Fluorine poisoning in victims of the 1783-84 eruption of the Laki fissure, Iceland.

Eystri Ásar & Búland – pilot study excavation report

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Cover photographs show the cemeteries of Eystri Ásar (on the left) and Búland (on the right).

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1 Introduction

1.1 Background

The eruption of the Laki fissure in southern Iceland in 1783-1784 produced the largest amount of lava of any eruption in historical times and was the greatest calamity to affect Iceland since its settlement. The emissions from the fissure decimated the Icelandic vegetation, which lead to the death of most of the livestock (sheep, cattle and horses) over the 9 month period of the eruption through lack of sustenance. A famine swept the country and 10, 000 people, or 20% of the population, died from starvation and disease (Gísli Ágúst Gunnlaugsson *et al*, 1984).

The eruption has become increasingly topical for volcanologists and atmospheric scientists, who are now taking a keen interest in the effects of volcanic eruptions on climate and their role in global climate change. The emissions were carried in the troposphere towards Europe and even North America, where they may have been responsible for regional variations in weather large enough to affect agricultural production and, possibly, have had a direct effect on the health of people through air pollution. The “dry fogs” reported at the time may have their modern counterpart in global regional air pollution due to the Indonesian forest fires, or the “brown haze” of anthropogenic pollution recently identified over some of Asia’s more densely populated areas, the aerosols from which could affect climate variables such as cloud formation and global wind patterns. The haze reflects sunlight, possibly affecting surface temperatures and the amount of rainfall with potentially adverse effects on crops (Grattan *et al,* 2003).

The aim of this project is to address one aspect of the impact of the Laki fissure eruption, namely the causes of death in people who lived near to the centre of the eruption and on whom the impact was recorded by the pastor, Jón Steingrímsson. The pastor is also famous for being credited at the time for the miracle of stemming the eruption when the lava flow stopped not far from his church at Kirkjubæjarklaustur. He remained at his post throughout the eruption, providing a remarkable record of the volcanic events and human suffering. Largely because of his account of bony changes in the living and dead livestock, it is widely considered that many animals in the area died from fluorosis by ingesting the toxic ash emitted during the eruption whilst grazing on the stunted vegetation. Less appreciated is his account of similar changes in humans, which suggests that they too may have died from sub-acute fluorine poisoning. For humans, the source of fluorine would have had to have been from drinking water taken from rivers contaminated either by copious ash falls or by disturbances to the groundwater sources, and the rain water which would have been strongly acid due to absorption of halogen gases from the degassing plume. A “Blue Haze” accompanied the eruption, which was bad enough to reduce visibility for fishermen trying to find the shore (Sveinbjörn Rafnsson, 1984), for example, and this may have interacted with clouds and affected rainwater composition, as well as having a deleterious impact on respiratory health. The composition of this haze is unknown.

Evidence that people died with fluorine poisoning, let alone sufficient to cause bony changes, has not been recorded in volcanic eruptions before. Confirmation of these findings would not only be of archaeological and historical interest, but also add to the growing body of knowledge on the impacts of volcanoes on human health. It would also be of importance as a consideration in emergency planning for future large-scale eruptions in Iceland, and it would affirm the importance of fluoride as an atmospheric emission in Icelandic eruptions, whose effects may be experienced further a field over Europe and North America as a result of tropospheric transport.

To date, no studies or analysis of the bones of animals from the eruption period has been undertaken. No bone specimens have been preserved. The prevalent view that the animals died from fluorosis is based entirely on Steingrímsson's accounts and is a reasonable supposition as derived also from historical accounts (Hannes Finnson, 1970) and recent studies of animals affected by fluorosis in eruptions of Hekla (Guðmundur Pétursson *et al*, 1984), a known fluoride emitter.

1.2 Objective

No skeletal remains from individuals who lived in the vicinity of the Laki fissure at the time of the eruption had been excavated in Iceland. The aims of this preliminary study were therefore twofold.

1. Carry out a test excavation in the cemeteries of Eystri Ásar and Búland in Skaftártunguhreppur, both of which were in use during the Laki eruption, to assess both the accuracy with which individual graves in the cemetery could be dated and the preservation of any skeletal material found.
2. To carry out chemical and histological analysis of any human skeletal material recovered to asses whether the individuals suffered from fluoride poisoning

The cemeteries of Eystri Ásar and Búland were selected because of their proximity to the Laki fissure, they are both located in Skaftártaunga which was affected by the eruption. Both were in use during the eruption, but went out of use in 1898 when the two parishes were united and the church moved to Gröf (Oddgeir Guðjónsson *et al*, 1985).

1.3 Methodology

All the excavation was carried out by hand and followed single context excavation and recording. All units were given unique context numbers, and then recorded by planning and description on *pro forma* sheets and photographs taken where applicable. After the excavation was completed all areas were backfilled and re-turfed to minimise any visual damage to the sites.

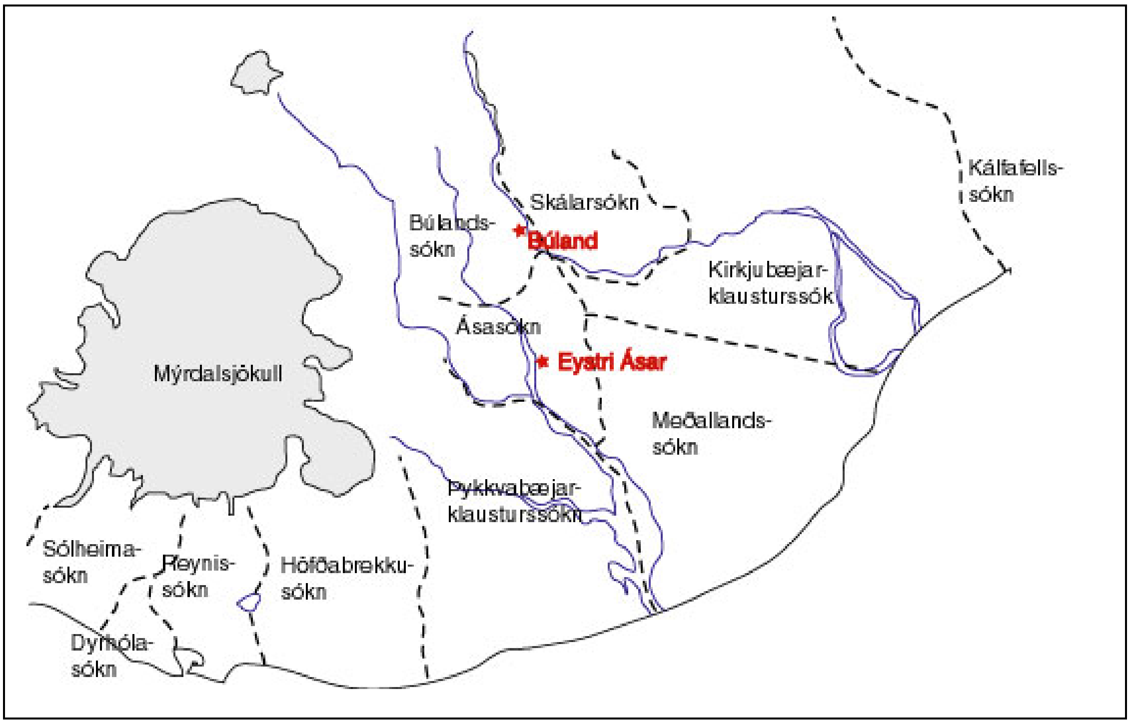

Figure 1. Parishes in Vestur-Skaftafellssýsla in 1783, showing the location of Eystri Ásar and Búland (based on Gísli Ágúst Gunnlaugsson, 1984)

2 Eystri Ásar – SF-175 (EAS)

The cemetery at Eystri Ásar stands on the southern edge of the Eystri Ásar homefield on the banks of the Eldvatn River. The site is in danger from erosion from the river, and in the recent past large areas of land immediately west of the cemetery has collapsed into the river. The erosion appears not to have affected the cemetery itself yet, although its southern edge has subsided considerably.

The cemetery has remained untouched since its abandonment in 1898, and was fenced off in 1950, with concrete corner posts and a wooden gate at the centre of its northern side. The cemetery is rectangular, orientated east-west and measures 22x38m. The remains of the church can still be clearly seen in the eastern end of the cemetery, measuring 9x9m. High grave mounds, some still standing up to 0.5m high are still visible in the cemetery, in particular to the west of the church. Three of these still have grave markers, all dating to the latter half of the 19th century. Building up of graves with turf blocks up to 0.7m height is a tradition that continues in Skaftártunga, which can still be clearly seen in the cemetery at Gröf.

2.1 Excavation

Prior to excavation within the cemetery several auger tests were done outside its perimeter to try and identify tephra. These test proved inconclusive. Immediately southwest of the south-western corner post of the cemetery was an eroded section with *in situ* tephra, identified tentatively as from Katla eruptions in 1918, 1755, (1660?) and 1625 (see figure 2). Following this 11 test pits, numbered from 1-11 (each c. 50x50cm) were excavated over the entire area of the cemetery (see figure 3) to try and identify the tephra seen in the section and its association with grave cuts. Two of these (3 & 11) were extended into larger area excavations.

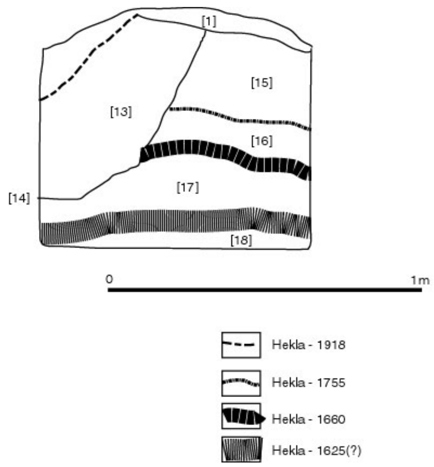

Figure 2. Section by south-western corner post

2.1.1 Test pit 1

South-eastern corner of cemetery 3.5m east of the south-eastern corner of the church, 50x50cm, 30cm deep. The uppermost 30cm were homogenous medium brown soil sealing a tephra layer (K-1918). Two 20cm auger core were taken in the north-eastern and south-western corners of the pit. This revealed a coarse dark grey tephra, c.2cm thick (K-1755), 12.5cm below the K-1918, which sealed anthropomorphic soil containing disturbed dark grey tephra. No finds were recovered from this pit, and no further investigation was carried out.

2.1.2 Test pit 2

Situated 3.7m east of the church structure, 50x50cm, and 24cm deep. Uppermost 24cm consisted of homogenous topsoil sealing a black fine tephra, 1cm thick (K-1918). Core in north-eastern corner revealed a 12cm thick light brown anthropomorphic soil which sealed a dark grey coarse tephra, at least 4cm thick (K-1755). One find, several fragments of probably one glass vessel was recovered from the top soil <5>. No further work was carried out.

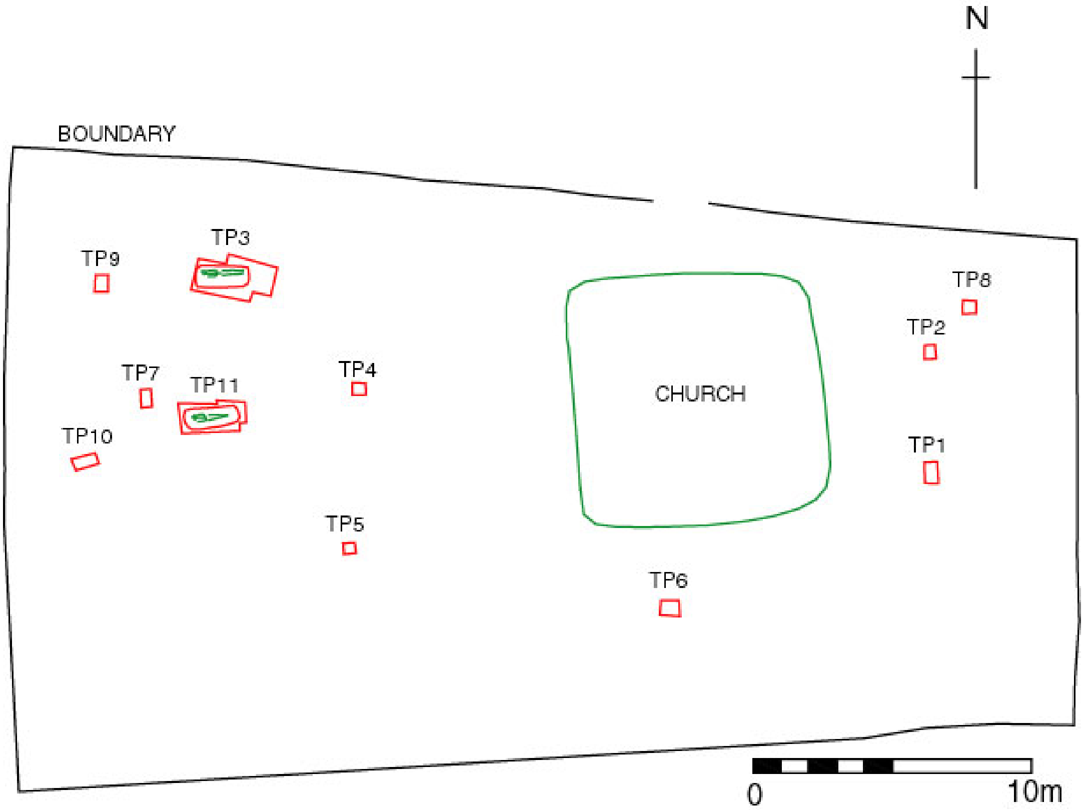

Figure 3. Eystri Ásar showing location of test pits.

2.1.3 Test pit 3

Located 10.5m west of the northwest corner of the church, orientated northwest – southeast, 1.5x2.9m in size. The entire area was sealed by 30cm of bioturbated medium brown topsoil [01]. This sealed a 5cm thick firm dark brown silty soil [02] containing a dark tephra (K-1918), located in the south-eastern corner of the excavation area. This in turn sealed a thin layer (1-5cm) of debris containing charcoal and burnt bone [03], extending along the southern edge of the area, which sealed the elements of the grave itself. Sealing the grave were clear turf blocks [04], containing a dark grey tephra (K-1755) indicating that surface of the grave had been built up with turf. The fill of the grave itself consisted of mottled sandy silt [05] containing disturbed tephra, burnt animal bone, charcoal and disturbed human bone. The grave cut [09] was orientated east – west, measured 0.7x1.8m and was 2m deep (to the base of the coffin). The edges of the cut were vertical – undercut, the base was not excavated as the coffin was left in. Contained within grave cut [09] was a near complete wooden coffin with lid [11], containing a skeleton (EAS-002) which had been laid supine with both arms crossed across the waist, on a bed of wood filings. Clearly seen in the section of grave cut [09] was a dark greyish coarse tephra (K-1755). The tephra found in situ on site indicated a date between 1755-1918.

Figure 4. Skeleton EAS-002

2.1.4 Test pit 4

Situated 7.4m west of the church structure, 50x50cm, and 24cm deep. The top most 24cm were homogenous medium brown topsoil sealing a black tephra (K-1918). Cores in the northeast and southwest corner revealed 15cm of slightly disturbed soil sealing course dark grey tephra (K-1755). No finds were recovered, and no further investigation was carried out.

2.1.5 Test pit 5

Situated 8.2m west of the southwest corner of the church structure, 50x70cm, and 27cm deep. This pit was taken through the northern edge of a very clear grave mound. The top most 27cm were homogenous topsoil which included disturbed black tephra. This sealed mottled upcast soil. A core in the north-western corner of the pit revealed 15cm of upcast type soil sealing a coarse dark grey tephra layer (K-1755). A core in the south-western corner of the pit revealed at least 20cm of mottled upcast type soil, probably grave fill. One find was recovered from the topsoil of the pit, a fragment of clear window glass <7>. No further investigations were carried out.

2.1.6 Test pit 6

Situated 2.7m south of the church structure, 50x50cm, and 25cm deep. The top 25cm consisted of homogenous topsoil, which sealed slightly lighter, very homogenous soil.

Cores in the north-eastern and south-western corner of the pit revealed this to be 7-15cm thick, and sealing a coarse dark grey tephra layer (K-1755) which in turn sealed anthropomorphic soil. An iron nail <*8*> was recovered from the topsoil. No further work was carried out.

2.1.7 Test pit 7

Situated 15.1m west of the church structure, taken through the northern edge of a very clear grave mound. Orientated northeast-southwest, 50x70cm, and 23 cm deep. The top 23cm were homogenous topsoil. This sealed the construction of the grave mound which was turf built, containing a coarse dark grey tephra (K-1755), which had been placed on their side outlining the grave. Two fragments of glass bottles <9>, not the same vessel, were recovered from the topsoil. No further work was carried out.

2.1.8 Test pit 8

Located 5.5m east of the north-eastern corner of the church, 50x50cm, 25cm deep. The top 25cm consisted of homogenous topsoil which overlay a fine black tephra (K-1918). A core in the north-eastern corner of the pit revealed that the tephra was c. 2cm thick, and sealing a medium brown quite organic soil, at least 8cm thick before the auger hit something hard, probably a stone. Cores in the south-western, south-eastern and north-western corners of the pit revealed 14cm of turf/turf debris sealing a 3cm thick coarse dark grey tephra (K-1755). In the north-western core the auger the clearly rubbed against a stone, indicating that there might be some structural elements in that area. No finds were recovered from the pit, and no further work was carried out.

2.1.9 Test pit 9

Located 16.6m west of the north-western corner of the church, 50x50cm, 30cm deep. The top 30cm consisted of very homogenous topsoil, slightly darker than seen in the other pits. Cores in the northwest, southeast and south-western corners revealed a coarse dark grey tephra (K-1755) a few centimetres under this surface, 3cm thick, which in turn sealed 3cm of homogenous brown soil which sealed another coarse dark grey tephra, 5cm thick. This lower tephra in turn seals at least 8cm of homogenous brown soil. The lower tephra is possibly one of the 17th century Katla tephras, or the tephra layers seen in the cores are disturbed, possibly within turf, and are both the K-1755. However no further work was carried out in TP9 and no finds were recovered from it.

2.1.10 Test pit 10

Located 17.1m west of the centre of the church, measuring 50x85cm, 25cm deep and orientated southwest-northeast. This test pit was cut into the northeast corner of a clear grave mound, which stood approximately 30cm high. The K1755 tephra was found under 25cm of homogenous topsoil, although whether this was *in situ* or in turves capping the grave, as seen in the excavated burials in TP3 and TP11 is unclear.

2.1.11 Test pit 11

Located 11.8m west of the centre of the church, orientated east – west, 1.1x2.4m in size. The entire area was sealed by 30cm of bioturbated medium brown topsoil [01]. This in turn sealed a medium brown silty soil [06] containing in situ black tephra (K-1918), 5cm thick, which appeared to be gathering in the hollows between the graves. Also sealed by the topsoil [01] were turf blocks [07], 10cm thick, covering an area 30x100cm, and containing coarse greyish tephra (K-1755) which had been used to build up the mound sealing the grave. This in turn sealed the grave fill [08], mottled silty soil containing disturbed tephra. The grave cut itself [10] was orientated east – west, measured 0.7x1.6m and was 1.64m deep (down to the coffin base). The grave edges were vertical – undercut, and contained within it was a wooden coffin [12] of which most of the lid had not been preserved, containing skeleton EAS-001, which had been laid supine in the grave with both arms crossed on the waist. The coffin was not lifted.

Figure 5. Skeleton EAS-001

2.2 The finds

- Analysis of pottery and glass carried out by Gavin Lucas.

The excavation at Eystri Ásar recovered a total of 38 objects, recorded under 33 finds units (see finds register – appendix 3). All finds were cleaned, dried, repacked and registered in the excavation database. Conservation work was carried out by the National Museum.

Several test pits were dug in the cemetery at Eystri Ásar. Artefacts were recovered in seven of these: TP2, TP3, TP5, TP6, TP7, TP11 and in the section by the SW post of the cemetery (see figure 3). In the smaller test pits artefacts were found in top soil context [01]. In test pits 3 and 11 graves were excavated, and in these, artefacts were found both in the top soil and in the grave fill. Preservation of organic material at the site is very good. Wood was especially very well preserved, but textile was decomposed. Iron is on the other hand is very misshapen and corroded.

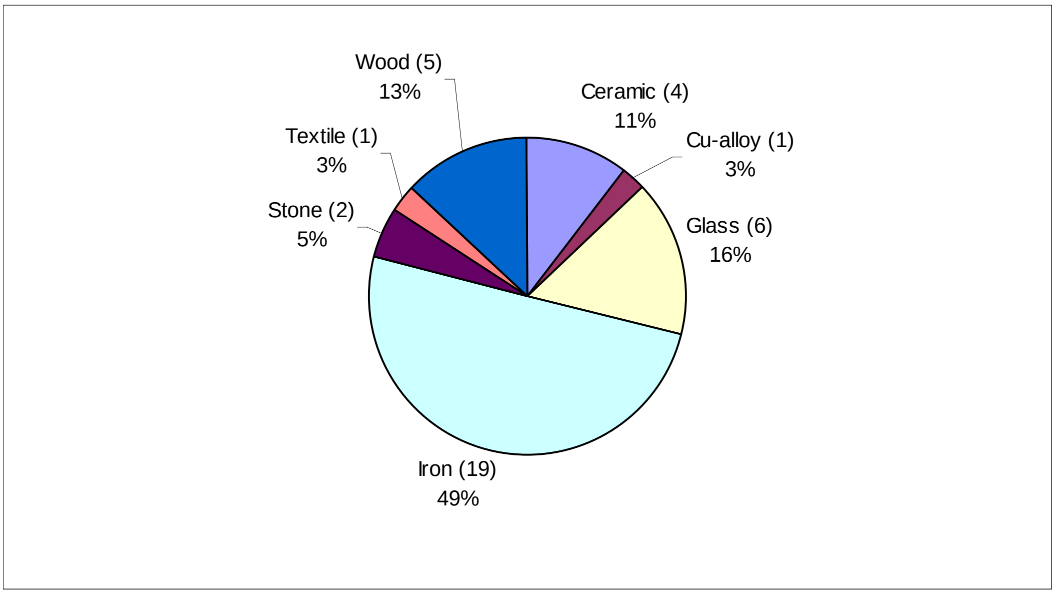

Figure 6. Material at Eystri Ásar. Divided by count and percentage

2.2.1 Section at SW post

Four finds were retrieved by the section that was made outside the graveyard, at the SW post, finds number <*1-4*>. Those are: Iron rivet <*1*>, wood fragment, from coffin? <*2*>, ceramic, small whiteware sherd dated to 19th century or later <*3*> and a schist whetstone <*4*>.

2.2.2 Test pit 2

In test pit 2 two finds were retrieved. Find <*5*> includes five fragments of green, blown bottle glass; probably dating from the 19th century. The other is a blue glass bead <*15*> known as a "fancy bead". Fancy beads were manufactured in Italy, Czechoslovakia and Germany in the 17th-20th century. These beads were made by both blowing and moulding and are very fragile (Elín Ósk Hreiðarsdóttir, 2005).

Figure 7. "Fancy bead" ***(15)***

2.2.3 Test pit 3

The grave containing skeleton EAS-002 was excavated in this area. In total sixteen finds were registered under thirteen finds numbers. Six finds were recovered from the topsoil [01] <*6, 10, 12, 13, 17* and *18*>. Find <*6*> is clear machine made glass, probably 19th century, 105 fragments in total, clearly from the same item, as well as a small fragment of dark green window glass – probably 18th/early 19th century. Find <*18*> is a small whiteware sherd with repair hole, probably 19th century or later. Finds <*10* and *12*> are both machine cut nails that may be dated to 19th century (ca. 1830-1890). Find number

<*17*> is misshaped by corrosion but could be a decorated coffin nail, from coffin lid for instance, but x-ray is needed for further analysing.

From the grave fill [05] were nine finds registered under seven finds numbers <*19, 21, 22, 30, 31, 32* and *33*>. All those finds are remains of a wood or iron. Find <*30*> is a coffin lid. The coffin is made of plain wood boards, base and lid. Only the lid was lifted because of the situation at site (deep graves and unstable sections) but the lid is raised, trapezoid in form. The coffin is ca. 155 cm long, 42 cm broad at the "head" end and 30 cm at the "foot" end, and is nailed together with iron nails. The coffin boards are well preserved and in a good condition. Other finds are nails and a staple. The nails and staple <*21, 22* and *33*> are misshapen by corrosion but nails <*31*> are machine cut nails that can be dated to 19th century (ca. 1830-1890). Those finds are all part of the coffin.

Find number <*32*> is interesting. It is a wood stick that has been left in the grave after the burial. It was a known procedure (though not common) in Iceland (as well as Norway, Sweden, Russia and N-America), that if a priest was not available to perform the funeral, to bury a staff with the graves with one end resting on the coffin and the other exposed at the top of the grave. When a priest was available, the staff was removed and the consecrated soil put into the hole left by it. This custom was known into the early 20th century in Iceland (Þór Magnússon, 1971). It is possible that the stick was in the grave because of this practice, but had broken when its removal was attempted. The stick itself is coarse and almost triangular in shape, not well worked so that suggest that next suitable stick was used.

Figure 8. Grave in TP3. Wood stick *(32)* is on the coffin lid *(30)*. Facing east.

2.2.4 Test pit 5

In the topsoil [01] a single fragment of machine-made plate glass was found, find number <*7*>. It is dated to 20th century.

2.2.5 Test pit 6

In the topsoil [01] a nail was found, find number <*8*>. The nail is machine cut that may be dated to 19th century (ca. 1830-1890).

2.2.6 Test pit 7

In the topsoil [01] a base of a bottle was retrieved, find number <*9*>. It is of a hand-blown bottle in amber glass, with deep, dome-shaped kick-base and pontil mark. Dated to 18th/19th century.

2.2.7 Test pit 11

The grave containing skeleton EAS-001 was excavated in this area. In total thirteen finds were registered under eleven finds numbers. From the topsoil [01] are three finds <*11*, *14* and *16*>. Find <*11*> is a small cu-alloy sheet, folded. Find <*14*> is a hand of porcelain doll, probably from 19th century (see figure 9) and find <*16*> is a small

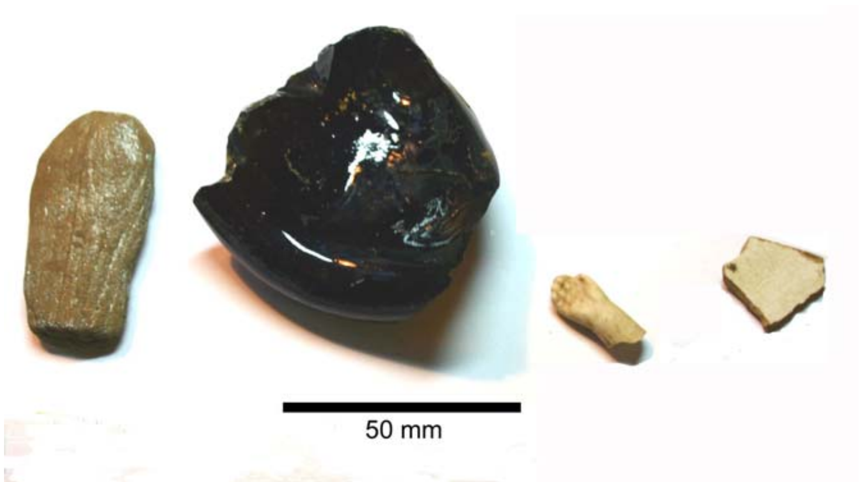

Figure 9. From left: Whetstone (*4*), bottle (*9*), doll hand (*14*) and ceramic fragment (*18*).

whiteware sherd, dated to 19th century or later.

From grave fill, [08] are ten finds registered under eight finds numbers <*20, 23, 24, 25, 26, 27, 28* and *29*>. Finds <*26, 27* and *28*> are coffin nails, all machine cut that can be dated to 19th century (ca. 1830-1890). The body was covered in cloth, find <*25*> a tabby weaved (einskefta) material. The material was decayed and very bioturbated. Find <*24*> is a coffin lid. The coffin is made of plain wood boards, base and lid. Only the lid was lifted because of the situation at site (see above). The lid is raised, trapezoid in form. The coffin is ca. 170 cm long, 42 cm broad at the "head" end and 22 cm at the "foot" end, and is nailed together with iron nails. The preservation of this coffin is poorer than in the grave in TP3.

The finds from Eystri Ásar seem to include chiefly 19th century artefacts along with few finds that could be earlier (18th century). They chiefly represent church/graveyard activities, but also more secular activities.

2.3 Discussion

Two skeletons were excavated in the Eystri Ásar cemetery. The tephra found *in situ* on site indicated a date for both the excavated burials between 1755-1918. Analysis of the finds from the grave fill, however, indicates that both burials is from the latter part of that period (c.1830-1890) and therefore post-dating the Laki eruption by at least 50 years.

3 Búland – SF-179 (BUL)

The cemetery at Búland stands in the middle of the homefield, immediately southeast of the byre which stands east of the farmhouse. The cemetery is orientated east-west, 10x20m remain of its size. The cemetery was abandoned in 1898 and fenced off in 1950 with a wooden gate with concrete post facing west, and four concrete corner posts joined by a wire fence. The cemetery was clearly at some stage larger than the area which is fenced off today. The cemetery boundary is marked by a dirt track to the north and east, by a gully leading away from the byre on the west, and a high drop off on the south. The fenced off area has at some stage been levelled, so no trace of a structure or burials can be seen within the cemetery today. A large stone has been placed at its centre to mark the supposed location of the church, and trees have been planted along the northern and southern fence lines.

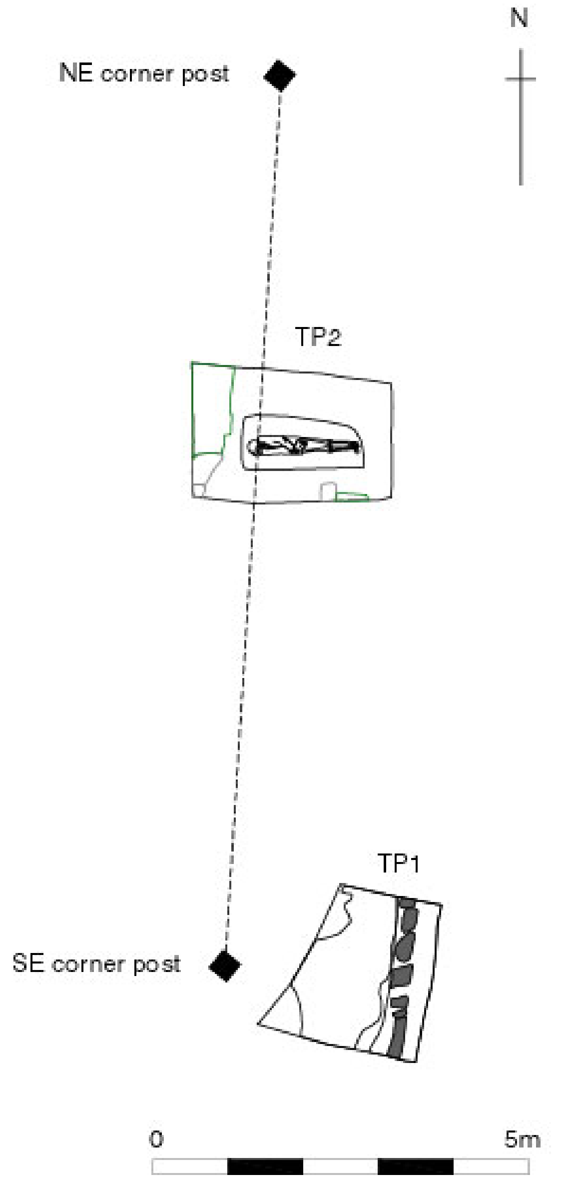

Figure 10. Location of the excavation at Búland

3.1 Excavation

The fence marking the eastern edge of the cemetery stands on a bank c.0.7m high, although tapering towards the north-eastern corner post. A 9m long section could be cleaned from the southeast corner post. Within this section were several grave cuts, indicating that at some stage the cemetery extended further east than the fenced off area. Also within this section were 3 *in situ* tephra layers, from the 1845 eruption in Hekla, the 1783 eruption in Laki and probably the 1625 eruption in Katla. Two areas were excavated at Búland.

3.1.1 Test pit 1

Located immediately northeast of the south-eastern corner post of the cemetery. It was orientated northeast – southwest and measured 1.9x2.2m. The entire area was sealed by an overburden of silt containing small pebbles [01] which lay against the section cleaned along the eastern edge of the cemetery. This in turn sealed a stone wall [02] which ran north – south along the eastern edge of the area, constructed of stones c. 20x30cm, with the flat edge facing east. This sealed a homogenous silty soil [03] in the eastern end of the area, which in turn sealed a reddish brown silty soil [04]. None of these units were removed. A grave seen in the section which truncated the L-1783 and sealed by the H-1845 was intended to be excavated. It was however clear once the turf within the cemetery was removed that the southeast corner post of the cemetery sat in the western end of this grave and so further excavation of TP1 was abandoned.

3.1.2 Test pit 2

Further cleaning of the eastern section of the cemetery revealed a second grave cut truncating the L-1783 and sealed by the H-1845, 5.1m north of aTP1. A second test pit, 2 was opened in this location the western edge extending underneath the line of the fence of the cemetery. The area was orientated east – west and measured 1.7x2.7m, of which 1.4m were west of the section, sealed by the grass surface of the cemetery and 1.3 in the east of the section, sealed by the overburden [01] adjacent to the track which marks the eastern limit of the cemetery. Underneath the grass root in the western end of the excavation area was a silty soil sealed by a fine black tephra layer (H-1845) [06]. This in turn sealed a mottled sandy grave fill [07] filling grave cut [08], which was orientated east – west, 0.7x1.6m with vertical – undercut sides. The grave cut was not fully excavated, but its maximum depth was 1.6m (down to the coffin base). At the base of the grave cut was a badly preserved wooden coffin [09], covered in a white fungus identified as *basidiomycete* which would have fed on the cellulose in the wood. The presence of the fungus indicates that there was enough moisture and oxygen in the grave to allow it to flourish (Guðríður Gyða Eyjólfsdóttir, pres comm.). The coffin was not lifted. Within the coffin was a supine skeleton (BUL-001) with the hands crossed on the pelvis. Although the preservation of the bone was very good, the preservation of other organic material was excellent, hair was still present on the head and the skeleton was dressed in a knitted sweater with a blanket placed over the lower half of the body.

Figure 11. Skeleton BUL-001 (the white is the *basidiomycete* fungus)

3.2 The finds

In total 16 finds under 14 finds numbers were retrieved from the excavation. Of those one find <*13*>, is unworked animal bone (fish vertebra). All finds were cleaned, repacked and registered in the excavation database. Conservation work was carried out by the National Museum.

The finds were found in three areas, test pit 1, test pit 2 and by SE-corner post of the graveyard. Preservation at the site is excellent for both organic and inorganic materials.

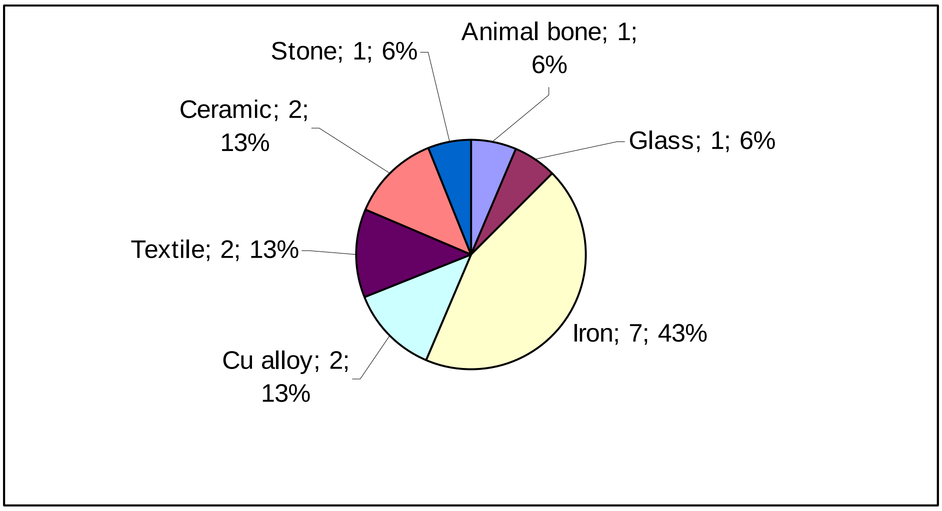

Figure 12. Material at Búalnd. Divided by count and percentage..

3.2.1 Iron

Nails: Nails of various types create the largest finds group, in total 6 pieces – probably mainly whole coffin nails. The preservation of the nails is varied, some are broken, but of those that can be diagnosed can be dated to late 18th and 19th century, both wrought and machine cut nails. A surface find, dense T-shaped nail <*1*> is probably a decoration from a coffin.

Knife: In the topsoil [05] in TP2 a small knife <*8*> was found. The tang is broken but the blade is whole, total length is 45 mm.

3.2.2 Cu-alloy

Nail: Find <*3*> is a small bronze nail with flat hammered end but the other broken, probably decoration.

Pendant/mount: In context [04]: a turf debris layer, was a pendant (or a mount from a coffin?), find <*4*>. It is a round decorated object, 44 mm in diameter. It is formed by two similar pieces which are fastened together through eight holes at its edges. Seven of the holes are small and between some of them is a textile cord and at the top is the largest hole. At one side the object is decorated with band pattern (similar to tabby weave (einskeftuvefnaður) but more elaborate). The other side is decorated with plant motifs and is solid except for one hole – in which the remains of a textile cloth inside the object are visible. Similar object was found in the church at Reykholt in Borgarfjörður, W-Iceland (find no. RKH04_364) (Guðrún Sveinbjarnardóttir & Oscar Aldred, 2005). These could be religious objects, possibly relic of some sort, and need further attention and research.

Figure 13. Artefact *(4)*. Back and front view.

3.2.3 Stone

Whetstone: One whetstone <*2*> was found in context [01]: disturbed overburden layer. It is tapering at one end but broken at the other. It is made from a coarse, micaeous stone.

3.2.4 Textile

Cloth: In the grave fill [05] TP2, woollen cloths in an excellent condition were retrieved. The burial was dater to between 1783 and 1845, and the woman buried there had been laid to rest in a sweater on the upper body and the lower body was covered by blanket <*10*>. The upper part garment (the sweater) has a clear design and is probably based on specific pattern. The back and the front are made from one piece of tabby weaved (einskefta) cloth. The total length of the cloth is c.1200 mm but when folded the back and front piece are c. 600 mm long. The neckline is cut trough the material and the neck opening is terminated at the front by a c. 250 mm long slit and a band was used to tie it together. The sleeves and the collar are knitted (stocking stitch – sléttprjón) and attached to the garment by sewing. The sleeves are c. 420 mm long and 130 mm broad. The

Figure 13. Garment *(10).* Front view.

Figure 15 Garment *(10).* Collar, back and front view.

garment has been repaired and patched considerably both by woven and knitted patches. The wear is seen especially in armpits, shoulders, chest and in the crook of the elbow.[1]

[1] Analysed by Margrét Gísladóttir at the National Museum of Iceland and author.

3.2.5 Pottery and glass

Gavin Lucas

No. <5> Is a fragment of clear glass from a blown-in-the-mould polygonal medicine bottle; probably 19th century, but could be earlier.

No. <6>. Pottery sherd – probably of early tin-glazed earthenware (majolica), painted blue, possibly from an albarello. 15th-17th century.

No. <12>. Two conjoining pottery sherds - greenish-yellow glazed white earthenware, from an open form – dish or bowl. 17th/18th century.

3.3 Discussion

The singe skeleton excavated in the cemetery at Búland could be dated through tephrachronology to between 1784 (the Laki eruption) and 1845, a period of only 60 years. It is therefore highly likely that the female from Búland would have been affected by the Laki eruption.

4 The skeletal material

4.1 Methodology

The preservation of each skeleton was graded, from 1 (excellent)-5 (bad), depending not only on the amount of material present, but also its viability for palaeopathological study.

The sexing of the skeleton was based, where preservation allowed, on sexually diagnostic characteristics of the cranium and pelvis (see for example Buikstra & Ubelaker, 1994; Schwartz, 1995 and Walrath *et al., 2004*) and measurements of the width of several articular surfaces compared to standards presented by Bass (1995) and Brothwell (1981).

Age at death of adult skeletons was determined using as many of the following methods as preservation of each skeleton allowed. The Suchey-Brooks system for age determination from the os pubis (Brooks & Suchey, 1990); the auricular surface ageing method devised by Lovejoy *et al.* (1985) and ectocranial suture closure (Meindl & Lovejoy, 1985 and Nawrocki, 1997).

The calculations of the living stature of adult skeletons were based on measurements of complete long bones compared to standards devised by Trotter (Trotter 1970).

4.2 Results

As only three skeletons were recovered, it was not possible to carry out any statistical analysis of the results, so these will be presented as a summary of each skeleton.

4.2.1 EAS-001

- **Preservation:** Excellent, slight flaking or fragmentation in a few instances. **1**.
- **Sex:** All analysis indicates that the individual was **female**.
- **Age:** Suture closure and changes to the auricular surface indicate that age at death was **35-45 years**.
- **Stature:** Measurements could be taken of most of the long bones, giving a stature of **157±2cm.**
- **Dentition:**[2]

2	2	2	AM	AM	PM	P	PM	PM	P	P	1	1	2	2	2
NE	2	2	1	1	PM	PM	PM	P	PM	PM	2	2	2	PM	NE

- **Palaeopathology:**
    - **Trauma:** There is a small circular hole in the centre of the proximal articular surface of one unsided proximal lower phalange. The hole is 0.2mm in diameter and has rounded edges. This possibly represents osteochondritis dissecans, which is caused by the death of bone tissue within a joint due to a significant obliteration of the blood supply to the bone because of some traumatic event. The necrotic fragment is then loose within the joint, resorbed or can heal back (Roberts and Manchester,

[2] Grade denotes calculus (1 = flecks, 2 = medium, 3 = severe); P = present; AM = Ante mortem tooth loss; PM = post mortem tooth loss; NE = Not erupted.

1995), although that diagnosis is not certain due to the small size of the lesion.

- **Joint disease – Spinal:** There is osteophyte formation on the bodies of C6, C7 and T11, and the costal facets of T12. These are age associated degenerative changes and are in no instance severe enough to allow diagnosis of osteoarthritis. In addition there are Schmorl's nodes on the inferior body of T5-L1 and the superior body of L2-L3. Schmorl's nodes are changes on the vertebral body surfaces, usually affecting the thoracic and lumbar vertebrae, associated with the degeneration of the intervertebral disks. Their specific aetiology is uncertain, but trauma is frequently implicated (Roberts & Manchester, 1995). Detailed descriptions of the spinal joint changes are given below

Bone	**Change**	**Loacation**	**Side**	**Grade**
C6	Osteophytes	Both quadrants – Inferior body	Right	2
C7	Osteophytes	Both quadrants – Superior body	Right	2
T5	Schmorl's nodes	Both quadrants – Inferior body	Right	2
T6	Schmorl's nodes	Both quadrants – Inferior body	Right	2
T7	Schmorl's nodes	Both quadrants – Inferior body	Right	2
T8	Schmorl's nodes	Both quadrants – Inferior body	Left	2
T9	Schmorl's nodes	Both quadrants – Inferior body	Left	2
T10	Schmorl's nodes	Both quadrants – Inferior body	Left	1
T11	Schmorl's nodes	Both quadrants – Inferior body	Left	1
T11	Osteophytes	Both quadrants – Inferior body	Left	2
T12	Schmorl's nodes	Posterior quadrant – Inferior body	Left	2
T12	Osteophytes	Costal facets	Both	1
L1	Schmorl's nodes	Inferior body	?	1
L2	Schmorl's nodes	Superior body	?	1
L3	Schmorl's nodes	Central superior body	n/a	1

- **Occupational stress:** There are sesamoid bones in both the hands (one, 6.2mm in diameter) and the feet (five, maximum 11.1mm in diameter). Sesamoid bones are formed within tendons and assist in mechanical action and pressure. These can form within the tendons in the hand and feet when they are under excessive strain (Roberts & Manchester, 1995).

- **Neoplasm:** There is a possible neoplasm in the right nasal aperture. There is a bulbous new bone formation, quite cyst like, formed from very thin bone, which appears to be hollow. The new bone is 8.8mm in diameter and fills almost the entire right hand side of the nasal aperture. Further analysis is required here, possibly with the aid of radiographs.

Figure 16. EAS-001, nasal neoplasm

- **Dental disease:** There is a slight increase in porosity of the alveolar bone on the mandible, from the right 1st premolar to the left 2nd incisor, indicative of periodontal disease. This is a disease process which starts with the inflammation of the soft tissues, gingivitis, commonly due to calculus formation, which can eventually transmit to the bone, resulting in resorption of the alveolar bone, and eventual tooth loss (Roberts & Manchester, 1995).

4.2.2 EAS-002

- **Preservation:** Excellent, all elements represented with very little flaking or fragmenting, **1.**
- **Sex:** All sexually diagnostic characteristics indicate that this is a **female.**

- **Age:** Age could be assessed based on suture closure and age related auricular surface changes, all of which indicate and age of **25-35 years** at the time of death.
- **Stature:** All of the long limb bones could be measured to estimate stature, which was calculated at **148±3cm.**
- **Dentition:**[3]

AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM	AM
NE	1	1	1	1	AM	1	AM	AM	2	1	1	1	1	1	NE

- **Palaeopathology:**
    - **Trauma:** There is a long standing healed oblique fracture on the shaft of the left 5th metacarpal. The fracture has caused no displacement of the bone, but there is slight superior apposition of the distal fragment. In addition there is a small (1.6mm in diameter) hole in the antero-lateral quadrant of the posterior calcaneal articular surface of the right talus. The edges of the depression are well rounded, indicating that if it is a lesion it is healed. This is possibly osteochondritis dissecans, caused by the death of bone tissue within a joint due to a significant obliteration of the blood supply to the bone because of some traumatic event (Roberts and Manchester, 1995), although that diagnosis is not certain due to the small size of the lesion.
    - **Joint disease - Spinal:** There is osteophyte formation on the bodies of T7, T8, L4 & L5 and an increase in porosity on the body of C5 and the transverse process of T1. All these changes are slight and indicate activity or age related degenerative changes. The moderate increase in porosity and osteophyte formation on the transverse processes of T10, and increased porosity and osteophyte formation on two ribs indicates osteoarthritis. For further detail see below.

[3] Grade denotes calculus (1 = flecks, 2 = medium, 3 = severe); AM = Ante mortem tooth loss; NE = Not erupted

Bone	Change	Loacation	Side	Grade
C5	Porosity	Superior body – all quadrants	n/a	1
T1	Porosity	Transverse process	Right	1
T7	Osteophytes	Inferior body – anterior quadrant	Both	1
T8	Osteophytes	Inferior body – anterior quadrant	Both	1
T10	Porosity	Transverse process	Both	2
T10	Osteophytes	Transverse process	Both	2
L4	Osteophytes	Inferior body – posterior quadrant	Right	1
L5	Osteophytes	Superior body – anterior quadrant	Both	1

- **Joint disease – Other:** There are changes indicative of osteoarthritis in the right foot, with slight osteophyte formation and increased porosity on both lateral quadrants of the head of the right talus and the entire posterior articular surface of the navicular, which also has slight eburnation on the supero-lateral quadrant.
- **Occupational stress indicators:** There are four sesamoid bones within the feet, with a maximum diameter of 8.3mm. Sesamoid bones tend to form within the tendons of the hands and feet when they are subject to continued strain (Roberts & Manchester, 1995).
- **Infectious:** The alveolar bone of the maxilla has been entirely resorbed with most of the teeth missing ante mortem. The entire bone is gone, making the area of the alveolus level with the palate. The erosion has opened into the maxillary alveolus above the root of the M1. There is also some erosion of the inferior side of the facial part of the maxillary bones, particularly on the left side. There is also some resorption of the mandible, with several teeth lost ante mortem, and those which are still present have a large part of the root exposed. The right I2 is warped to the right, as the C has been lost ante mortem. The bone of the alveolus is porous, indicating that the resorptive process is active. In addition to the changes to the maxilla, there is striated compact bone on the tibial tuberosity on both tibias, at the attachment site of the muscles which extend the knee. The aetiology of this severe erosion of the alveolar bones

is uncertain. It seems very severe to be caused by periodontal disease alone, and could be the result of some of infective disease, possibly leprosy or syphilis, although there are no changes to the nasal area nor the cranium (*caries sicca*) and the changes are purely resorptive with no evidence of bone regeneration, as would be expected in the case of syphilis (Roberts & Manchester, 1995). Such severe tooth loss could also be ascribed to a deficiency, particularly of vitamin C, or scurvy, however, it is unusual to see only the alveolar bone of the maxilla affected so heavily, with much less severe changes changes to the mandible. As to the changes on the tibia, such bone formation could indicate an infection or excessive muscle strain. However the fact that the new bone formation is isolated to the muscle attachment site, indicates that scurvy might be a cause for these changes, as vitamin C is necessary for normal formation of body tissues, and its deficiency therefore predisposes bleeding under the periosteum especially at sites with repeated strain, like the teeth and muscle attachment sites (Roberts & Manchester, 1995). The isolated and aggressive involvement of the maxilla, sparing the mandible sways the tentative diagnosis of these pathological changes towards an infection, most likely venereal syphilis, although vitamin C deficiency, scurvy, must be mentioned as a differential diagnosis

Figure 17. EAS-002 showing resorption of alveolar bone and dental loss

4.2.3 BUL-001

- **Preservation:** All the elements are represented, although there is some flaking and fragmentation **1.**
- **Sex:** All analysis indicates that this individual is **female.**
- **Age:** Cranial suture closure and morphological changes to the pubis and auricular surface indicate that the age at death was **25-35 years.**
- **Stature:** All of the lower limb long bones could be measured, giving a stature of **150±3cm.**
- **Dentition:**[4]

1	2	2	2	2	1	1	1	AM	1	1	1	1	2	2	2
NE	1	1	1	1	1	1	1	1	1	1	1	1	1	1	NE

- **Palaeopathology:**
  - **Trauma:** There are three instances of osteochondritis dissecans, caused by the death of bone tissue within a joint due to a significant obliteration of the blood supply to the bone because of some traumatic event (Roberts and Manchester, 1995). The first is an elongated depression (6mm long) in the centre of the inferior part of the trochlear notch of the right ulna. The second a circular depression, 15.9mm in diameter on the anterior quadrant of the medial epicondyle of the left femur. The third is a deep (5.5mm) circular depression, 5.6mm in diameter, in the malleolar fossa of the left fibula. This lesion is not actually on the articular surface, and can therefore not as readily be identified as osteochondritis dissecans. The lesions on the femur and fibula have rounded edges, indicating that they had healed at the time of death, while the lesion on the ulna has a sharp edge, indicating that it was active.
  - **Joint disease – Spinal:** There are slight osteophyte formations on T7 and T10, indicative of age or stress related degeneration. For detail see below.

[4] Grade denotes calculus (1 = flecks, 2 = medium, 3 = severe); AM = Ante mortem tooth loss; NE = Not erupted

Bone	Change	Loacation	Side	Grade
T7	Osteophytes	Transverse process	Right	1
T10	Osteophytes	Superior body – anterior quadrant	Right	1
T10	Osteophytes	Inferior body – anterior quadrant	Right	1

- **Occupational stress indicators:** There are four sesamoid bones in the feet, with a maximum diameter of 11.8mm. Sesamoid bones tend to form within the tendons of the hands and feet when they are subject to continued strain (Roberts & Manchester, 1995).

5 Examination of bones and teeth for evidence of fluorosis.

5.1 Methods

Teeth had been examined for evidence of enamel changes of dental fluorosis (permanent teeth show changes if the person had been exposed to excess fluoride intake in the diet between two to 8 years of age when the permanent dentition is forming). Inspection of the complete skeleton was undertaken *in situ* and after its removal, with special emphasis on the gross appearance of long bones and vertebrae for signs of bony changes that might be due to high fluoride intake. A humerus, two vertebrae and one pelvis bone from each of the three skeletons were sent to Addenbrooke's Hospital, Cambridge, UK (Baxter) where they were photographed and X rayed before bone material was sent to G. Boivin in Lyon for histological examination and analysis for fluorine. Control humerus bones from a collection at the National Museum in Reykjavik were also sent. Bone sections from the specimens were prepared in the University Department of Medicine, Cambridge, where they were studied microscopically; in addition, samples of bone were prepared and sent to the Health and Safety Laboratory, Buxton, for ICP-mass spectroscopy analysis for fluoride, as well as a full elemental analysis.

More detailed histological examination of bone sections by Boivin were necessary to show whether the normal lamellar structure had been disorganised, with collagen woven into randomly assorted fibres as seen in fractures or growing bone, and in skeletal fluorosis. In normal bones very little fluoride is found, so Boivin also measured the bone fluoride content in his laboratory. Six different dry bone samples were taken from one iliac crest for each of the three skeletons with each being divided into three fragments: 1) one was embedded in methyl methacrylate for the microradiographic analysis of the degree of bone mineralization and then for elemental analysis using X-ray microanalysis; 2) one was powdered and analyzed using X-ray diffraction to characterise the bone mineral substance and possible interactions of fluoride or other elements with the apatite crystals of bone mineral; 3) one was ashed and powdered for the determination of the bone fluoride content using a specific fluoride electrode. The bone samples were also processed and embedded, sectioned and stained for histological examination. In addition, two bone samples from the same location as above (the ilium) for each of the three skeletons were sent for ICP-mass spectroscopy; samples were washed in ether (4 hours) and formic acid (3 minutes), rinsed three times with water and dried in an oven overnight. Samples were acid digested using nitric acid and hydrogen peroxide in closed vessels in an ultrasonic bath (4 hours).

5.2 Results

Dentition in the three skeletons had not shown evidence of fluorosis. Microscopic examination of the bones in the Department of Medicine, Addenbrooke’s Hospital, did not show the features suggestive of fluorosis. The bones were well preserved with mainly cortical bone evident. Some samples showed areas of cancellous bone, but these structures were not as well preserved. Some areas of periosteal bone showed indications of degradation (presumably caused by the age of the skeleton and the length of time buried). Cortical bone was predominantly lamellar bone. The control bones were long bones and more control bones form the same anatomical site as the study bones were needed. There was considerable intra-variability between different sites of the same bone sample, but the general feature in the study bones was the open nature of the cortex with less well-organised osteonal systems and fewer osteocytes

Radiological examination of the bones was mainly unremarkable, except the state of preservation was very satisfactory. To the naked eye the pelvic bones of two of the three skeletons showed a small degree of thickening and spicule formation, which was probably within normal limits, and they were normal on radiological examination, with one exception, which was the ilium of the Búland skeleton which had multiple growth lines suggesting chronic illness or dietary disturbance during adolescence. Some bones showed translucent areas and linear fissures indicative of post-mortem artefacts. There was no macroscopic evidence of bone fluorosis.

Fluorosis is an osteo-condensation at the tissue and organ level associated with high bone fluoride content - BFC (a BFC of at least 0.5-0.6 % of bone ash). The BFC of the six iliac crest samples from the three skeletons were within normal limits. In a previous series of 67 bone biopsies from patients with skeletal fluorosis Boivin found the BFC was 0.82 % (SD 0.36 %) of bone ash. The results for our samples using two different methods were a mean BFC of 0.164 (SD 0.095) %, and 0.1%. The microradiographs showed a wide range of the degree of mineralization of bone (DMB). This great heterogeneity of DMB suggested that there was active remodelling of bone going on at the time of death and there was no evidence of impairments of calcification (mottled periosteocytic lacunae, linear defects of calcification) as seen in skeletal fluorosis. There was no increased mineralization of bone in any of the samples. The texture of the bone tissues was perfectly laminar and not woven. X-ray diffraction confirmed that the mineral substance of the six samples was always a calcium phosphate crystallised as a hydroxyapatite not different from normal bone, and there were no crystallographic signs of fluorine substitution or the presence of fluorapatite. The additional elemental analysis done at HSL was also within normal limits and showed no increase in bone fluoride.

These studies provided firm evidence for the absence of skeletal fluorosis in any of the bones examined.

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Appendix 1. Unit register – Eystri Ásar

Unit	Trench	Description
01	All	Topsoil
02	TP3	Soil with K1918, probably in situ
03	TP3	Mixed layer, dark brown silt with burnt bone and charcoal
04	TP3	Tephra layer (K1755?) in turf sealing grave in TP3
05	TP3	Grave fill
06	TP11	Soil with K1918, probably in situ.
07	TP11	Turves capping grave in TP11 (containing tephra K1755?)
08	TP11	Grave fill
09	TP3	Grave cut
10	TP11	Grave cut
11	TP3	Coffin containing skeleton EAS-002.
12	TP11	Coffin containing skeleton EAS-001.
13	Section	Upcast, fill of [14].
14	Section	Cut feature
15	Section	Upcast material, sealing H1755
16	Section	Silt, between H1755 - H1660
17	Section	Silt, between H1660 – H1625
18	Section	Silt, sealed by H1625

Appendix 2. Unit register – Búland

Unit	Trench	Description
01	TP1	Heavily disturbed overburden sealing the archaeology
02	TP1	Stone wall – not excavated
03	TP1	Homogenous soil, sealed by stone wall [02] – not excavated
04	TP1	Coarse turf debris, west of stone wall [02] – not excavated
05	TP2	Topsoil
06	TP2	Soil sealed by H1845
07	TP2	Grave fill
08	TP2	Grave cut
09	TP2	Coffin containing skeleton BUL-001
10	Section	Silt sealing L1783
11	Section	Silt sealed by L1783
12	Section	Turf debris with disturbed tephra
13	Section	Silt sealed by K1625(?)

Appendix 3. Finds register – Eystri Ásar

Finds no	Unit no	Area	Type	Material	Weight	Count
1	u/s	SW post	Rivet	Composite	16	1
2	u/s	SW post	Fragment	Wood	1	1
3	u/s	SW post	Fragment	Ceramic	0,5	1
4	u/s	SW post	Whetstone	Stone	22,5	1
5	1	TP2	Bottle	Glass	12	5
6	1	TP3	Window glass	Glass	81	2
7	1	TP5	Window glass	Glass	1	1
8	1	TP6	Nail	Iron	3,5	1
9	9	TP7	Bottle	Glass	67	1
10	1	TP3	Nail	Iron	6	1
11	1	TP11	Fragment	Cu alloy	0,3	1
12	1	TP3	Nail	Iron	1	1
13	1	TP3	Plate	Iron	2,5	1
14	1	TP11	Doll	Ceramic	2	1
15	1	TP2	Object	Glass	0,3	1
16	1	TP11	Fragment	Ceramic	2	1
17	1	TP3	Nail	Iron	6,5	1
18	1	TP3	Fragment	Ceramic	1	1
19	5	TP3	Fragment	Wood	1	1
20	8	TP11	Fire cracked stone	Stone	96	1
21	5	TP3	Nail	Composite	8	1
22	5	TP3	Nail	Composite	11,5	1
23	8	TP11	Object	Iron		2
24	8	TP11	Coffin	Wood		1
25	8	TP11	Shroud	Textile		x
26	8	TP11	Nail	Composite	10,5	1
27	8	TP11	Nail	Composite	5,5	1
28	6	TP11	Nail	Composite	5,5	1
29	8	TP11	Fragment	Iron	2	2
30	5	TP3	Coffin	Wood		1
31	5	TP3	Nail	Iron	13	3
32	5	TP3	Stick	Wood		1
33	5	TP3	Staple	Composite	4	1

Appendix 4. Finds register – Búland

Finds no	Unit no	Area	Type	Material	Weight	Count
1	1	SE-corner	Nail	Iron	6	1
2	1	TP1	Whetstone	Stone	29	1
3	3	TP1	Nail	Cu alloy	1	1
4	4	TP1	Relic?	Cu alloy & twine	15	1
5	5	TP2	Bottle	Glass	1	1
6	5	TP2	Vessel	Ceramic	1	1
7	5	TP2	Nail	Iron	6	1
8	5	TP2	Knife	Iron	3	1
9	6	TP2	Nail	Iron	3	1
10	7	TP2	Cloth	Textile	X	2
11	7	TP2	Nail	Iron	6	1
12	7	TP2	Vessel	Ceramic	7	1
13	7	TP2	Animal bone	Bone	0,5	1
14	4	TP1	Nail	Iron	10	2