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THE USE OF MARINE MAMMAL BLUBBER: PARAMETERS FOR DEFINING FAT-RENDERING STRUCTURES

Abstract
A large number of structures, primarily pits, dating to the Bronze Age / Early Metal Period and Iron Age are situated along the coasts of Sweden, Finland, Åland Islands and Norway. The article discusses a series of examples of such structures thought to be genuine fat-rendering structures located in the Counties of Troms and Finnmark (northern Norway), the Åland Islands (Finland), and Västerbotten (Sweden), and compares them to contemporary pits from Sweden and Finland, the interpretation of which is less certain. Results from archaeological excavations and experimental reconstructions of north Norwegian slab-lined pits form the basis for discussing the interpretations given to the structures in question.

Keywords: Marine mammal blubber, fat-rendering, Bronze Age/Early Metal Age–Iron Age, northern Scandinavia

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INTRODUCTION

Throughout prehistory the utilization of marine resources such as mammals, fish, shells and crustaceans is likely to have been of the utmost importance in coastal areas, both as a source of food and of raw materials. This article focuses on one of the more elusive materials of marine origin in archaeological assemblages, recorded either directly or indirectly: blubber from marine mammals. Although blubber decomposes much easier than bones (Isaksson 2008: 651–2), there nonetheless exist sites that display possible traces of various uses of marine mammal blubber in Scandinavian prehistory.

A recent ethnographic study from North America has documented how seal pokes, i.e. air-tight bags made from an entire seal skin, can be used to ferment or mechanically produce seal oil by placing such a bag filled with seal fat in water or gravel. This procedure is also documented in archaeological material (Frink & Giordano 2015). Even though such a low-temperature refining procedure of seal blubber has not been directly documented in Scandinavia, there have been studies discussing the possibility of the same procedure being employed based on use-wear studies of 12000-year-old Hensbacka awl bits and flake axes (Schmitt 1998; Schmitt et al. 2009: 13–4).

The oldest confirmed use of blubber is related to the utilization of marine fat as fireplace fuel. The *Skärgård 10000 år* (En. The Archipelago 10000 Years) project in Tyresta Municipality, Stockholm County (Sweden), revealed a number of seal hunting stations in an archipelago that was among the most extreme maritime settlements of the Scandinavian Mesolithic. One of the excavated huts, labelled Topp 85, was dated around the first half of the eight millennia cal-BC. Some of the finds were burnt bones of grey seals (*Halichoerus grypus*) and a cemented organic residue uncovered inside the hut (measuring 3.6 x 4.8 m) as well as outside the structure. Lipid analysis of the organic material confirmed that the origin was marine (Isaksson 2010). The excavations also revealed grass embedded in the organic material, interpreted as being used for wicks. The traces of marine blubber were interpreted as being used for a heating source in a landscape that contained little or no wood (Petterson & Wikell 2013: 79–85).

Ulla Odgaard (2001: 110–28) has demonstrated the efficiency of fuelling fires with seal blubber through reconstructions of box-shaped fireplaces of a type investigated at Independence I sites in Greenland. A box-shaped fireplace constructed with stone slabs 40 x 40 cm in size was filled with wood in a crisscross pattern. When adding 2.5 l of seal blubber, the fire burned so violently that getting close to it was difficult. Another test revealed that by using moss dipped into marine-mammal oil and adding 50 g of seal blubber, the fire continued to burn for 20–25 minutes (Odgaard 2001: 120–2). Odgaard (2001: 124) also concluded that an elevated temperature stemming from an organic material other than marine fat was necessary if seal blubber was going to function as a good fuel source. This conclusion was also strengthened by unsuccessful test results using blubber when trying to start a fire from a cold hearth.

Marine mammal blubber can be utilized in different manners, as demonstrated by the above two examples. However, the abundance of material associated with marine blubber in the Scandinavian archaeological record has been associated with train oil production in pits or chambers associated with fire-cracked stones.

The conversion of solid marine fat into liquid oil using hot stones has been discussed in several studies spanning a large geographical area and time span (see e.g. Hesjedal et al. 1996; Bjerck 2008; Halting 2012; Solberg 2014a; 2014b). However, the interpretation of several of these pit locations is debatable. For example, the fat may not have been confirmed as having a marine origin due to its decomposed state (see e.g. Hesjedal et al. 1996: 96–100; Bjerck 2008: 251–4, with lipid analysis by Isaksson 2008: 655 and Heron 2008: 658) or the organic samples lacked reference material collected from outside the pit structures, making the interpretation questionable (see e.g. Östlund et al. 2007: 17, 20, with lipid analysis by Isaksson 2006).

But even if the interpretation is sometimes uncertain, there are examples of sites where the basis for interpreting the structures as marine train oil production facilities using hot stones are solid. Because these structures are located over a vast geographical area and a substantial time period, the purpose of this article is not to present a complete overview of the material. The article instead focuses on some examples that highlight the following questions: are there common denominators of the actual sites interpreted as train oil production structures? And can an evaluation of common denominators, combined with experiences from reconstructing slab-lined pits, shed some new light on the evaluation of Scandinavian pit structures interpreted as marine fat-rendering facilities?

EXAMPLES OF TRAIN OIL PRODUCTION STRUCTURES ASSOCIATED WITH FIRE-CRACKED STONES IN SCANDINAVIA

Harrsjöbacken (Sweden)

A number of sites in Scandinavia display indications of marine train oil processing using hot stones. One example is the site of Harrsjöbacken in the County of Västerbotten, Sweden. The site is situated by an old bay or lagoon in Bureå Parish, Skellefteå Municipality. On the south-east side of the lagoon several pits were excavated during the 1990s. Feature 2 was a pit measuring 1.8 x 1.3 m and 0.8–0.9 m deep and dated 1320±50 BP (Beta-61442; 'seal train oil'). The bottom of the pit was lined with stones and burnt animal bones, most probably seals. A dark charred organic residue was detected in-between the stones inside the pit. Chemical analysis of the residue revealed a 6.2% fat content. The residue was later determined to be remains of hide or fat tissue of marine origin (Österlund 1997: 6–9, 35).

Feature 6 revealed many of the same traits as Feature 2. The pit measured 1.1 x 1.8 m (and c 0.9 m depth according to drawings) and was dated 2440±80 BP (Beta-61444; charcoal). The bottom of the pit was covered by a 15 cm thick layer of charcoal and fire-cracked stones. A 3 cm thick greasy material was encountered on top of the charcoal layer. The material from Structure 6 was chemically analysed, bearing results highly similar to those of Structure 2 (Österlund 1997: 14–5, 35).

A third pit, Feature 5, displayed features similar to the ones in Features 2 and 6. The pit measured 2 x 0.6 m (c 0.4 m deep according to excavation drawings), was lined with stones and dated 1550±60 BP (Lu-3915; charcoal). A greasy organic residue was present in this pit, too, but was not further analysed. Because it was similar to the material found in Features 2 and 6, it was thought highly likely that this residue was likewise related to marine fat (Österlund 1997: 13, 35).

The Harrsjöbacken pits, which were situated by the sea when in use, featured fire-cracked stones, possible seal bones and an organic residue with high fat levels. The pits were consequently interpreted as marine fat-rendering structures. Many of the same features are also present at a number of structures studied on the Åland Islands (Finland), predominantly in the Municipality of Kökar (see also Fig. 1).

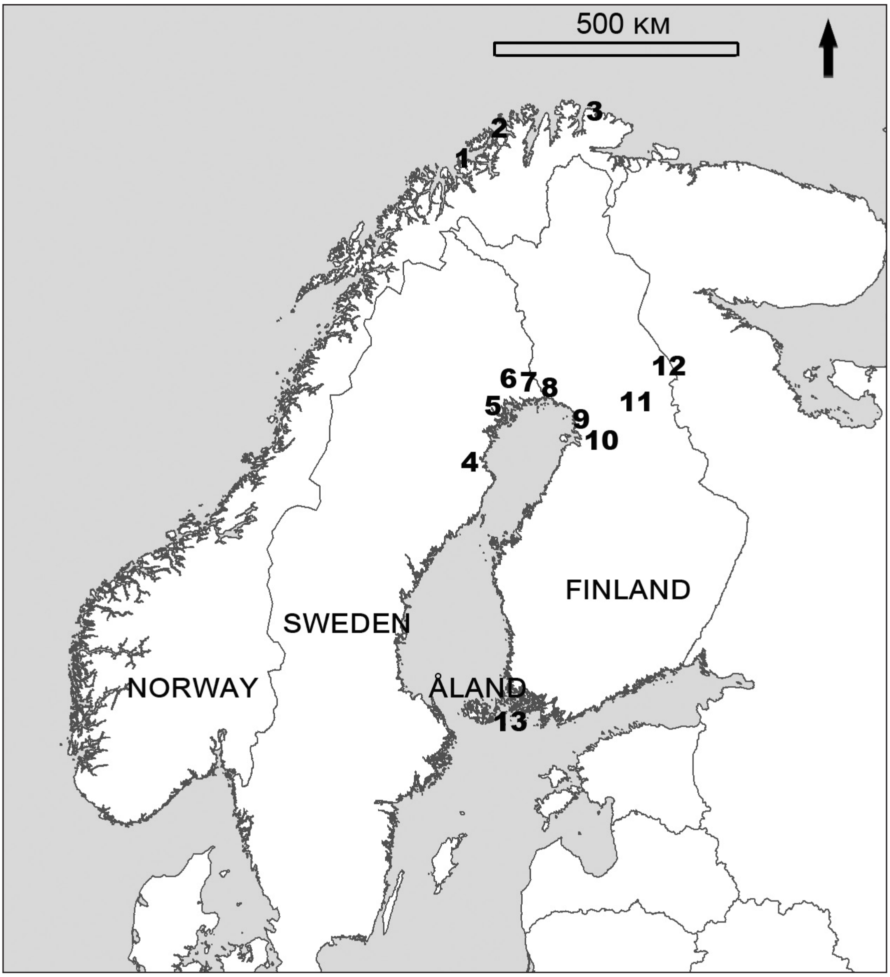

Fig. 1. Map of research area and some locations mentioned in the text: 1 – Skjervøy Municipality; 2 – Hammerfest Municipality; 3 – Berlevåg Municipality; 4 – Skellefteå Municipality; 5 – Lule River Estuary; 6 – Kosjärv, Kalix Municipality; 7 – Sangis River Estuary; 8 – Haparanda, Haparanda Municipality; 9 – Oulujoki River Estuary; 10 – Kalimeenoja River Estuary; 11 – Pudasjärvi; 12 – Kuusamo; 13 – Kökar Municipality. Map: G. Nilsen.

Åland Islands (Finland)

The Åland Islands form a geographical and cultural bridge between mainland Sweden and Finland, with evidence for a strong cultural influence from areas belonging to present-day Sweden from the Bronze Age onwards (Gustavsson 1980: 3; 1997: 11). Åland consists of c 6500 islands and islets, with the Kökar Municipality representing the southernmost location facing the open sea (Gustavsson 1997: 11). More than 150 heaps of fire-cracked stones have been documented at between 10–27.5/30 m a.s.l. at Kökar. The sites are dated between 1300 calBC and calAD 450, and are predominantly located in the Karlby area (Gustavsson 1980: 53–4, 84). In recent years, corresponding structures have also been documented outside Kökar in the neighbouring Municipalities of Föglö and Sottunga (Gustavsson 1997: 14). Kenneth Gustavsson (1997: 13) described the fire-cracked stone heaps in the following manner (see also Fig. 2):

> Basically these heaps were constructed according to a common scheme. The stone packing, often in the shape of a horse-shoe, was placed on a gently sloping outcrop, surrounding a natural depression in the rock. In the small space between the stone packing and the depression, there are always larger, unburned stones forming a kind of stone frame, open to the depression. The sizes of the stone packings vary from c. 3 m to over 20 m in diameter.

Gustavsson has excavated three of the heaps on Karlby in the Municipality of Kökar. Although the outer shape of the structures varied somewhat, the constructions resembled each other in that they consisted of layers of fire-cracked stones mixed with soot and greasy charcoal. The largest excavated heap, Kö 4:91, was c 10 m long, 7 m wide and 1 m high, and was dated to 1910±95 BP (St-6904), 2017±95 BP (St-6905) and 2100±95 BP (St-6906) (Gustavsson 1980: 67). The natural depression, in which the structure was located, had a size of 6 x 2 m and it was 0.1 m deep. In between the heap and the depression, 16 larger stones were laid out as a framework. Microscopic investigation of a com-

Fig. 2. Seal blubber-rendering site at Karlby, Kökar Municipality, Åland, Finland. Photo: G. Nilsen.

pressed organic residue found inside the structure revealed traces of a decomposed skin or hide. A fill that consisted of up to 4.6% fat was restricted to the area in-between the stones of the heap.

To sum things up, the high fat content of the organic material, traces of possible hide, and fire-cracked stones associated with a marine-oriented settlement all support the hypothesis that fat rendering from marine mammals using hot stones took place in these structures. The train oil production chambers on Kökar seem to have been built on top of the bare rock. The procedure of producing liquid oil from solid blubber must have been quite similar to the process used at the Harrsjöbacken pits, where the blubber became exposed to hot stones in a production chamber. The same elements can also be observed at numerous slab-lined pits of northern Norway.

Northern Norway

So called slab-lined pits form a common type of Iron Age sites found particularly in the Counties of Troms and Finnmark in northern Norway. These pits are located along the outer coast in areas dominated by various types of sites associated with the Sámi and are particularly numerous at the island of Arnøya (Troms County) at the estuary of the Lyngen Fjord (Henriksen 1996; 2000).

Slab-lined pits, closely associated with the contemporary shorelines, are on an average 2–4 m long and 1–2 m wide, featuring 0.3–1 m deep depressions that are sometimes marked by an outer wall. The inner walls may also be lined with flat stone slabs. The stones inside the pits show clear signs of being affected by heat, and excavations have uncovered large amounts of fat and greasy charcoal and fire-cracked stones associated with this type of structures (Henriksen 1996) (see Fig. 3). Based on lipid analysis, it has been possible to determine that the fat rendered in the pits was of marine origin (Aspenes 1996; Heron et al. 2010). Bones from whales have also been documented in several pits in Skjærvika at the Municipality of Hammerfest (County of Finnmark) (see also Fig. 1). One example is Structure S5C, where large amounts of bones from a right whale (*Balaenideae*) species, most probably the North Atlantic right whale (*Eubalaena glacialis*) were found. The pit had a clear stratigraphy revealing two phases of use, ^{14}C-dated to calAD 640/680–780/890 (1348±25 BP, Wk-31294, deciduous tree; 1315±25 BP, Wk-31238, deciduous tree; 1307±37 BP, Wk-27220, Betula; 1236±40 BP, Wk-27219, Betula; Amundsen 2009: 46; Hufthammer 2013: 478, Tab. 1) (the radiocarbon dates given in this paper are calibrated using the software OxCal 3.10 and 4.1.2 and given a 2-sigma confidence level).

Both individual pits and sites of up to 30–40 pits have been documented in northern Norway. At present, 722 slab-lined pits are registered in the national heritage database, *Askeladden*, 45 of which have been excavated to some degree. These excavations have yielded 93 ^{14}C dates. The excavated pits are located between Haugnes, Skjervøy Municipality, Troms County and Mellaneset, Berlevåg Municipality, Finnmark County (see Fig. 1). The ^{14}C dates indicate that the pits were in use from c 1 calBC/AD until calAD 1200, with a peak c calAD 600–900 (Schanche 1992; Henriksen 1996; Nilsen & Wickler 2011; Henriksen & Valen 2013; R.A. Nilsen 2014). In summary: the shoreline location, the presence of fire-cracked stones, marine lipids and marine mammal bones here, too, strongly support the interpretation of the pits as marine train oil production structures.

The examples from northern Norway, Åland (particularly Kökar) in Finland, and Harrsjöbacken in Sweden all display strong indications of pits or above-surface chambers being used to process solid marine fat to produce liquid oil using hot stones. The question then arises, given these indications, is it possible to utilize the findings associated with these structures to interpret the less well understood pit sites from mainland Sweden and Finland?

Pits from Finland and Sweden

While some of the pits and chambers of northern Norway, Åland and Sweden (Harrsjöbacken) have a fairly solid interpretation as train oil production facilities (see Gustavsson 1980; Schanche 1992; Aspenes 1996; Henriksen 1996; 2000; Österlund 1997; Heron et al. 2010; G. Nilsen 2011; 2016; Hansen & Olsen 2014: 57–70), the vast majority of outwardly similar-looking pits from Sweden and Finland must be

Fig. 3. An example of excavated slab-lined pit at Mellaneset, Berlevåg Municipality, Norway, excavated by Elin Myrvoll (2011). Photo: G. Nilsen.

regarded with more caution. The following discussion should not be considered as an overview of the entire pit material from Finland and Sweden. It simply presents some structures that may be interpreted as marine fat-rendering facilities using hot stones. This assemblage of pits provides a basis for further debate.

Numerous large pit fields dating to the Bronze Age / Early Metal Period and Iron Age have been documented along the coasts of northern Sweden and Finland, often featuring up to 50 structures (Lundin 1992; Forsberg 1999: 259; Äikäs 2009: 150). The number of pits is particularly high between Sangis and the Lule River Valleys in the County of Norrbotten, Sweden (see Fig. 1), where they generally lie between 25 and 45 m a.s.l., but not all of them were associated with prehistoric shorelines (see e.g. Bennerhag 2009: 7–8). In Finland, many of the sites were located along river estuaries. For example, as many as 346 pits are clustered along Oulujoki and Kalimeenoja Rivers at 22–35 m a.s.l. (Äikäs 2009: 150–1) (see also Figs. 1 & 4). In Sweden, Lars Forsberg (1999: 259) describes the pits as large, often having a diameter of c 2–3 m, with a depth of c 1 m. In Finland, Tiina Äikäs (2009: 150) described them as generally having a diameter between 1–4 m and a depth of 1 m.

As mentioned, the interpretation of this material remains problematic. One of the most clearly-stated cases of interpreting a pit as a marine fat-rendering structure is Feature 15 from Grundskatan, Skellefteå Municipality, Sweden (see Fig. 1). Feature 15, measuring 10 x 12 m wide and 2 m deep, was investigated by Noel Broadbent (2005: 17–20; 2010: 72–91, 157–9). Grundskatan is characterized as one of the largest seal-hunting stations from the Late Iron Age in Västerbotten (Broadbent 2009). Broadbent (2010: 90) interpreted the pit as follows:

> There is no access to this pit which shows it was not a tar-rendering pit. It is an unlikely place to dig a large solitary hunting pit, and is interpreted as most probably associated with seal oil production during the period A.D. 1033–1500 (1641?).

Broadbent (2010: 157) elaborated later on:

> A substantial pit (measuring 10 x 12 m) at Grundskatan (Figure 9) is interpreted as a large-scale blubber-rendering basin analogous to those known from the White Sea region (cf. Tegengren 1965). Taken together with the dwellings, the caches and blubber-

rendering pits are evidence of the extensive exploitation of resources and the appropriation of these resources by local communities for systematic intercourse with the outside world.

Based on the zooarchaeological evidence, the Grundskatan site was clearly a seal hunting community. Although he does not state it explicitly, Broadbent seems to base his interpretation of the pit on the fact that it was constructed in an a site with a marine orientation, and that he did not find other interpretations plausible. However, no lipid analysis was performed and no seal bones were found inside the actual pit. Only a thin layer of charcoal was detected at ground level, and Broadbent (2005: 18) does not mention if it had a greasy character or if it contained fire-cracked stones. By simply basing the interpretation of the pit on one factor – the structure's association with a community dependent on seals – the assumption provides weak support in assessing the pit as a true marine fat-rendering facility. Evaluating juxtaposed experimental reconstructions also weakens the interpretation given to this structure (see G. Nilsen 2016 and below).

Broadbent is not the only archaeologist to have interpreted pits from Sweden as marine fat-rendering facilities. Other examples are the investigations made by Lars Forsberg (1999), Kerstin Lundin (1992) and Gunilla Larsson (2001: 77–8). All seem to share the interpretation of the pits as marine blubber rendering pits based on their seashore location and an association with communities largely dependent on seal hunting. However, pits found at sites with a marine oriented subsistence should not be automatically interpreted as fat-rendering pits. Other pits from the same region have been offered other, equally plausible interpretations.

According to Äikäs (2009: 152–3) the possibility of these pits being used as seal blubber oil-production structures should not be totally dismissed, but the presence of pits in the interior at Pudasjärvi and Kuusamo (Northern Ostrobothnia) (see also Fig. 1) in Finland weakens the hypothesis (Äikäs 2009: 150). A GIS analysis of the pits' location in the terrain also showed that

Fig. 4. Examples of pits at the Mikonkangas SE site, Finland. Photo: G. Nilsen.

they were placed at sheltered spots (Äikäs 2009: 150). To Äikäs (2009: 152) these facts support an interpretation of the pits as structures used for smoking meat or fish (e.g. salmon). Äikäs's interpretation also finds support in recent investigations in Sweden, close to the Finnish border.

At Kosjärv in the Municipality of Kalix (Norrbotten, Sweden) (see also Fig. 1), two of the five pits investigated were rectangular and three were circular in shape. The rectangular ones, Features 5 and 6, dated to calAD 650–780 (1320±30 BP; Ua-33211) and calAD 570–660 (1430±30 BP; Ua-33212), were deemed as being unrelated to seal blubber-rendering, because of a lack of support from archaeological science and their location 1.2 km from the contemporary shoreline (Östlund et al. 2007: 17, 20). The three circular ones – Features 4, 7 and 8 – were dated to 400–340 calBC and 300–200 calBC (2275±30 BP; Ua-33210); 790–520 calBC (2505±30 BP; Ua-33213); and 410–350 calBC and 300–230 calBC (2295±30 BP; Ua-33214) respectively. Sven Isaksson (2006) performed lipid analysis on material from the pits, but due to lack of reference material sampled from outside the structures, no definitive conclusions could be drawn. The circular pits did however show some elevated lipid levels indicating that animal fat had been fed into the pits. Even though seal bones were detected at the site, the meat smoking hypothesis gained the strongest support, because a number of small postholes were encountered outside the pits. These were interpreted as the remains of some form of drying rack for smoking meat, fish or inner bark (Östlund et al. 2007: 6, 14, 18–20).

At Haparanda (in Norrbotten, Sweden, see also Fig. 1), two cooking pits were excavated: Feature 3 at Location 20 and Feature 36 at Location 39 (Bennerhag 2009). Feature 3 had a diameter of 2 m and was 1.3 m deep, and it was filled with a layer of fire-cracked stones on top of a charcoal layer. A greasy dark brown sandy layer was uncovered outside the depression as well as in the middle of the pit and on top of the fire-cracked stones. Burned and unburned bones were also found associated with the structure, but it was not possible to determine the species (Jonsson 2009). The pit itself was in use during the period 600–400 calBC (2445±30; Ua-33334), with a second activity phase relating to the charcoal on top of the fire-cracked stones dated to calAD 1040–1220 (890±30 BP; Poz-23732) (Bennerhag 2009: Appendix 8:1).

The second pit, Feature 36, was c 2 m in diameter and 1 m deep. Fire-cracked stones were found as an inner lining at the bottom of the pit as well as in a layer inside the depression. Charcoal and fire-affected sand were found in layers between the stones and mixed with the fire-cracked stones. No artefacts were found. The pit was dated to 170 calBC–calAD 30 (2045±30 BP; Poz-23735) (Bennerhag 2009: Appendix 8:1).

These pits were not directly associated with a contemporary shoreline, which makes it less likely that they were for marine fat-rendering. However, the bones found at the sites present a dilemma. Seal bones at sites associated with the pits indicate that some form of refinement of seals have taken place, but this refinement is not necessarily associated with train oil production. Locations 20 and 39 were not closely associated with the beach, but nonetheless yielded seal bones and fire-cracked stones and a greasy layer. These factors indicate some sort of a marine fat-rendering activity. On the other hand, bones of fish species such as pike, dace, burbot, common whitefish, perch, fourhorn sculpin, as wells as bones of seals and squirrel, marten, beaver and birds indicate a mixed terrestrial and marine utilization of resources. Lipid analysis of ceramics found at the sites detected traces of vegetal, marine and terrestrial remains, including traces from cloven-hoofed animals, confirming the view of a mixed utilization of resources (Bennerhag 2009: 18).

Of the few bones from sea-living creatures found in the material from Haparanda, 11 fragments were determined as belonging to the seal family, including one from a ringed seal (*Phoca hispida*). The seal bones entered the matrix during the time described as phase 3 at Haparanda, c 50 calBC–calAD 250, a period when the activity areas became more retracted from the sea due to land uplift (Bennerhag 2009: 21–6).

Based on these examples, there are evidently some common traits shared between the pits from Sweden and Finland and the marine fat-rendering structures of Åland, northern Norway and Harrsjöbacken. There are also indications in the Swedish and Finnish examples that are in conflict with interpreting them as having been used primarily for train oil production. Are the similarities superficial, or do they form a solid basis for interpreting a structure as a marine train oil production facility?

FACTORS FOR INTERPRETING MARINE FAT-RENDERING STRUCTURES

Based on the above discussion, there emerges a number of recurring arguments for identifying a structure as a marine train oil production site. These are as follows:

Proximity to contemporary shorelines

This is common sense criterion, though not explicitly discussed in the examples above, and concerns large mammals. It would make little sense for local inhabitants to transport meat and fat from large marine mammals from the coast to the inland for further refinement, given the long distances and heavy haul. It would make equally little sense to transport large land-dwelling animals to the shore for smoking the meat or rendering fat. Therefore, pits located in the close proximity of contemporary shorelines are often interpreted as being related to the utilization of maritime resources.

In the case of northern Norway, Åland, and Harrsjöbacken, the location of structures close to a contemporaneous shoreline is one of several criteria used in assessing the structures as marine fat-rendering pits (see Gustavsson 1980; Henriksen 1996; 2000; Östlund 1997). Many of the pits from Sweden and Finland are similarly located in proximity to contemporary shorelines, but as noted, not all of them share this characteristic (see Östlund et al. 2007; Äikäs 2009; Bennerhag 2009), and it thus cannot be used as the only criterion. What other factors need to be assessed?

Hide or bones from marine mammals in or in close proximity to pits

Pits that do not contain remains of hides or bones from marine mammals, but are linked to a settlement with profuse organic material from aquatic-living mammals have been interpreted as being used to render marine mammal fat, as in the case at Grundskatan in the Municipality of Skellefteå (Västerbotten, Sweden) (Broadbent 2010: 90, 157). The lack of lipids, bones or elevated fat levels inside the actual structures makes the argument weak. When traces of marine mammals are found in the actual pit itself, the case becomes much stronger, as for example at the sites of Skjærvika in Finnmark, Norway (Henriksen & Valen 2013) and Kökar on Åland, Finland (Gustavsson 1980). Yet, these two factors can only form a basis for interpreting the structure as being related to some form of processing of marine mammal resources. This activity may not necessarily involve fat-rendering by the use of hot stones.

Fire-cracked stones

If we are looking at a true fat-rendering facility using elevated temperatures to produce oil, one should expect to find fire-cracked stones (G. Nilsen 2011; 2016). This feature has been detected in association with many of the sites discussed so far, although the amount of stones differs. Also, fire-cracked stones could have been used to heat a number of substances, not only blubber, even in communities dependent on marine mammals. The presence of such stones thus cannot be the only criterion to base an interpretation on. As mentioned, smoking meat can also be a viable interpretation in some cases. Cold smoking, however, does not seem to be the best interpretation, as the finds of calcified bones and fire-cracked stones indicate much higher temperatures than what is required in cold-smoking technology.

Greasy charcoal or organic residue

Several of the investigations of possible fat-rendering pits have uncovered charcoal with a fatty or greasy character (see Gustavsson 1980; Henriksen 1996; Östlund et al. 2007). The organic material often has a cemented character, which Carl Heron (Heron et al. 2010: 2188) has described as 'a matrix of sand and gravel cemented together by brownisheblack putative organic material'. Marine mammals are fat-rich, so it makes sense that structures being used as marine train oil rendering pits still would display elevated fat levels and such cemented organic residues.

To sum things up, detecting a pit or a chamber at a seashore location, filled with fire-cracked stones and fat-rich material, associated with communities determined as dependent on marine mammals, gives a solid basis for interpreting the structure as a marine fat-rendering structure. However, even with structure types that are generally interpreted as train oil production facilities such as the slab-lined pits from northern Norway, there are examples of pits which lack some of these defining elements.

Kjersti Schanche (1992) performed excavations of 11 slab-lined pits at Tareneset in Municipality of Skjervøy. Several of the pits turned out seemingly empty (Schanche 1992: 57). In feature 2, a 1 x 3 m long trench was excavated across the mid-section of the slab-lined pit. There were no slabs, fire-cracked stones or charcoal detected, even though the excavation extended 25 cm down through the sterile gravel. A 50 x 50 cm test pit was also dug in the mid-section of Features 3 and 5, as well as a 1 x 2.5 m trench across the central part of Feature 4. None of these features bore evidence of traces of a hot fat-rendering process in the form of fire-cracked stones, charcoal or organic residue.

Other contradictory material from structures that provide overwhelming evidence supporting their interpretation as marine train oil production facilities comes from Kökar, where within one of the train oil production heaps, Gustavsson (1980: 61–9; 1997: 13–4) uncovered a 0.5 m thick greasy layer, 12 m^2 in all, mixed with larger charcoal pieces and fragmented bones. It was not possible to determine the species, but the bones probably did not belong to an aquatic animal, but most likely to a young sheep or goat. Kökar has an extreme maritime orientation consisting of small islands facing the open sea. Probable terrestrial animal bones were also found at the dwelling site of Otterböte, which lies 17–18 m a.s.l and is dated to 1200–900 calBC. The site, excavated in 1946 and 1950 and later reinvestigated by Gustavsson (1997), displayed a high dependency on grey seals, as 80% of the bone material (altogether 1670 fragments weighing c 8.4 kg) was related to that species. Although 3.3% of the bones were determined to belong to ringed seals, there were terrestrial and domesticated animal bones from species such as mountain hare, sheep/goat, pigs and cow or moose also present in the material (Gustavsson 1997: 44–6).

Empty pits in northern Norway and remains of terrestrial animals found at Kökar show that structures firmly established as marine train oil production features also display traits that seem unrelated to the practice. Given these varying traits, isn't it possible the pits of Finland and Sweden could have been used as train oil production structures, though only as a secondary activity?

Archaeological science

The results from analysing the organic remains from Åland and Harrsjöbacken provides strong support for interpreting the site. This is in line with the greasy character of tissue from marine mammals (see Gustavsson 1980: 66–7; Österlund 1997: 6–9, 35). Recent investigations use sophisticated methods such as gas chromatography/mass spectrometry, bulk carbon isotope determinations and lipid extractions (see Aspenes 1996; Isaksson 2008; Heron et al. 2010).

The most comprehensive study is related to gas chromatography/mass spectrometry and bulk carbon isotope determinations of samples from 12 excavated slab-lined pits from northern Norway (Heron et al. 2010). Long-chain unsaturated and isoprenoid fatty acids as well as oxidation and thermal alteration products of unsaturated acids (dicarboxylic acids, dihydroxy fatty acids and **ω**-(*o*-alkylphenyl) alkanoic acids) provided a solid basis for interpreting the pits as marine oil extraction structures. For example the presence of **ω**-(*o*-alkylphenyl) alkanoic acids that are produced through prolonged heating of tri-, di- and/or monounsaturated fatty acids at 270°C or above substantiates a hot and quick rendering process. The bulk isotope analysis on cemented organic residues also displayed consistency with modern reference samples of blubber and experimentally produced seal and whale oil in slab-lined pits.

Similar conclusive analysis based on archaeological science is lacking in the Swedish and Finnish material. Given this analysis, could

Fig. 5. Seal skin being placed inside a reconstructed slab-lined pit. Photo: G. Nilsen.

there be other factors that may contribute to the interpretations of this questionable material?

EXPERIMENTAL RECONSTRUCTIONS

Referring back to the introduction of this article, ethnographic and archaeological reconstructions made the two examples of marine blubber use as fire fuel and possible refinement in seal pokes more comprehensive. Given these examples, could it be possible that the results from experimental reconstructions of north Norwegian slab-lined pits might also shed some light on the function of the Swedish and Finnish pits?

A series of reconstructions of slab-lined pits from northern Norway have been conducted using blubber from common, ringed and grey seal as well as minke whale (see G. Nilsen 2011; 2016 for details). Age of animal, location of harvested blubber on the carcass, feeding season when killed and butchered and species all contribute to different fat structures, which influenced the procedure when refining solid blubber to liquid oil using hot stones (see G. Nilsen 2016: 204–11).

Processing blubber from species of lesser size than adult whales, such as seals, was likely performed in open pits. The process was fast and hot; a bonfire, having temperatures over 700°C, was made to preheat stones. The hot stones and blubber were simultaneously added to the production chamber. The bottom of the pit was covered with seal skins to prevent the oil from penetrating the subsurface (G. Nilsen 2016: 204–6) (see also Fig. 5).

To produce oil, the ideal temperature of the blubber was between c 80–200°C. The higher the temperature, the quicker the outflow of oil. However, blubber temperatures above c 400°C resulted in the blubber self-combusting, and when blubber temperatures fell below 80°C, the rendering process slowed down, stopping altogether in temperatures below 70°C. It is important to note that when such high blubber temperatures are attained, the secondary material being heated (wood and stones), must have a much higher temperature in order to be able to heat the actual blubber to a melting point (G. Nilsen 2016: 206).

To render oil from seal blubber is not an easy process. It requires high temperatures, most easily achieved in smaller pits (see G. Nilsen 2011; 2016). The largest chamber used in the study measured 1.8 x 0.65 m and 0.2 m deep. The larger pit, combined with the use of blubber from an adult grey seal, made it more challenging to produce oil, due to the blubber's fibrous consistency and the difficulties with heating greater quantities of blubber. Smaller pits, c 1 m long, 0.5 m wide and 0.4 m deep, filled with more loose, greasy and less protein fibre-rich fat from common and ringed seal, proved to yield the best results (see G. Nilsen 2016 for explanation).

The investigations of Odgaard (2001) and the experimental reconstructions of slab-lined pits (G. Nilsen 2011; 2016) have proved that blubber does not function well as fuel when it is cold. However, wood is not the only material that could have been used to fuel the fat-rendering process, as the experiments showed that using residual heat from one pit to fire up another pit decreases the need for wood (G. Nilsen 2016: 210–1). The mass of stones with residual heat, charcoal, hides, partially unrendered blubber as well as bones, may function well as fuel in the next pit in a 'production line'. The use of such residual material and heat from an initial rendering pit makes sense when dealing with large quantities of blubber. Such a process can also explain the presence of calcified bones in pits (i.e. due to the need for secondary fuel material being heated to high temperatures).

This observation may also contribute to the fact that for example many of the north Norwegian slab-lined pit are set in rows. This arrangement of using several smaller pits makes sense when distilling large quantities of blubber. Having just one large structure, as for example the Grundskatan pit, makes it less likely that train oil production was the primary function of the structure. It would have been very difficult to create sufficient heat to bring the mass of blubber to the elevated temperatures needed to release the oil in such a large pit.

THE SIGNIFICANCE OF SIZE

As previously noted, sites interpreted as seal fat-rendering structures include large ones, such as a pit with a diameter of 10 m in Sweden discussed by Broadbent (2005; 2010), while other archaeologists such as Lundin (1992) and Forsberg (1999) have also interpreted the vast material of smaller pits as having a similar function. As discussed, there are a number of factors to consider when assessing the interpretation of the structures. One factor that has not been yet been discussed is the size of the pits. Should size also be counted as an indicator of function, seen in light of the results from archaeological excavations and the experimental reconstructions of slab-lined pits?

Based on the examples discussed here, the genuine train oil production chambers are of modest size. At Harrsjöbacken the production chambers measured c 1.8 x 1.3 x 0.8–0.9; 2 x 0.6 x 0.4; and 1.1 x 1.8 x 0.9 m (Östlund 1997: 8, 13–5). The sizes of the production chambers/frames at Kökar are not described in the cultural heritage database (www.kulturarv.ax), where only the measurements of the fire-cracked stone heaps are listed. Gustavsson (1980: 57–8) does not describe the size of the production chambers/frames explicitly. However, he does mention the measurements of the stones themselves, which varied between 0.2–1 m, but were generally between 0.3–0.5 m high, which also indicates the depth of the production chamber. Gustavsson mentions that the number of stones varies between 1 and 32 stones are reported, but 5–10 stones are most common. Based on the drawings of the three excavated heaps, the sizes of the chambers are relatively modest; c 2 x 1 m, c 1.5 x 0.8 m and c 2 x 1 m (Gustavsson 1980: 59, 65).

The slab-lined pits in the Norwegian database Askeladden are not consistently described: 212 pits lack any mention of size, and in the case of 30 of the pits only the outer measurements are listed. In a number of cases it is difficult to determine whether the measurements refer to the size of the outer walls or the interior production chamber. With these uncertainties in mind, the largest depressions described are 4 x 3 m. One exception (ID 67746 in the Municipality of Loppa in Finnmark) is said to be 6 x 3 x 0.3 m. However, the description notes that it could be a boathouse rather than a slab-lined pit.

The maximum size of what can be assessed to be the actual production chambers in Askeladden correspond with slab-lined pits that have been excavated. According to Jørn Henriksen (1996: 51), in cases where slab-lined pits have been excavated to a sufficient extent, the production chambers vary in size from 3.5 x 1.5–2 m down to 1.5 x 0.5 m, with depths ranging between 0.5 and 1 m. Slab-lined pits dug in recent years have revealed slightly larger chambers. Examples include the 3.8 x 1.8 x 0.4 m pit on Mellaneset in Finnmark (Myrvoll 2011: 90) and the two largest pits at Skjærvika, measuring 3.6 x 2.7 x 0.65 m and 4.1 x 2.36 x 0.6 m (Henriksen & Valen 2013: 191, 197). All of these sites also yielded whale bones.

As previously mentioned in relation to my own reconstructions of slab-lined pits, it became evident that it was easier to keep the blubber temperature above 80°C in a fairly small pits (G. Nilsen 2016: 204–7). This observation would support the interpretation that production chambers smaller than c 4 x 2.5 x 1 m functioned as true fat-rendering pits, while the larger structures were constructed for other purposes. However, secondary use of the larger pits as marine fat-rendering pits cannot be totally ruled out, as they also sometimes feature remains of organic material from marine mammals and fire-cracked stones.

CONCLUSIONS

The examples discussed in this paper demonstrate that archaeologists have based their interpretation of a particular set of structures, pits and chambers, as marine blubber-rendering structures on a set of criteria. This discussion, based on a few select examples, has only considered sites with actual pit- or chamber structures. Other types of structures and sites possibly associated with train oil production pits/chambers were not considered.

Even though the function of the structures from northern Norway, Åland and Harrsjöbacken represent examples of true marine fat-rendering pits and chambers, as evidenced by archaeological science, some aspects of the material found – such as probable terrestrial faunal material – provide contradictory evidence. This also calls attention to the Swedish and Finnish sites, which may have primarily been constructed for purposes other than trail oil production, but the presence of seal bones, greasy organic residue and locations along the shoreline may suggest that the processing of marine mammal fat was at least a secondary activity practiced at these site.

The size of the production chamber of in true fat-rendering pits is modest. The largest ones are documented in northern Norway, measuring c 4 x 2.5 x 1 m. It is therefore very likely that the largest pits in Sweden and Finland of up to 10 m in diameter were constructed for purposes other than marine fat-rendering.

The contradictory elements and the significance of size should not be overlooked, but addressed, discussed and further analysed, especially when trying to distinguishing between single and multi-purpose pits. Some of the pits presented are undoubtedly marine mammal fat-rendering pits built for this single purpose, while others may have been intended as multi-purpose pits, as well as for some other single-purpose use, such as smoking meat or bark.

It is important to focus on the factors discussed in this article and note that using just a few criteria increases the possibility of false identifications. Conversely, being too strict with the criteria may overlook too many structures that may have been associated with train oil production, even if only as a secondary activity. In the future, scientific methods and studying other types of sites associated with marine fat-rendering will probably present opportunities for better understanding of the use of the elusive marine blubber in Scandinavian prehistory.

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