic-stained clay.
X571: the base of the main turf mound, the uppermost set of water-lain layers over the layer of sods dividing this from the middle set of 'wash' layers. **X572** was taken from immediately underneath this, capturing the main part of a laid sod and the upper part of the middle layer of water-lain lenses, where 'flow' structure was visible in the field (Lewis & Hart 2003). The basal sod of the mound was a tilled topsoil (Ap) that had developed a turf line before being used in mound construction. Under this horizon was 3–4 mm of leached sand, as noted in the X570 sequence, over a 1–2 mm-thick sorted infilling of very fine sand, silt and clay. Under this was a series of alternating leached layers (2–4 mm thick) & brown sand layers (1–5 mm thick). In X572, the sod underlying these deposits was a sandy A horizon which was mixed and disturbed; it may have originated from a tilled profile before being incorporated into the barrow. A fragment of possible earthenware pottery was seen in this material.

Figure 15.4. *Criss-cross ard marks under Skelhøj and visible in profile in the base of the buried A horizon; sampling location for X561-X562-563A/B. Image: Helen Lewis.*

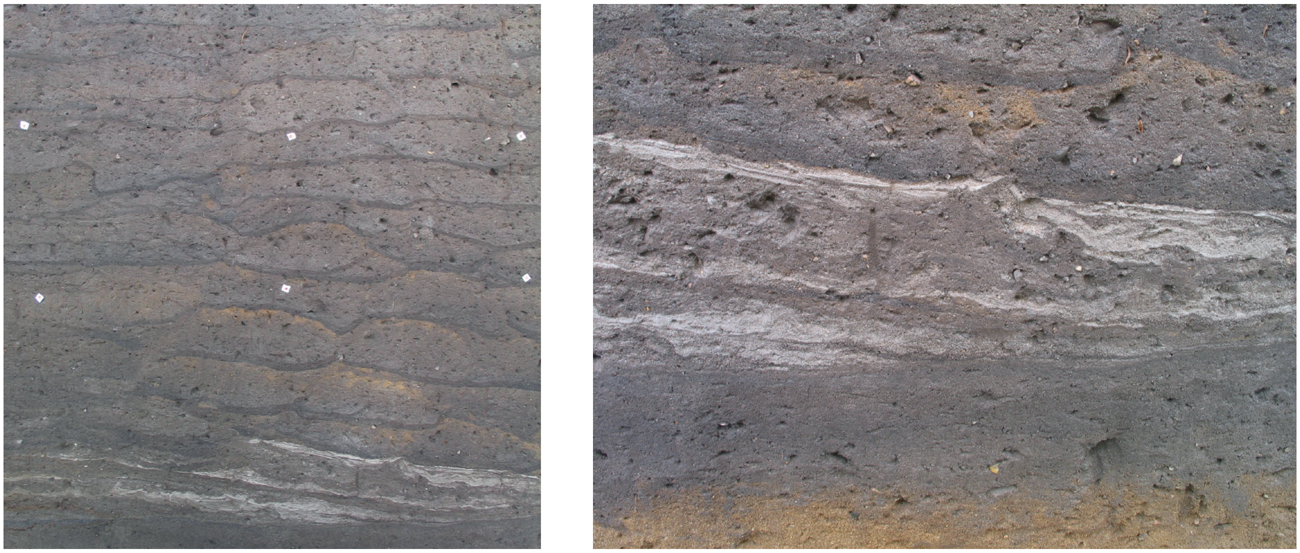


Figure 15.5. *Two views of the sand layers at the base of the Skelhøj barrow mound; these overlay compacted sods. The entire unit rested directly on the buried soil. Also visible in the mound are sods with a thick A horizon, and sods with a thin A over an orange B horizon. All sods appear to be turned upside-down, with the possible exception of the sod layer in between the first and second sand layers; the dark brown lines are the sod turf surfaces. Scale distance between white dots 50 cm. Images: Ann-Maria Hart.*

The buried soil was also sampled at K39 underlying 'wash' sediments (Figs 15.2 and 15.3), and K109 (ard marks) at the northern side of the mound. In this location the upper 10 cm of the bAp had a 'frangipan'-like microstructure: layers of oblong peds (0.5–1 cm size in the horizontal plane) surrounded by infilled horizontal planar voids. The infilling may relate to much later illuviation, although a possible relationship to the events creating the overlying 'wash' layers (discussed below) cannot be ruled out. The structure might relate to compaction or compression from the weight of the mound, plus later infilling. It could also relate to glacial or periglacial deposits, but no macroscopic corollary was noted in the field. Otherwise, the bAp was similar to that described above, but with gravel inclusions throughout. There was an intermittent lens of orange sand that might represent a tilling boundary separating the upper and lower bAp, and a sharp boundary where ard marks cut the reddish-brown sandy loam B horizon. The B had illuviated 'dusty' clay, organic matter and iron, and was possibly a Bs or incipient Bt/Bfe.

Initial mound construction phases:
water-lain/'wash' layers and compacted sods

Three phases of water-lain and/or water-sorted and leached sands, separated by laid sods, were seen on the surface of the buried soil. The specific construction elements where these occurred in the mound have been interpreted as 'approach slopes' (Figs 15.2 and 15.5; Holst 2013c, 291, 298). A set of samples through these deposits on the north-western side of the mound (at K39) included the lowermost phase of sorted sand and silt lenses with some flow structures ('waves') on the surface of the buried A horizon. This phase was under a layer of laid sods (one sod thick), overlain by a second, middle set of 'wash' sediments. A further layer of laid sods, and a final, upper set of water-lain lenses overlay this. Over this sequence was the main turf mound.

The water-lain layers were not typical of sorted infilling sequences from leaching, nor of 'agricutan' deposits (mentioned above), but akin to thick, sorted depositional crusts. These are normally seen where there is puddling and flooding of disturbed and bare soils, cryoturbation, or sorting under low-energy stream flow deposits (run-off).

For example, samples X568-9 from the lower part of the sequence (Table 15.2; Fig. 15.5 right; Appendix, Table A15.3) comprised size-sorted lenses of sand and silt, interspersed with compressed sods; many distinct layers of sorted sand interspersed with probable sods were seen over 10 cm thickness. A similar series of deposits was seen in the two overlying (later) phases. For example, X570 from the second (middle) set of water-lain layers included a turf sod from a blocky topsoil at the top, with some disturbance indicators and an alluvial component. Under this, with a sharp boundary, was a layer of sorted medium sand with

Table 15.3. *Interpreting individual mound sod samples (micromorphology descriptions in Table A15.7 in the Appendix to this chapter).*

X564: from an outer layer of the south side of the mound; a complete upside-down sod with 1 cm turf line, a grey heavily rooted Ah & a thin light brown/grey gravelly B/C. This sod represented an organic grassland soil.
X565: just below X564 in a different sod: 1 cm turf line over 3 cm grey A of medium to fine sand, and a lighter (perhaps leached) horizon, over an Fe-rich medium sand B/C with gravel.
X573: marked Fe mottling throughout an upside-down sod of loamy sand with a thin grey Ah over lighter grey (Ap) and an Fe-rich B(t/fe). A light grey zone with bands of Fe oxide underlay this. Some infillings suggest it may have been an Ap horizon previously & there was some possible *in situ* burning of turf vegetation.
X581: taken across an Fe-pan border between two different sod phases. To the right of the pan a partial sod was included: grey medium to fine sand A with a light grey gravelly coarse to medium sand layer above. Just beneath the Fe pan and at the bottom of the sod was a grey medium sand layer. To the left of the pan was a medium to fine sandy grey layer interspersed with grey bands.
X585: an upside-down sod of very dark greyish brown sand A with a B/C of yellowish-brown sand with no gravel. The base of the B/C from the underlying overturned sod was also caught in the sample. The sods here were visually different from those elsewhere, in that the profile did not appear to include actual turf horizons at the surface, and there were no Fe or Mn oxide features noted in the field (Lewis & Hart 2003). However, this thin section included an Fe panning zone which many have related to a soil boundary, and a possible developing A which was very thin (*c.* 3 cm) of very dark brown, amorphous organic- and Fe-stained sandy loam. Despite the lack of macroscopic oxidation features, there were frequent Fe-stained grain coatings, including the 'split' coatings typical of Fe pans, & infillings. The B/C sand horizon had some 'agric' features.
X586: from an area of strongly oxidized sods in the barrow mantle. It had a gravelly B/C (Lewis & Hart 2003). The sample comprised an upside-down sod with the following right-side-up sequence: 1–2 cm reduced O; Fe oxide lens; 1–3 cm zone of Fe mottling (possible rooting zone); 3–6 cm of gravelly yellowish brown sand B/C. This was similar to X585 in characteristics, but with a fine surface horizon which was Fe oxide- and organic-stained, with roots. No Mn oxidation features were noted. Both of these samples show loss of much of the A, & 'new' growth of a thin turf line. We suspect that these types of sods represent an area de-turfed and then left for a few seasons to grow another turf before the Skelhøj construction process.

occasional charcoal and clay fragments, but leached of all other fine fabric and organic matter. Under this were two very thin layers similar to a 'micro-spodic' horizon: a 500 μm-thick layer of amorphous organic and iron coatings on sand grains, over a 1000 μm-thick layer of dense sand and silt infillings around sand grains. The lower layer was relatively well-sorted (with finer, later infillings), suggesting it may have originated as a water-lain/puddling deposit later affected by illuviation (leaching). Since the sods were placed upside-down, and in light of the thick 'wash' layers seen in the field, the sequence probably relates to post-depositional leaching, and does not indicate that these sods came from podzol profiles. Under these layers was a compacted/compressed laid sod, with in-mixed clay fragments probably originating from a B horizon at its original location. Despite being a turf sod when used in mound construction, this soil may have had a history of tilling. Under this sod were layers of sorted, leached sand and iron-stained sand, the latter with frequent complex coatings and cappings of organic-stained clay.

Skelhøj mound construction: the core

Several types and stages of iron panning were seen, the most significant being the pan separating the core from the mantle. The sods within the core were an anaerobic homogenous soil, with individual outlines barely visible (dark grey triangle seen in Fig. 15.6), in contrast to the oxidized mantle. These were described as influenced by redox and gleying by the excavation team, who distinguished three parts of the core based on degree of gleying by depth, which they related to 'duration of water saturation': the lowermost part of the core was anaerobic for the longest, while the upper parts were subject to some level of oxidation, possibly through disturbance (Breuning-Madsen & Dalsgaard 2013, 224). The upper iron pan covering the core varied from 0.5–12 cm thick, and the iron pan at its base was 1–2 cm thick. Both iron pans also contained manganese oxide panning, and some roots protruded between these. There was a yellow loamy sand lens between the sods of the mantle and the upper iron pan, possibly the result of weathering or part of the construction.

Samples were collected to examine the degree of preservation of organic material within the core, from a profile including the upper iron pan through to the buried soil beneath the core on the northern side of the mound (Appendix, Tables A15.4–A15.7; Hart 2005; 2006). The mantle sod sampled was gravelly loam, probably originating from an upper B/C horizon with turf grown on the subsoil. The iron pan included iron, manganese- and iron-rich clay. The upper core was a homogenous gleyed loamy sand, with massive to crumb structure. The centre of the gleyed core, while apparently homogenous in the field, showed remnants of individual laid sods in thin section, demarcated by black lines marking the edges of turf layers. Several micro-horizons were identified, with 'turf' lines over silty clay A horizons, and well-preserved organic inclusions. The gleyed lower core was highly organic, but with fewer preserved organic inclusions than the main core. A set

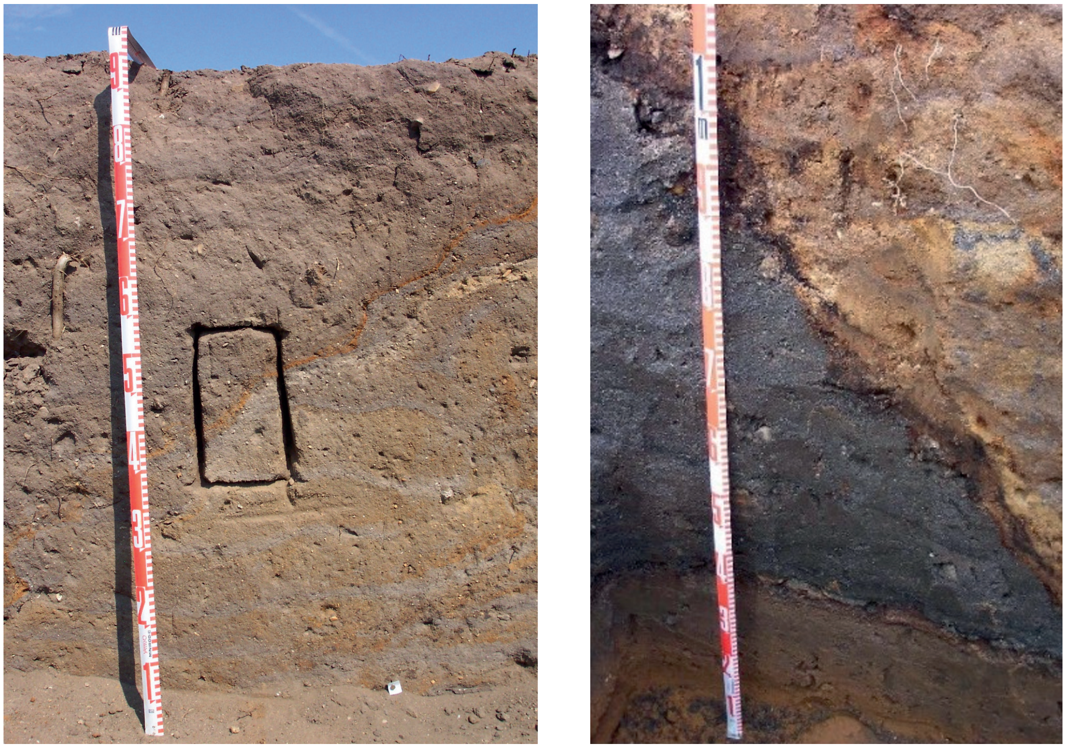


Figure 15.6. *Iron pans and redox conditions at the Skelhøj barrow. The left image shows the very top of the extant barrow mound, marked by iron panning between the upper mantle and the modern topsoil A horizon. Lower down in the mound, the dark grey triangle (base of the barrow core) on the right comprised homogenized organic and reduced sods, separated from the oxidized mantle (orange soil, right) and the buried soil (grey-brown at the base) by iron panning layers. Images: Ann-Maria Hart.*

of sods with turf lines was also identified here. There was a <1 mm-thick dark green-grey layer directly above the lower iron pan. The latter comprised the following sequence of micro-layers: iron pan, manganese pan, iron-rich clay, iron pan, iron-rich clay, 'irregular' iron panning, 'irregular' manganese panning, iron-rich clay, and 'irregular' manganese panning. Directly below the pan was a slightly leached sand layer (3–5 cm). Below this was the buried A (10–12 cm), a brown medium to fine sand with some gravel, with mixed massive to crumb structure.

Land use in the nearby area: the evidence of the barrow sods

There were several different types of sods within the Skelhøj barrow, all representing local soil profiles, and we took additional samples to represent this variety (Appendix, Tables A15.6–A15.7; Lewis & Hart 2003; Hart 2005). Thicknesses noted are those measured in the field, and represent compacted/compressed thickness, not original sod sizes. All profile variations had strong iron oxidation lenses and mottles, and some had iron panning horizons. The prevalence of these features appears to mainly relate to much later leaching and rooting impacts, with the possible exception of the thicker iron pans found around the core. Some sods represent an area de-turfed or tilled and then left for a few seasons to grow new turf before the Skelhøj barrow construction process began, i.e. the final land use was turf production for 'harvesting' for construction. In summary, the types of land use represented by soil micromorphology samples from the mound and the buried soil fell into three major categories:

- **Wet pasture**: 10–20 cm-thick sods with moder/mor and A only, with no indicators of previous disturbance, suggesting an origin from longstanding Ah horizons (possibly pasture, perhaps of a type similar to that found next to the nearby riverbed today; Lewis & Hart 2003). This type of sod was seen mainly in the barrow core.
- **Truncated pasture/arable/rotation**: sods with various thicknesses of moder/mor and Ah(p) over iron oxide-stained B/C (with or without gravel). Some had relatively thick A horizons (>10 cm), with only the top of the B/C horizon included

at their bases, while others had thin A horizons (1–5 cm) or just moder/mor, with the majority of the sod composed of B/C material. These variations in A horizon thickness could indicate local 'natural' variation in turf growth, or different stages of regrowth of vegetation on previously tilled and/or deturfed areas, possibly reflecting rotations or planning for turf growth needed to construct burial mounds. Many of these showed disturbance indicators.

- **Arable or deturfed**: a few sods in the mantle of the mound did not show moder/mor layers, just lower A(p) horizon material over B/C. These sods could come from lower in the original profile (i.e. an area already deturfed), or from tilled topsoils with no surface vegetation. Most of these showed microscopic disturbance indicators (e.g. 'dusty' clay or silty clay infillings/coatings).

Comparing preservation environments

Hart (2005; 2006) compared preservation conditions at Skelhøj and Tobøl I to the results of an experimental study of archaeological mounds and soil profiles, including an experiment at Lejre in Denmark based on the Egtved mound, with wet and dry cores (Breuning-Madsen *et al*. 2003). The field estimated moisture readings of the archaeological sites (Table 15.4) showed a low water content, reflecting both season of reading (late summer), as well as the impact of excavation on the mound. Higher readings were found from a study carried out earlier in the excavation season (H. Breuning-Madsen, 2003, pers. comm.). The surface of the modern soil had the highest readings due to its vegetation layer, where much of the soil moisture is expected in sandy, well-drained soils. Higher readings were also seen in transition phases and near iron pans in the Skelhøj mound sods, probably related to texture changes and the iron pans acting as impediments for water movement.

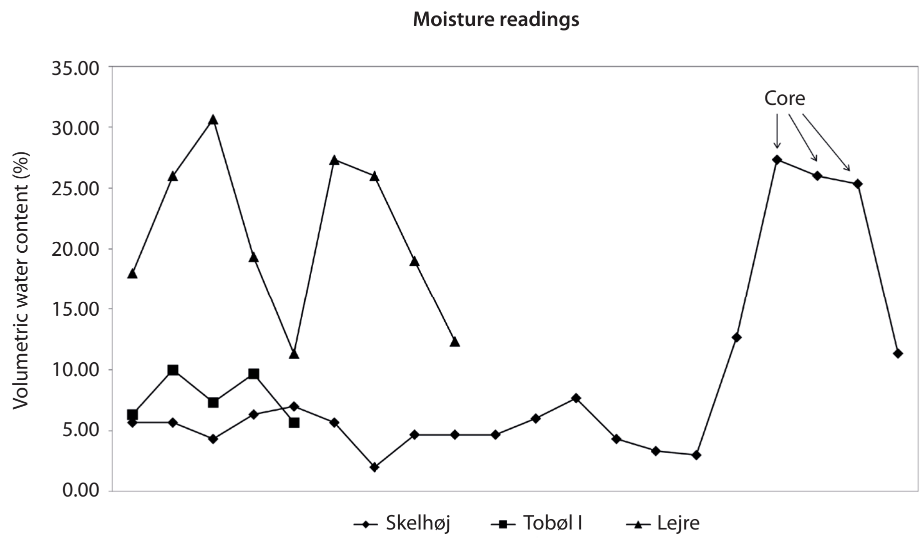
Geochemistry showed the Lejre experiment to be a representative gauge for preservation for Skelhøj and Tobøl I (Figs 15.7 and 15.8; Hart 2005). The ICPAES for manganese and the MS results seemed to relate to each other. Estimated moisture content, measured both in the field and in the lab (LOI), was consistent between the Danish sites, with the exception of the in-field measurements, where Lejre differed from the archaeological sites. The higher peaks in the Skelhøj moisture and organics data represent the modern Ap horizon from the control pit, and the samples taken from the moist core of the mound (*ibid*.).

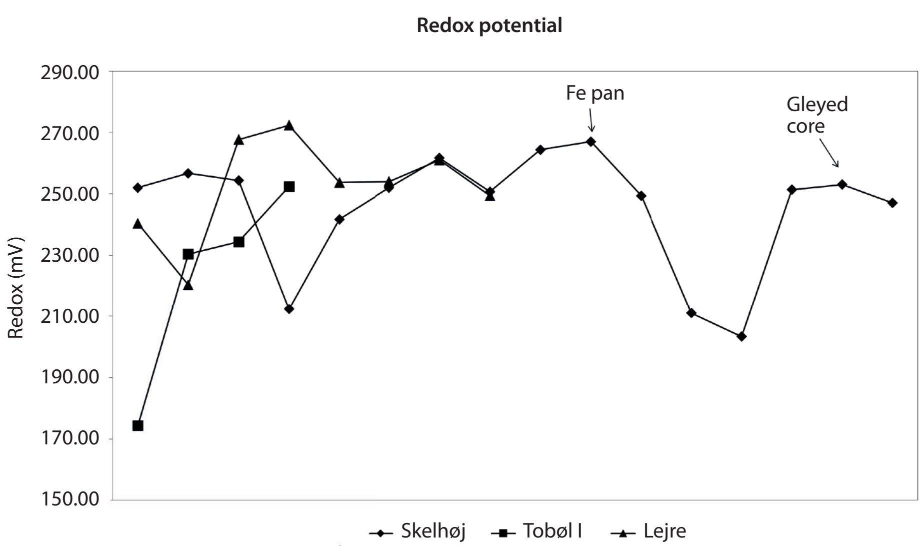
The separation seen between the sites in the moisture and organic data represents a difference in timescale. Both measurements were higher in the modern experimental site and the modern Skelhøj topsoil than in the Bronze Age mantle (Hart 2005). The peak from the barrow core at Skelhøj reflects conditions noted in the field: excellent preservation of organics and a 'wet' environment compared to the barrow mantle and the buried soil. The Tobøl I mound has seen more disturbance, which has resulted in poorer organic preservation; it was most similar to the samples taken from the mantle of Skelhøj (*ibid*.).

In comparison with the micromorphology, it appears that in the presence of iron panning excellent

Table 15.4. *Moisture readings from sampling locations. VWC=average estimated percentage water (Hart 2005).*

Site	VWC	Location of reading	Site	VWC	Location of reading
Modern test pit	8	Surface of control pit, X587-588	**Skelhøj**	5.67	X573
	5	70cm from base of pit		5.67	X564
	6.33	60cm from base of pit		4.33	X565
	4.33	50cm from base of pit		6.33	sandy lens X569
	2.67	40cm from base of pit		7	between Fe pans X569
	3.33	30cm from base of pit		5.67	upper buried soil X569
	3.33	20cm from base of pit		2	lower buried soil X569
Tobøl 1	6.33	Ap		4.67	water-lain sediment X567
	10	transition Ap-B/C		4.67	turf line of buried A X567
	7.33	B/C		4.67	upper 'gley' buried A X567
	9.67	'Gley' above Fe pan		6	main buried Ap X567
	5.67	Sods		7.67	upper B/C X567
				4.33	above Fe pan X581
				3.33	below Fe pan X581
				3	Fe pan X581





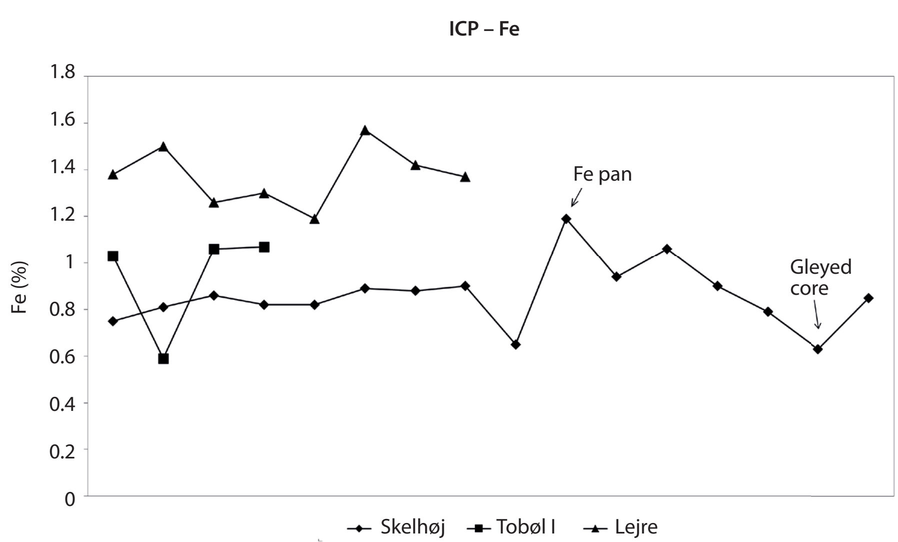


Figure 15.7. *Line graphs illustrating the results from: top) ICPAES for percentage of total Fe; centre) for redox potential, and bottom) percentage volumetric water content measured in the field for Skelhøj, Tobøl I, and Lejre (after Hart 2005). Note that the X-axis is individual samples only, not a measurement, and shows no trend. Images: Ann-Maria Hart.*

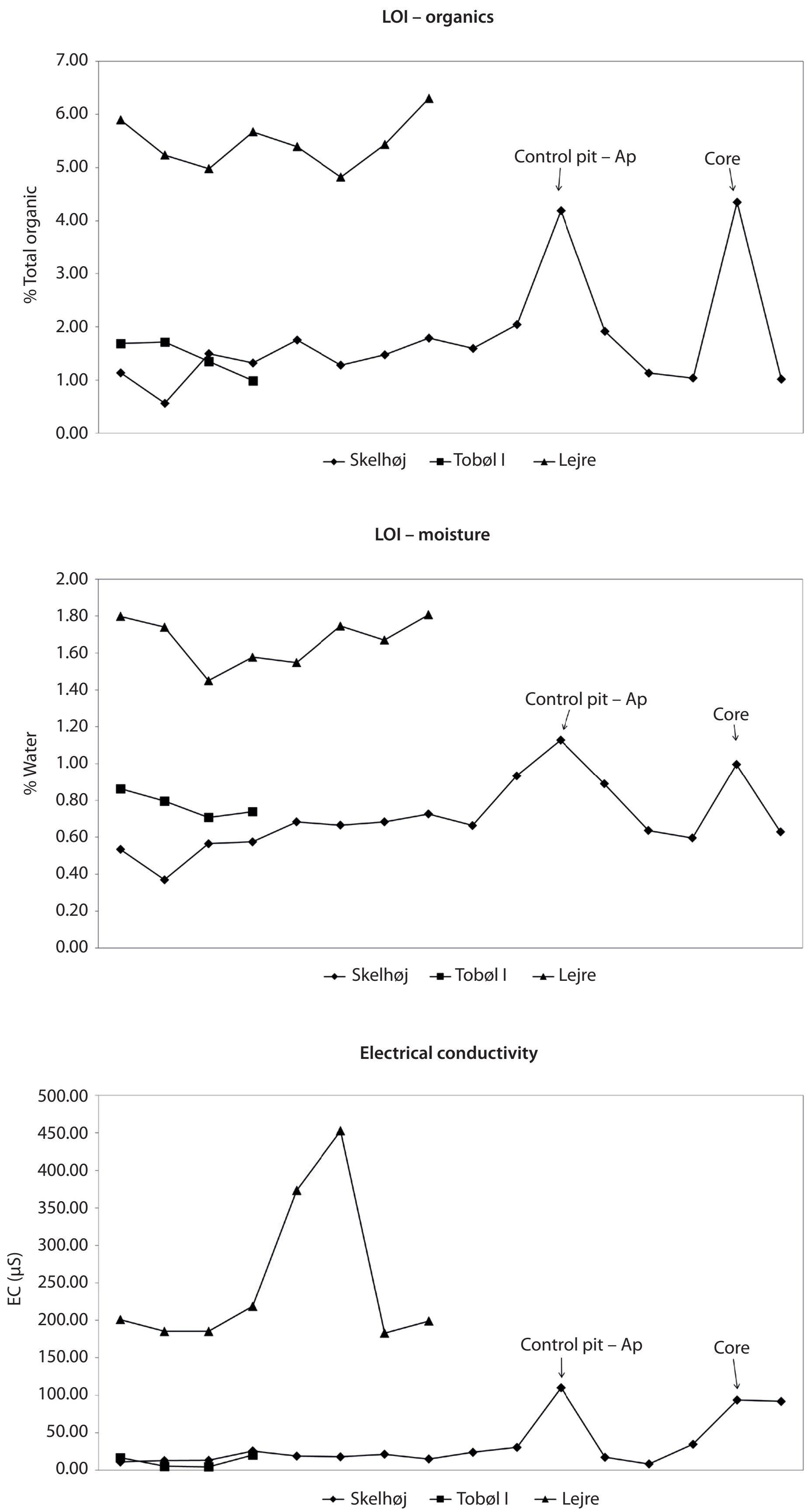


Figure 15.8. *Line graphs presenting the results of: left) loss on ignition (LOI) carried out in the lab for moisture content, centre) LOI for organic matter content, and right) electrical conductivity readings for Skelhøj, Tobøl I, and Lejre (after Hart 2005). Note that the X-axis is individual samples only, not a measurement, and shows no trend. Images: Ann-Maria Hart.*

organic preservation exists. Other iron oxide features, such as nodules and staining of the groundmass, are indicators of an oxidized environment, and the expected low quality of organic preservation was seen to decrease from thirty-forty per cent, to ten-twenty per cent or lower (Hart 2005).

Discussion

Land-use practices

The EBA Skelhøj barrow was built on a turf surface, but this was not a well-developed grassland soil, and it had previously been an arable (ard-ploughed) field. Before the barrow was built, the location saw repeated and possibly long-term cultivation before being left 'fallow' for a period of time to vegetate over, at least long enough to create a thin moder profile. Possible truncation of the buried soil cannot be ruled out, i.e. the length of time between cultivation and barrow construction is unclear, and the phase(s) of tilling noted might be much older than the date of barrow construction. This is a common issue for features underlying monuments, and many buried soils under barrows in Denmark show signs of tilling that can only be dated to 'pre-barrow' (e.g. Aner & Kersten 1973; Holst *et al*. 1998).

This history of land use is also seen in many of the sods examined from the barrow mantle which show disturbed A, truncated (lower) A or even upper B/C horizons directly underneath thin turf lines. These sods did not come from the land under the mound, but could have come from land nearby that saw the same land-use history. Some showed a relatively well-developed Ah growing after an earlier Ap, while others had only a very thin turf line directly onto an Ap or B/C. Perhaps some locales were deturfed or otherwise devegetated more than once, or had seen more intense erosion under arable farming in the Neolithic to EBA. Although we can discuss a sequence in land use in general, temporal relationships between these phases of land use cannot be demonstrated from this study.

Typical ard mark micro-features were described in many locations, and throughout the buried soil, not only where macroscopically visible at the bAp/B-C boundary. The buried soil samples also had frequent micro-fragmented charcoal, disturbance indicators such as 'dusty', sandy or silty clay infillings and coatings, and fragments of lower horizons brought up into the topsoil. Arable land use was clearly a long-term practice in the area before the barrow was built. As noted above, this was often followed by a phase of stable grassland, suggesting possible rotation with pasture.

The Tobøl I barrow was extremely disturbed, with frequent infillings of fine fraction soil materials, at times creating whole soil coatings. These were found in all A horizon and mound layers, both above and below a 1 cm-thick iron pan. As these disturbance features are probably related to recent cultivation, it is suggested that the iron pan at Tobøl I is also relatively recent, or has at least been reinforced through historic ploughing, erosion and leaching. The panning layer marks the base of the barrow mound, so it could be ancient in origin, or be modern but reflecting an ancient profile boundary. The comparative modern soil profile was less disturbed than this barrow, with a well-developed Ah horizon and a highly leached B horizon, and with some textural features suggesting previous disruption of the soil. Since we know that this soil has seen modern ploughing, we suggest based on structural indicators that some bioturbation impact may have 'erased' some disturbance features in the modern soil, and possibly also be reflected in size sorting over depth of gravel inclusions seen in the profile.

The creation and preservation of an anaerobic barrow core

The presence of the iron pans surrounding the core of the Skelhøj mound enabled an anaerobic environment to persist, resulting in moisture regimes emulating the preservation conditions of relatively fresh organic material. Through combined soil moisture, bulk sample and soil micromorphology studies, Hart (2005; 2006) discussed the impact of iron pans around experimental mounds and at Skelhøj for developing anaerobic conditions leading to organic preservation within the mounds. Through comparison with experimental mounds, she saw that in the absence of iron panning, soil leaching and oxidation led to poor organic preservation conditions. These results were expected based on field observations and support the model of how such mounds function regarding organic preservation, developed in various articles in Holst and Rasmussen (2015).

The development of redox conditions and iron panning in these types of mounds has seen a variety of models (e.g. Holst *et al*. 1998; Breuning-Madsen *et al.* 2015). Breuning-Madsen and Dalsgaard (2013) suggest that the Skelhøj mantle and core were constructed from originally similar soil materials, citing the similar texture of all of the turves (loamy sand) and the absence of evidence of a separate construction phase associated with the upper iron pan. They suggest that the development of the solid lower iron pan and subsequent perching of the water table above that was responsible for the gleying processes identified in the core. In addition, they suggest that the turves for the core came from land around the mound and not from the local river valley.

Some of the Danish mounds were constructed of materials from profiles developed on sands with a tendency to see podzolization (Holst *et al*. 1998). All soils examined here were acid brown earths, but with some tendency to brown podzolic soil types, and some features of podzolization were identified in the disturbed topsoil on the Skelhøj mound, but no developed podzol soils were identified in the well-drained mantle (Breuning-Madsen & Dalsgaard 2013). There is a significant amount of leaching evidence, and some indicators of certain post-depositional podzolization processes, including 'micro-podzol' profiles (after Macphail 1983) with micro-horizons optically similar to spodic, albic and placic horizons. The iron pan layers seen were either clearly placic, or were more similar to iron oxide formation seen in root pseudomorphs (e.g. at Tobøl 1). We believe these could have started forming very soon after mound creation, based mainly on the evidence from the early platform layers at Skelhøj. They continued forming up to the present day, as did many types of iron and manganese oxidation features. The other horizons typical of podzols – leached ('albic') and accumulation layers ('spodic' horizons) did not appear to be part of the original soil profile of the various sods examined.

Although the iron pans around the cores of such barrows can be designated as placic horizons, there are often no signs of substantial albic or spodic horizons typical of podzols (Breuning-Madsen & Holst 1998), and the issue of whether these panning layers developed primarily through podzolization or primarily through gleying has been debated since Gripp's (1942) suggestion that iron pans formed naturally in mounds over time through leaching and podzolization. Humus podzol Bh horizons have been known to act as 'aquitards' in soil profiles, and bonds between grains coated with iron and organic compounds are important in altering the local hydrology of podzolizing soils (Torgersen & Longmore 1984; Longmore 1997). Holst *et al*. (1998) discuss iron pan formation at the Lejrskov barrow as resulting from gleying. In other examples, at Silbury Hill in England iron pan formation related to lenses of good organic preservation seems to have developed in relation to compaction of deposits and localized redox (Canti *et al*. 2004). At the Medieval motte at Werken, Belgium, iron pan formation appears to have followed a change in groundwater table level resulting in clay deposition that changed porosity and led to the creation of localized zones of aerobic and anaerobic sediments (Gebhardt & Langohr 1999). Breuning-Madsen *et al*. (2012) document anaerobic core formation in Viking Age barrows at Jelling, Denmark, without iron pan formation; in that case a perched water table appears to have developed through compaction of the mound sods, reducing soil permeability for rainfall. They suggest that continued leaching of water into impermeable cores would feed the system and allow organic preservation and gleyed core sods up to the present day.

We identified leached and 'spodic'-like micro-layers at the base of the Skelhøj mound, in the layers of sorted 'washed' sands. Many of these sand layers were very leached, while others were influenced by later illuviation of iron oxide, clay and organic matter, as coatings on sand grains. We also described micro-layers with accumulation of amorphous organic matter, and with illuviated clay. Where a sequence of these horizons was seen, as in certain sods sampled from the 'wash' layers, this sequence was 'right-way up', and not upside down (as the sods were), suggesting any potential micro-podzol formation is post-depositional. Leaching processes have clearly been important, and this is expected from the local soil type and environment. The development and retention of a reduced core is clearly related to the development of surrounding iron pan layers, which have created a near-impermeable boundary that has promoted moisture retention. We agree with the findings of Breuning-Madsen *et al*. (2015) that the iron pans and gleying are characteristics of redox processes within the monument; although there is evidence throughout of leaching, the soils involved do not tend to develop into podzols proper, and we see no profiles that are characteristic of podzol soils.

Monument construction

In thin section, the turves in the lower part of the core show different profile characteristics (horizonation) than those elsewhere in the barrow – notably the usual absence of a B or C horizon, and we believe that this reflects their original field context. We think they are from organic topsoil horizons of greater thickness than those seen in the mantle turves, which could mean longer-term pasture soils that did not see disturbance through ploughing in the Neolithic or earlier EBA. This suggestion is somewhat at variance to the interpretation of Breuning-Madsen and Dalsgaard (2013), although we do not disagree with their data.

In our study we observed that mound core sods appear to have been thicker and possibly more organic to begin with; we suggested from field descriptions that they may have originated in thick organic topsoils such as grow in wet meadows (Lewis & Hart 2003). These sods were not the same as those in the outer mantel, which appear to have come from soil profiles like those at the modern comparative site and in the buried soil under the barrow: freely draining shallow and oxidized topsoils (in some cases just a thin turf line) on top of loose, acidic sand and gravel. This variation appears to us to have been a conscious choice of materials on the part of the barrow builders. Complex arrangements and planning, along with quick barrow erection, have also been seen at other types of 'coffin' barrows in the region, along with indicators pointing to the bringing in of thick sods of wet pasture soils as part of barrow construction on freely draining sites (e.g. Enevold 2011; Frost *et al*. 2017). The variation in selected soil types in the core and mantle would have created an immediate difference in drainage and chemical properties. We suggest that these choices were deliberate, and that they show a good understanding on behalf of the barrow builders of key soil properties and processes, and their engineering qualities. The thicker organic topsoil sods in the core would have provided a relatively moisture-retaining microenvironment, and well-drained gravelly sods in the outer mound provided a relatively leaching and iron-rich environment that would have enhanced the movement of iron in solution.

Field and soil micromorphological study of barrow sods and buried soils at the Skelhøj mound support a proposal (Holst 1998; 2015; and developed by Holst *et al*. 2015a; 2015b) that specific and intentional practices were carried out leading to compacted, moistened and texturally altered deposits on the platform, before the main mound was constructed. The presence of thick, sandy, water-lain depositional crusts in the lower part of the mound is the result of repeated and significant wetting episodes during an early construction phase. The potential use of water in barrow mound burial and construction has been discussed by Holst *et al*. (2015a), who examine certain comparative sites. Whether or not heavy rainfall events or deliberate wetting events are responsible for these surface crusting/flow features – whether natural or cultural – they would have added a significant amount of water and substantial textural variation to the lower part of the barrow mound. This is likely to have altered the drainage and chemical properties of the lower mound. These changes surely had some impact on the development of the redox conditions seen (Breuning-Madsen *et al.* 2015).

Although thinner wash layers are noted elsewhere in the mound sequence (Holst 2013c), the thick depositional crusts we recorded were not seen during our examinations anywhere else in the mound, including its external mantle, despite the presence there of sods with strong leaching, features showing movement of the fine fraction (infillings, coatings), and well-drained soil profiles. The lack of such features at other phases, including the top of the mound, suggests the type of water impact seen at this phase was not a regular or even occasional 'natural' occurrence. The addition of water may have been intentional, saturating the lain sods in the platform construction phases, creating puddling and surface crust formation. The 'wetting' of these parts of the platform occurred at least three times before or during main mound construction, separated by phases of sod laying (and possible compaction). While it remains unclear whether this was by actively wetting the platform (a relatively quick procedure), or by leaving the platform exposed to heavy rainfall events for longer intervals between the sod laying episodes, the soil micromorphology of the platform supports the interpretation of relatively quick construction, with no other evidence for soil profile growth, mixing, or 'standstill' episodes.

Following a model outlined by Holst *et al*. (1998), some of the early parts of the mound – the 'access' areas (Holst 2013c) – would have been wetted and then compacted. Compaction and/or compression changes the pore structure of the soil, and has been related to microscopically identified iron panning as well as fine fraction accumulation (infillings) in other situations (e.g. at the edges of feature cuts; Lewis 2012). While their study of Lejrskov mound did not show such wetting indicators, Holst *et al*. (1998; after Aner & Kersten 1973; Jørgensen 1984) suggested that 'irrigation of the mound' may have been part of the process of creating the observed soil conditions there. We believe that this was possibly a deliberate process; at Skelhøj there were 'flow' structures (e.g. 'waves'), and the thick depositional crust features seen under the microscope are most similar to features reported from permafrost (saturated) conditions (e.g. van Vliet-Lanoe 1985a,b). The impact of frost heaving has not been discussed here, as it seems unlikely to have had a major impact on the Holocene sandy soils of this location. If this were a factor, several seasons of exposure would be implicated in the creation of the phases of depositional crusting seen.

The model of platform creation by wetting and trampling was later dismissed because it could not be 'securely demonstrated' (Holst 2015, 122), and an explanation of strong rainfall events and the impact of activities on the interpreted access ramps where these features were seen was preferred (Holst 2013c). 'White water-deposited layers' were also found at Eshøj 1, where they were interpreted as representing rainfall events (Frost *et al.* 2017). If these layers at Skelhøj represent rainfall events at various intervals over time, that would suggest the platform was created, revisited, and added to over some period of time before the mound was built, allowing time for exposure to major rainfall events to create the three phases of multiple layers of sorted sands. A break in mound construction flow would not be unusual; many barrows show several phases of construction, sometimes separated in time by many decades or possibly even centuries (e.g. *ibid*.), but this does not fit the Skelhøj proposal of a quick and continuous (uninterrupted) construction sequence.

Conclusions

The sequence of deposits and the events they represent suggest to us that there could have been knowledge of and possibly a desire to create anaerobic soil conditions in the core of the Skelhøj barrow. This depth of understanding of soil formation processes and of the properties of soil as a construction material may seem surprising to us today, but the Bronze Age people in this region had been using soil for monument building and had been observing soil and sediment properties in relation to agricultural practices and plant distribution for millennia. In south Denmark, EBA people likely would have been very familiar with the preservation conditions available in wet, organic environments (such as river/lake shores and bogs), as well as with the qualities of iron pans from both boglands and in podzols, because they constantly engaged with the soils and sediments of their area. Was there an intention to preserve the dead? This is not unknown in other Bronze Age societies in northern Europe and beyond (e.g. mummification; Booth *et al*. 2015). Was the 'wetting' part of the funerary ritual of constructing the barrow core? We cannot propose anything so dramatic from our soil study, only that we see some planning and organization that would at least promote the preservation conditions that resulted. An overview of the issue of the deliberate or accidental creation of these conditions has been presented for the South Scandinavian EBA barrows by Holst *et al*. (2015b).

Our research embeds well with the aims of the excavation project, to focus on how construction sequences can inform us about Bronze Age life and burial practices (Holst & Rasmussen 2013; 2015). The Danish mounds fit into a general picture of Neolithic and Bronze Age earthen monument construction across northern Europe of systematic and systemic land-use practices being related to planning and preparation for monument building. In his review and critique of past interpretations of South Scandinavian EBA barrow mounds, Holst (2013b, 74–6, 84) notes that the construction process is generally seen to begin with the primary burial(s). We suggest that in the case of the oak-coffin burials (at least), the process likely began with preparation of the site, which may have been chosen some years before construction began in order to allow turf regrowth, and with consideration of soil and other materials required for creating the desired or 'appropriate' burial practice, in addition to the labour and ceremonial aspects of the practice itself. This decision-making was likely embedded in and part of the cosmology of the local society, as part of the traditions and local conditions of burial and monument construction.

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Inspired geoarchaeologies

Geoarchaeological research captures dimensions of the past at an unprecedented level of detail and multiple spatial and temporal scales. The record of the past held by soils and sediments is an archive for past environments, climate change, resource use, settlement lifeways, and societal development and resilience over time. When the McDonald Institute was established at Cambridge, geoarchaeology was one of the priority fields for a new research and teaching environment. An opportunity to develop the legacy of Charles McBurney was bestowed upon Charles French, whose 'geoarchaeology in action' approach has had an enormous impact in advancing knowledge, principles and practices across academic, teaching and professional sectors. Many journeys that began at Cambridge have since proliferated into dozens of inspired geoarchaeologies worldwide. This volume presents research and reflection from across the globe by colleagues in tribute to Charly, under whose leadership the Charles McBurney Laboratory became a beacon of geoarchaeology.

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