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Comparing Levels of Subsistence Stress amongst Norse Settlers in Iceland and Greenland using Levels of Bone Fat Exploitation as an Indicator

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Abstract
The background to the Icelandic and Greenlandic sites under investigation is outlined and prior work on the Norse economies of the two islands is discussed. The importance of fat in the diet and the use of levels of bone marrow and grease exploitation as an indicator of subsistence stress are explained. The methodology for establishing levels of bone fat exploitation is outlined. This methodology involves the detailed study of fragmentation levels of different types of bone, study of bone fracture types and many other taphonomic indicators. The results of the study are described and discussed. On Greenland, the Norse inhabitants exploited almost all available fat from land mammal bones, leaving only the ribs. It is argued that this indicates a severe level of subsistence stress amongst the Greenlanders that is most likely related to a seasonal dearth in resources. On Iceland, whilst a certain amount of bone marrow is almost certainly exploited, the settlers appear to almost totally ignore the potential to exploit bone grease. This is likely to be indicative of a much more healthy subsistence economy than on Greenland. These results are discussed in relation to differing climate, availability of good soil, fishing practices and seasonal rounds.

Keywords: Norse, Iceland, Greenland, Bone marrow, Bone grease, Fat, Subsistence

Background

Norse Iceland and Greenland

The Vikings had discovered Iceland by no later than AD 850 and the subsequent settlement of the island, the *landnám*, took place over the period c. AD 870–930 (Byock 2001, 9). This early society was one of small farmstead units with little centralised governmental control (Byock 2001). The settlers quickly adapted to the different environment presented by the island and exploited both the marine and land resources that were available. The most common domestic animals represented on farmsteads were cattle and sheep, with goat, pig, horse and dog also present (Amorosi 1992, 123, 172; Tinsley in prep.). This pastoral economy was supplemented by limited exploitation of marine mammals such as common and harp seals, the occasional whale (Amorosi 1992, 124) and a reasonable amount of fishing, principally for gadids, with the presence of some salmonids (Amorosi 1992, 124; Tinsley in prep.). Although limited by wood supplies to fishing from relatively small boats, the rich coastal fishing grounds could yield good catches (Byock 2001, 47). A key economic feature of this activity is that fish, in particular cod, can be preserved by air-drying in winter to produce stockfish, without the need for large amounts of salt (Perdikaris 1999, 390) or fuel

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for smoking. The settlers therefore had access to stored fish and also stored milk products such as *skyr* (coagulated milk) (Byock 2001, 47), a factor that takes on more importance in discussions below. The Icelandic Norse had no arable crops, but the growing of sufficient fodder for livestock was of great importance (Zutter 1992). The early settlers had the advantage of living in the Little Climatic Optimum (c. AD 870–1170) (Byock 2001, 57), but, with the onset of colder weather leading into the Little Ice Age and soil exhaustion, productivity fell (Zutter 1992, 144). The initial *landnám* saw c. 60% of natural vegetation destroyed (Zutter 1992, 139) resulting in increasing erosion from the tenth century onwards (Byock 2001, 56). In these later, harsher conditions, some farmsteads went out of use but others adapted. Later medieval and post-medieval Iceland saw a greater dependence upon marine resources with some farmsteads seeing vastly greater exploitation of seals (Amorosi 1992, 124). By the fourteenth century, Icelanders became more and more reliant upon the commercial exploitation of stockfish, trading with Norway, Germany and England (Byock 2001, 44).

Greenland was reached by the Norse in c. AD 985 and was settled in two main areas, now called the Eastern and Western Settlements (Buckland *et al.* 1996). The economy was very similar but not identical to that on Iceland. It was based upon the pastoral exploitation of domestic cattle, sheep and goat and the hunting of wild birds, seals and caribou (McGovern 1985; McGovern *et al.* 1996). It is worth highlighting some of the differences, in comparison to Iceland. Icelandic settlers did not have access to caribou/reindeer. The few specimens of reindeer bone found on Iceland can probably be attributed to the importation of craft materials (Amorosi 1992, 123). The most important difference is that, whilst the Greenlandic Norse did have access to fish, their exploitation of it was negligible. Numbers of fish bones in Greenlandic middens are often limited to one or two per species and could easily have found their way there in the bellies of hunted seals (McGovern 1985, 80; McGovern *et al.* 1996, 115; Buckland *et al.* 1996, fig. 3). Furthermore, the absence of such bones cannot be blamed upon recovery methods (much fine sieving has been employed) or preservation conditions (which are very favourable) (McGovern 1985, 80).

If availability of good pasture and the ability to grow enough winter fodder was a concern for the Icelanders, it was even more a matter of life and death for the Greenlandic Norse. The grazing season in Greenland was probably very short indeed, June to early September (McGovern 1985, fig. 7), and the animals spent most of their lives in byres dependant upon fodder. The climatic downturn leading into the Little Ice Age resulted in repeated short and poor growing seasons that may have resulted in the final abandonment of Greenland by the end of the 15th Century (Buckland *et al.* 1996).

The Norse groups living on Iceland and Greenland were culturally similar and both attempted to operate largely pastoral economies in difficult environments. It is clear that the environmental difficulties in Greenland were more severe. It is also clear that there were significant differences in economy between the two, particularly with regard to fishing. This paper seeks to use the extent of bone fat exploitation as a proxy for comparing levels of subsistence stress in Iceland and Greenland in relation to their overall level of marginality and to their specific seasonal economies. The rationale behind using exploitation of bone fats as a proxy is outlined below.

Why bone fats are important

The acquisition of fat is of very great importance to any society that is dependent upon animal products alone for survival. As already established, the Norse in both Iceland and Greenland did not grow crops and therefore did not have any source of carbohydrate. Protein is not easily metabolised to provide energy and the intake of large amounts of protein (i.e. large amounts of lean meat) without accompanying carbohydrate or fat can lead to severe illness (Speth and Spielmann 1983; Speth 1983; 1987; 1991). Fat is also valued for its high calorie count, having a higher energy value than either carbohydrates or proteins by a ratio of 9:4 (Mead *et al.* 1986; Erasmus 1986). Given that the Norse peoples in question had no access to reliable sources of carbohydrate, the acquisition of fats would have been of great importance. But why are bone fats so important?

Bones represent one of the most reliable sources of fat in land mammals. This is because they are last in the fat-mobilisation sequence of starving animals (Cheatum 1949; Brookes *et al.* 1977; Peterson *et al.* 1982; Davis *et al.* 1987). This means that when animals are lean and there meat contains very little fat, there will still be considerable amounts of fat within their bones. This fat is held within the medullary cavities of long bones but also within the honeycomb of cancellous (spongy) bone that can be found in long bone epiphyses and most axial elements. Bone marrow can be recovered easily by breaking into the shaft of a bone, but the grease in cancellous bone can only be extracted by fragmenting the bone and boiling the fat out. Such rendering for bone grease has been noted in many ethnographies (e.g. Binford 1978, 158; Leechman 1951; 1954; Wilson 1924).

The above explains the importance of bone fats to the Norse, but they are important to the archaeologist because one is actually left with physical evidence for their exploitation. The bones survive and bear the scars of fat exploitation in the form of specific patterns of fragmentation and fracture (see below for details). What is more, it is possible to see how much effort went into obtaining fats. It is relatively easy to break a bone for its marrow, but the comminution of cancellous bone for grease rendering requires much more effort and is much further along a clear sequence of diminishing returns that may be indicative of greater desperation.

Two Norse farm sites in Greenland have already been studied for levels of bone fat exploitation by the current author (Outram 1998; 1999). Prior to this work it had already been suggested that, from the lack of fat-loving diptera lavae in Greenlandic middens, most fat must have been removed from bones by rendering before deposition (Buckland *et al.* 1996). The results of this author's work confirmed this, showing that almost all sources of bone fat were exploited to a level suggesting great subsistence stress. Furthermore, similar studies on Palaeoeskimo sites in Greenland, revealed that the Palaeoeskimos could afford to ignore many sources of fat (Outram 1998; 1999). In this paper the results from the two previously studied farmsteads in Greenland are summarised and compared with results from two newly studied farmsteads in Iceland.

The sites being investigated

The two Greenlandic sites previously studied by the author (Outram 1998; 1999) are both situated in the Western Settlement of Greenland. Sandnes (V51) is the largest farmstead in the Western Settlement, having a church, and was possibly the centre of the community (McGovern 1985). The site was first excavated in the 1930s and the bones were reported on by Degerbøl (1936), but the sample analysed here was taken from excavations carried out in the 1980s (McGovern 1985; McGovern *et al.* 1996) as the material was properly sieved. According to McGovern *et al.* (1996, Table 3) the assemblage consisted of (in terms of %NISP, Number of Identifiable Specimens) 7.56% cattle, 11.12% sheep, 14.72% caribou and 31.23% seal. The second site was Niaquussat (V48), which was excavated in 1976/77. The site is of lower status than Sandnes and has fewer cattle 1.15–2.96% TNB (Total Number of Bones) (McGovern 1985, Table 6). Sheep/goat account for 9.11–11.21% TNB and caribou for 4.75–6.56%. There was considerably more sealing at 79.27%–84.99% TNB (ibid.). It should be noted, however, that Outram (1999, 116) has argued that the heavy levels of comminution of land mammal bones, that is not observed in the sea mammal assemblage, may have resulted in the overestimation of seal numbers.

The following dates are available for the Greenlandic samples. At Sandnes (V51) the earliest calibrated radiocarbon date range obtained from midden layers is AD 1025–1215 and the latest is AD 1278–1387 (McGovern in prep.). The sample from Sandnes was from the upper part of the midden, so represents later end of this range. The Niaquussat midden has yield an earliest date range of AD 960–1160 and a terminal layers have yielded a date range of AD 1284–1405 (McGovern ob:*et al.* 1984). The sample, studied by this author, was a column taken through the deepest part of the midden and represents the entirety of that date range. There was no apparent change in the fracture and fragmentation pattern in relation to depth. It has been noted that species representation in the Western Settlement does not appear to change greatly over time (McGovern 1985). The samples can be taken as representative of the bulk of the occupation period in Greenland.

The newly studied material from Iceland consists of a large sample from Sveigakot (SVK) and a small, but still meaningful, sample from Hofstaðir (HST). Both of these sites can be found in the Lake Mývatn area of Northern Iceland. Excavations at Sveigakot began in 1999 and the most recent at Hofstaðir started in 1995 (Tinsley in prep.). At both sites, excavated material was sieved using a 4mm mesh (Tinsley in prep.). The faunal assemblage in the 9th century at HST and SVK contains 50% domestic fauna (mainly caprine and cattle, but also pigs and horses) with the rest of the assemblage made up of various fish species (trout, char, salmon, cod, haddock, saith) (Tinsley in prep.). There is a trend for an increase in wild species, including more birds, in the 10th century, which is reversed in the 11th century in favour of domesticates (Tinsley in prep.). The Hofstaðir sample taken for the present study came from HST98 Area G, layer 7, an early phase (layer 6 above it has AMS date range of AD790 – 1000) (Tinsley, in prep.), and consists of 2602 fragments of bone. The larger Sveigakot sample of 10,996 fragments came from SVK00 Area T, context 055 which has two AMS dates (AD 910–1030, AD 980–1140) (Tinsley, in prep.). Both samples therefore date to the period before climatic downturn.

Methods

Below, the methodology for establishing the extent and nature of bone marrow and grease exploitation, from the study of bone fracture and fragmentation, will be briefly outlined. Detailed discussion of various aspects of the methodology can be found in Outram (1998; 2001; 2002) and the specific methodology, as applied to the previous Greenlandic study, can be found in Outram (1999).

Patterns of bone fat exploitation

The most obvious source of fat in bone is bone marrow. The exploitation of bone marrow is very simple. One has to break into the medullary cavity of the long bone. This will occur whilst the bone is still relatively fresh and contains its organic component. As such, the fracture pattern created will be helical and at the point of impact there will be a dynamic impact scar (see Morlan 1984; Johnson 1985; Outram 2002). The overall pattern resulting from this activity will be one of undamaged articulations and axial elements with helical splinters of diaphysis bone.

In order to exploit bone grease, one has to render the fat from the cancellous bone found in epiphyses and axial elements. In most ethnographic examples, e.g. the Nunamiut (Binford 1978), the Hidatsa (Wilson 1924) and the Loucheux (Leechman 1951; 1954), this is carried out by storing up the appropriate parts until there are sufficient to warrant processing, then comminuting them and rendering the fragments in boiling water. As the water cools, or is cooled deliberately with snow or water, the fat coagulates at the surface and can be skimmed off. The resulting pattern will be one of large numbers of very small pieces of cancellous bone accompanied by larger, helical shaft splinters.

The extent of exploitation can be assessed by quantifying how much of the assemblage has been fragmented in this way. One can assess the level of marrow exploitation through noting how many shaft cylinders have been left unbroken and assessing the extent to which the fragmentation of cylinders was the result of deliberate, helical fracture. In the case of grease processing, one can assess how much cancellous bone has been left unprocessed (i.e. not comminuted). In some cases of incomplete exploitation it will simply be that a random selection of grease-bearing elements have been left unprocessed. In other cases, a selection for particular types of grease will have occurred. The grease from axial and appendicular elements can be different in nature (Binford 1978, 159) and some peoples may select to exploit one in preference to the other. It is possible that particular elements will be avoided as not being worth the effort, or because they offer poor quality fat.

In order to study these patterns archaeologically, one must establish how fragmented the assemblage is and which types of bone (in terms of marrow and grease utility) are fragmented and which potential sources of fat have been left unprocessed. One also needs to assess the evidence for deliberate fracture and record fracture types. Alongside this, one must keep a record of other taphonomic factors that can lead to attrition, so that one can know how much the fragmentation may be the result of human action rather than post-depositional taphonomic processes. All the factors must be considered together.

Fragmentation levels

The method used for recording the levels of fragmentation at both the Greenlandic and Icelandic sites is as follows. All fragments were included, whether identifiable or not. Whilst identification to species and element may not be possible, such fragments still carry valuable information in the form of size, fracture patterns and bone type. It is possible to tell cancellous bone from diaphysis bone on even very small fragments and such information is very important in the context of this study. The entire assemblage was divided into size classes (by maximum dimension). The size classes used were <20mm, 20–30mm, 30–40mm, 40–50mm, 50–60mm, 60–80mm, 80–100mm, 100+mm and part and whole bones. Whole bones clearly have not been exploited for grease at all. Part bones include bones that are not whole but represent whole units that could have been exploited for grease but were not broken up. Part bones include entire epiphyses and complete vertebral centra. In this study the part and whole class have been presented as a single (P/W) class, representing unexploited sources of cancellous bone. One difference between the Greenlandic study (Outram 1999) and the Icelandic study is that for Iceland the P/W class has been divided into small (<50mm) and large (50+mm).

Quantification of the size classes was by number and mass. Whilst numerical data was collected, only the mass data is displayed in this paper. The mass data is more meaningful because it represents actual amounts of bone present. Clearly one unbroken large bone represents the same amount of potential fat as a similar element broken into many pieces, yet the latter would be represented by many hundreds on a numerical count. By mass, both would be suitably equal. Brink (1997), in his study of bison, concluded that dry bone mass was an accurate predictor of elements' bone grease utility.

For each size class, a distinction is made between whether the bone is cancellous or cortical in nature. For large size classes, distinction was made between axial cancellous bone (other than ribs), ribs, articular bone from appendicular elements and diaphysis bone. This enables one to see, in terms of bone fat utility, which types of bone had been fragmented and to what level.

Fracture types

When dynamically fractured in a fresh state, dense diaphysis bone creates a very distinctive fracture pattern. Such fractures are characterised by helical fracture lines radiating out from the point of impact. The fracture surface will form either an acute or obtuse angle to the cortical surface of the bone. This fracture surface will also tend to be smooth in texture (Johnson 1985; Morlan 1984; Outram 1998; 2001; 2002). As bones dry out they develop small cracks that interfere with the fracture line, creating roughness or steps, hence affecting the fracture shape and surface texture. As bones loose their organic content they react differently to force. Loss of elasticity results in bones snapping in straight lines that tend to be perpendicular to the cortical surface. A largely mineralised bone will break with a straight, rough edge that is close to being at right-angles to the cortical surface.

The three criteria of fracture outline (shape), fracture angle (to cortical surface) and fracture texture (smooth or rough) can be used to characterise large assemblages of fragments in terms of the amount of deliberate fracturing of fresh bones versus levels of post-depositional breakage of dry bones (Villa and Mahieu 1991; Outram 1998; 2001; 2002). The indexing method used in the study of both the Greenlandic and Icelandic material was developed and tested experimentally by Outram (1998; 2002).

All diaphysis fragments of 30mm or more in length were studied for fracture type providing that preservation was good enough. Occasionally, fragments have eroded edges and fracture features are indistinct. Such fragments were disregarded, but were also very uncommon in all assemblages studied. For each of the three criteria a score of 0, 1 or 2 was awarded. In broad terms, a score of 0 denotes that that criterion is consistent with fracture of a fresh bone, a score of one denotes a mixture of fresh and unfresh features (but with fresh still dominating) and 2 denotes that unfresh features are dominant. Much greater detail is available in Outram (2002). Shape, angle and roughness are all estimated by eye. This is essential to make assessments of large samples practical. Individual misjudgements will be irrelevant as the method is being employed to characterise the assemblage in general and sample sizes are large. The angle and outline characteristics are fairly easily defined, but assessment of roughness is more subjective and relies upon the analyst having a good mental template (like much zooarchaeological analysis) of the possible range.

When the scores are added together one ends up with a score from 0 to 6 for each fragment, called the Fracture Freshness Index (FFI) score (Outram 2001; 2002). Scores of 0, 1 and 2 will represent bones broken in a relatively fresh state. Scores of 3, 4, 5 represent either bones that were broken when becoming fairly dry (unlikely to be for fat extraction) or bones which had some fresh fracture on them but were further fragmented when unfresh. A score of 6 represents a bone with no evidence of fresh fracture. The profile of scores and overall average for a sample can be displayed.

The FFI score is a very good indicator of the taphonomic history of the assemblage, but other indicators can be recorded that provide more detail and help to deal with potential problems of equifinality within the FFI. If one records whether or not a fragment has an example of an individual mineralised break it is possible to distinguish between bones that had fresh features, but then got broken when mineralised, and bones that showed no fresh or completely mineralised features, but were dry when broken (i.e. scores 4, 5, 6). Such completely mineralised breaks are easy to spot (on their own they would score 6). New breaks (caused by excavation or storage) can also be recorded, as the fracture surfaces will be an obviously different colour. Dynamic impact scars, created at the point of impact on a fresh bone, can also be recorded as evidence of deliberate fracture, much like bulbs of percussion on flints. If the bone cylinder was broken on an anvil, there may be a rebound scar due to the opposing force of the anvil (see Outram 2002, fig. 6.8).

Other taphonomic indicators

Several other criteria are important for understanding the taphonomic history of the assemblage. The above shaft fragments are also studied for evidence of animal gnawing and butchery (chops, cuts, polish and sawing). Numbers of burnt fragments are counted for the entire sample at the level of size class and bone type. Butchery can clearly add to the overall level of deliberate breakage, however, the breakage of bones for butchery purposes will be restricted to particular elements for a particular purposes, such as an alternative to disarticulating a difficult joint. There is also likely to be a difference between the fractures produced by chopping through meat and bone and those created by direct impact to the bone. It is essential that all indicators (fragmentation level, bone types, fracture patterns, gnawing, butchery and burning) are considered holistically to effect a successful interpretation and avoid pitfalls of equifinality.

A note regarding sea mammals

Sea mammal bone is very different in nature from land mammal bone in terms of its physical make-up, nature of fat and fat utility and is generally not exploited for its fat content (see Outram 1999, 115). It has been separated out in this study and will not be included. However, reference to the state of preservation of seal bones will be made, since this is a taphonomic indicator. Seal bones are not very dense, being composed almost entirely of cancellous bone with quite thin cortical shaft bone, and, as such, their survival would indicate relatively low levels of post-depositional attrition. The relevance of the exploitation of sea mammal fats will also form part of later discussion.

Results

Combined Greenland results (Figs. 1–3)

For the purposes of this paper, the results from Sandnes (V51) and Niaquussat (V48) have been combined graphically to show the mass of fragments (Fig. 1) and FFI score distributions (Fig. 3). For bone type (Fig. 2) only Sandnes results have been displayed. At Niaquussat the results were almost identical, but ribs were not separated from other axial bone, which made that data less informative. If one examines the masses of fragments in different size classes (Fig. 1), the most striking feature is the lack of bones that survive whole or as complete bone parts (vertebral centra and epiphyses). There is in fact an almost equal mass of bone that is comminuted to a size under 20mm! There is a fair amount of material surviving to over 100mm, but the assemblage is generally quite broken up.

In order to understand this pattern properly one needs to view it in conjunction with a graph showing the type of bone in each size category (Fig. 2). This shows that the bone in the larger size classes consists largely of shaft and rib fragments. It is clear that very little cancellous bone other than that in ribs survives in large pieces. Most of the cancellous bone can be found in size classes under 50mm. This is very important. The expected pattern for bone marrow exploitation and intensive grease production is one where most cancellous material will have been comminuted, leaving shaft splinters to dominate the larger classes. This is what we see here, with the exception of ribs that appear not to have been broken up. If this pattern is the result of human agency then it looks like a pattern of extensive bone fat exploitation where only the ribs have been disregarded in the rendering process.

The FFI data (Fig. 3) strongly supports this hypothesis. Fracture patterns consistent with the fracture of bone in a fresh state very much dominate the assemblage. There appears to be very little post-depositional damage to the bones, once they had begun drying out and loosing organic content. At both sites about 9% of shaft fragments bore direct evidence of dynamic fracture in the form of scars. This is a good proportion, considering that such scars are only found at the actual point of impact.

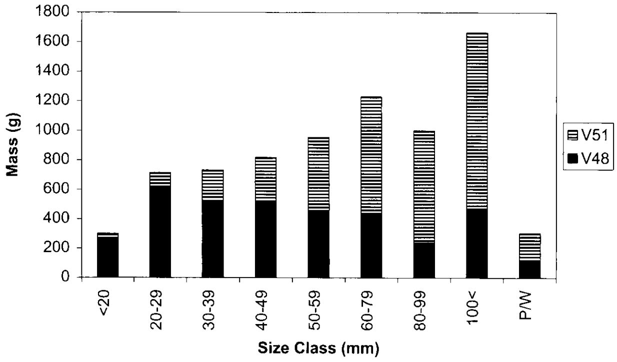

Figure 1. Masses of bone fragments in different size classes at Sandnes (V51) and Niaquussat (V48).

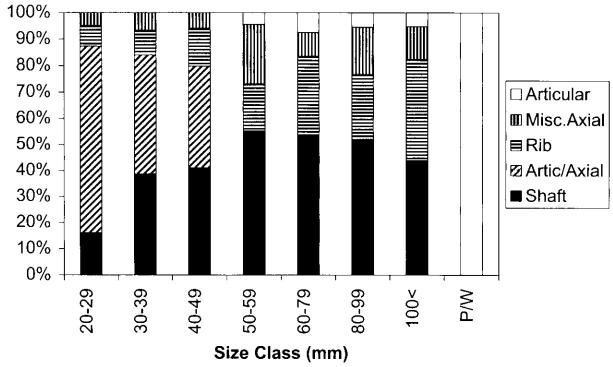

Figure 2. Types of bone fragments in different size classes at Sandnes (V51).

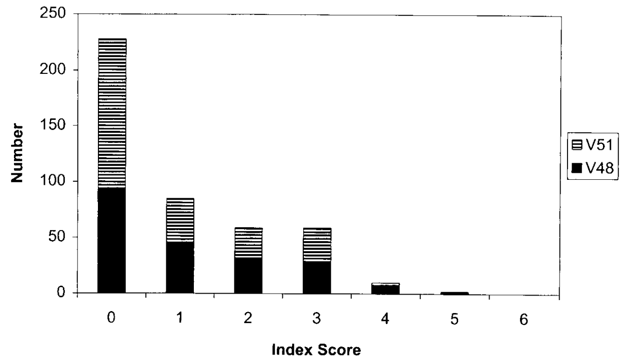

Figure 3. Fracture Freshness Index scores for shaft fragments at Sandnes (V51) and Niaquussat (V48).

There was evidence for only small amounts of damage from other causes. Carnivore gnawing was noted on 3.6% of specimens, mineralised fracture on 3.2%, new breaks on 1.2% and butchery marks on 0.5%. Burning was very low at Sandnes, at less than 1% of fragments in any class. At Niaquussat more than 30% of the very small class was burnt, but levels were much lower in larger classes. It is likely that that assemblage contained a small amount of fire output. The general lack of post-depositional damage is also indicated by the good survival of seal bone and land mammal ribs.

The interpretation therefore is that the Greenlandic Norse were exploiting bone marrow by fracturing long bone shafts, creating shaft splinters, and rendering almost all cancellous tissue except ribs for bone grease, leaving a pattern of comminuted appendicular and axial bone and large rib fragments. This would seem to be indicative of a society who needed to exploit fully the resources available to them, even though this would require much effort for a relatively small return. For a more detailed consideration of these sites specifically, see Outram (1999).

Hofstaðir and Sveigakot (Figs. 4–9)

The masses of fragments in different size classes at Hofstaðir (Fig. 4) and Sveigakot (Fig. 5) are very different from the Greenlandic sites. Whilst there is a certain degree of fragmentation the assemblages are dominated by large whole or part bones and large fragments. The bone types in different size classes are even more strikingly at odds with the picture in Greenland. At both Hofstaðir (Fig. 6) and Sveigakot (Fig. 7) vast amounts of cancellous bone survive in large, unrendered pieces. Shaft bone is poorly represented, largely because much of it survives attached to whole epiphyses or forms part of complete appendicular elements.

If one studies the FFI scores at Hofstaðir (Fig. 8) and Sveigakot (Fig. 9), one sees that, whilst there is still significant evidence for the fracturing of some fresh bones, there is also much indication of the breakage of bones when they were no longer fresh and the bone fats were no longer exploitable. The idea that some shaft breakage was deliberate is supported by the incidence of impact scars, 6.9% at Hofstaðir and 9.1% at Sveigakot (two examples had rebound scars). At Hofstaðir and Sveigakot respectively, gnawing was 0% and 1.2%, mineralised breaks were 5.9% and 4.0%, new breaks were 1.0% and 1.2% and butchery was 1% and 1.6%. There was a fairly substantial level of burning in the smallest size class at both sites, 25.5% at Hofstaðir and 25.7% at Sveigakot with levels in larger size classes being generally low.

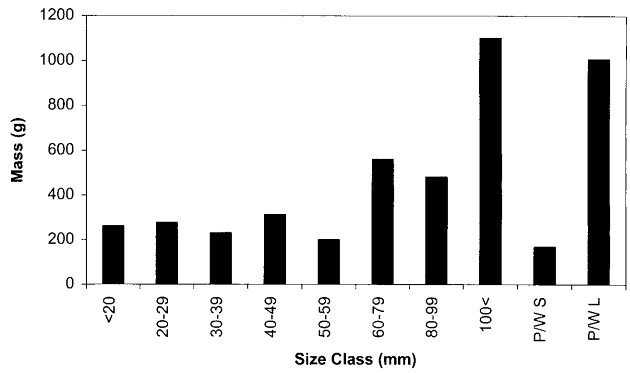

Figure 4. Masses of bone fragments in different size classes at Hofstaðir.

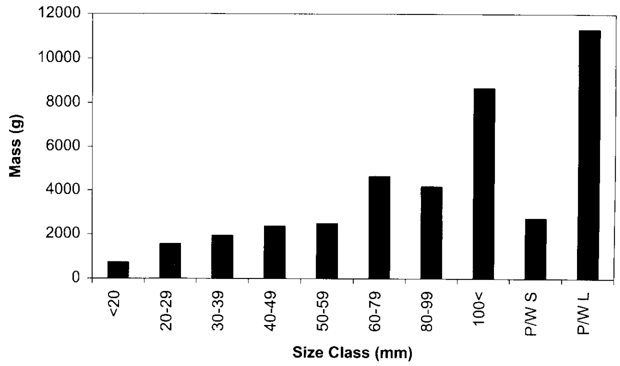

Figure 5. Masses of bone fragments in different size classes at Sveigakot.

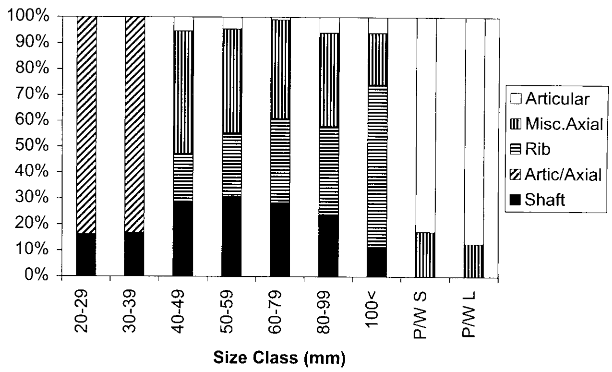

Figure 6. Types of bone fragments in different size classes at Hofstaðir.

The patterns at both Icelandic sites are very similar and show with great certainty that bone grease was exploited, if at all, at very low levels. Incidences of low FFI scores and dynamic impact scars suggest that some long bones were deliberately broken for their bone marrow, but the exploitation of this relatively worthwhile resource was not exhaustive.

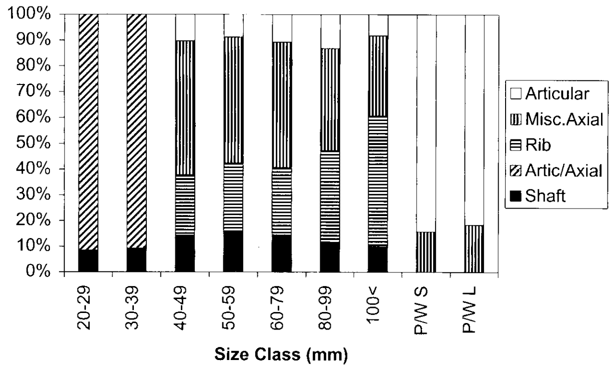

Figure 7. Types of bone fragments in different size classes at Sveigakot.

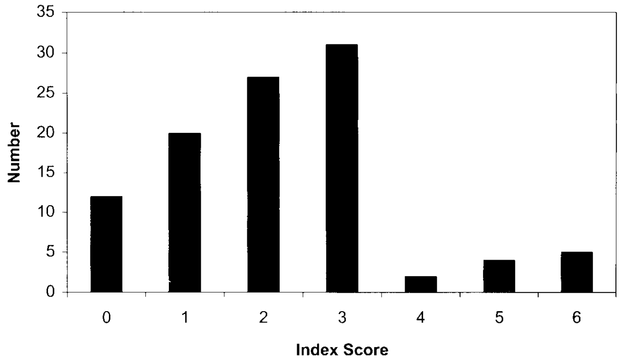

Figure 8. Fracture Freshness Index scores for shaft fragments at Hofstaðir.

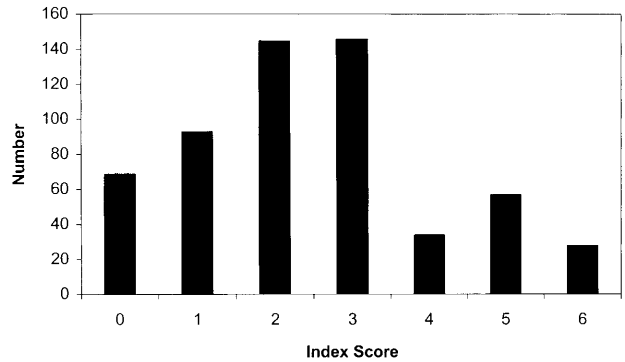

Figure 9. Fracture Freshness Index scores for shaft fragments at Sveigakot.

Discussion

Levels of subsistence stress

It is clear that the Greenlandic Norse were exploiting bones for their grease content very intensively. Such intensive exploitation is not a very efficient way to gain food, but one suspects that they had little option. The only type of cancellous bone that seems to have been systematically ignored is rib. It is interesting that Nunamiut informants told Binford (1978, 32) that rib grease was not thought of as very desirable and was only exploited in bad times and for lighting. It can be concluded that the exploitation of bone fats was very intense and probably indicates considerable economic stress. Even though there may have been sufficient stress to make the laborious task of rendering worthwhile, it seems that, on average at least, the settlers could still exercise a little taste and avoid the use of ribs.

The situation on Iceland during the early part of its settlement seems to have been very different. It is clear that most cancellous bone was not being rendered for grease. In fact, there is no really good evidence for rendering at all. Fracture patterns show that bone marrow was being exploited, but not exhaustively. It seems that the Icelanders could afford to let much bone fat go to waste, just using easily extracted marrow when they felt like it.

Causes of differential subsistence stress

It seems likely that there are three principal reasons for the apparent differences in bone fat exploitation patterns and inferred economic stress levels between these two communities. These relate to the overall productivity of their environment, their seasonal rounds and the production of stockfish.

A simple explanation for the difference is that the Icelandic settlers were far less limited in the grazing land available to them. In the early period of settlement the soils would not have become too depleted or eroded and, as such, the pastoral economy could have been considerably more successful than on Greenland, where pasture was very limited.

Another reason for the difference can perhaps be found in periods of seasonal dearth of resources and the need for stored foodstuffs. The Greenlanders sealed in the spring (McGovern 1985, 101). This activity would have brought both meat and much fat, in the form of blubber. The rendering of bones at this time would have been entirely unnecessary. Milking would have been possible during the summer and it is likely that culling of some domesticates and the hunting of the odd caribou would have taken place before the onset of winter. Winter would see little in the way of new resources. There would be stored dairy produce, possibly some dried meat and a stock of fat-bearing bones from the autumn kills. That is the likely time when intensive grease exploitation became necessary.

The winter situation in Iceland was different, principally because of the abundance of stockfish. This important resource of stored gadids could also be supplemented year round by the abundant availability of freshwater trout and char (Byock 2001, 52). Without an equivalent period of seasonal stress, the Icelanders need not have resorted to intensive bone rendering.

Conclusion

The detailed examination of the nature and level of bone marrow and grease exploitation, when considered alongside other economic and environmental data, is a powerful tool for understanding levels of subsistence stress in marginal environments. This study has shown up clear and interesting differences in the patterns seen on Greenland and amongst the early Icelandic settlers. It raises some interesting questions. It once again raises the conundrum of the lack of fishing on Greenland. Was this a purely cultural, if disastrous, decision or is there a clear practical reason why fishing could not be carried out? Such possible reasons could include a lack of time, a lack of wood for suitable boats or even the wrong conditions for air-drying fish. More work will be needed here. Another obvious question, and one that can easily be addressed in the future, is whether the nature of bone fat exploitation changes over time within Iceland. What are the effects of soil degradation, erosion and the onset of the Little Ice Age and the economic changes related to it?

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