Reviewed research article

A late Holocene jökulhlaup, Markarfljót, Iceland: nature and impacts

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Abstract — *Approximately 1200 years ago (c. 1230 ^{14}C yr. BP) a mature birch wood in southern Iceland was devastated by inundation in a catastrophic jökulhlaup flowing westwards from Katla. This flood was the youngest prehistoric flood in a series of Holocene jökulhlaups that covered the Markarfljót-Landeyjar area of southern Iceland. Sedimentological analysis presented here indicates the flood was associated with an eruption of the volcano Katla, similar to historical jökulhlaups along the south coast of Iceland. A new radiocarbon date, tephrochronological studies and observation of the remaining tree stumps combined with interpretation of previously published data shows that the trees were around 60–100 years old when inundated and that much of the lowlands of Landeyjar were probably similarly vegetated at this time. Deposits and scoured bedrock in similar stratigraphic locations upstream may relate to passage of the flow along the main Markarfljót valley from northwest Mýrdalsjökull. From a hazard perspective it is critical to establish that such medium-scale events have occurred in the past and their nature and impact, particularly since they are generally censored from older Holocene sedimentary records by later geomorphic activity.*

INTRODUCTION AND CONTEXT

Jökulhlaup-dominated sandur plains dominate the south coast of Iceland (Maizels and Russell 1992). The impact of these jökulhlaups on areas that have been subjected to repeated historical flooding (e.g. Mýrdalssandur, Skeiðárarsandur in southeast Iceland; Larsen 2000, Russell and Marren 1999) is well understood and hazard plans for such future events in these areas are well developed. Recent activity in the Katla Volcanic System has increased awareness of potential hazards associated with future Katla eruptions (Guðmundsson *et al*. 2005).

Throughout the Holocene, interaction between the volcano Katla and the overlying ice cap of Mýrdalsjökull has triggered many jökulhlaups, to the south and east during historical and late prehistoric time and to the west prior to settlement (Figure 1). Historical records of flood activity to the south and east of the ice cap document varying scales of flood from large-scale events (such as the 1918 flood which reached 300,000 m^3/sec, e.g. Tómasson 1996) to very much smaller floods (such as the Sólheimajökull flood of 1999, Einarsson 2000). No known historical Katla floods have occurred westwards along the major braided river Markarfljót. However, sedimentary records of flood activity in the Markarfljót valley indicate that a series of large, valley-filling floods occurred in prehistoric times (Smith 2004, Larsen *et al*. 2005). This record only includes the largest floods since subsequent jökulhlaups and fluvial activity have removed and buried traces of smaller events which did not wash deposits onto the less eroded valley sides. This limitation of the sedimentological chronology is important when considering flood frequency and scale in hazard assessment. This paper presents key evidence of

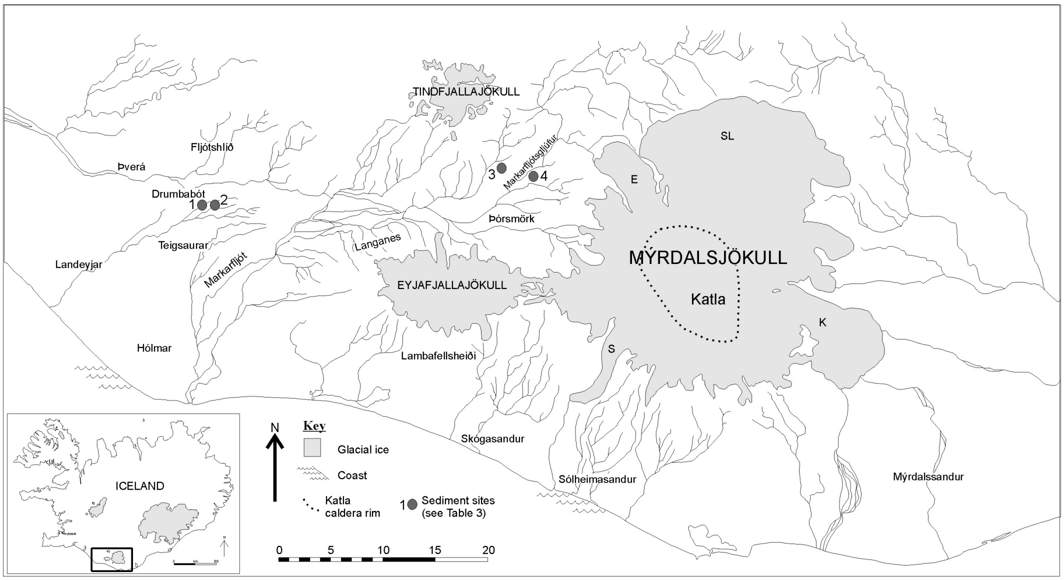

Figure 1. Mýrdalsjökull, the Katla caldera and Eyjafjallajökull. The main outlet glaciers are Kötlujökull (K), Sléttjökull (SL), Sólheimajökull (S) and Entujökull (E). Sediment sites 1-4 (1: Drumbabót; 2: North Aurasel; 3: Einhyrningsflatir; 4: North Þórsmörk) are described in Table 3. Inset: Location map of Iceland. – *Yfirlitskort af rannsóknarsvæðinu. Sýnatökustöðum 1–4 er lýst í Töflu 3.*

the existence and impact of an important, relatively recent, smaller scale Katla flood to the west.

Drumbabót in the Fljótshlíð area in the Markarfljót sandur plain is a key site in the westward-flowing Katla jökulhlaup story, indicating that not only have major floods flowed down this route from sources upvalley, north of the popular wooded area of Þórsmörk, but that a hundred or so years before the Norse settlement of Iceland (*landnám*) a medium to small scale event had a major impact on the landscape. The 'Drumbabót flood' swamped and killed an extensive mature birch wood in the Markarfljót lowlands. This paper describes these buried trees, and presents new data on their age and the sediments in which they are found. We place this in the context of earlier studies in the area and assess the implications for understanding the palaeo-environment and flood record of the Markarfljót valley. We present two new radiocarbon dates (from Smith 2004) and also discuss a number of published dates. Details of these are summarised in Table 1. We have calibrated all the radiocarbon dates that we discuss using OxCal v.3.10 (Bronk Ramsey 1995, 2001, 2005) with atmospheric data from Reimer *et al.* (2004) and present calibrated ages calculated at 95.4% confidence levels.

Past studies in Landeyjar and the Drumbabót trees

Around 1990 large-scale storms in the northern Markarfljót sandur area eroded extensive areas of the unvegetated sand deposits which make up the sandur plain at Drumbabót, an abandoned farm site just south of the rich agricultural area of Fljótshlíð (Figures 1 and 2), exposing mature birch tree trunks which protruded about 0.5 m above the sandur surface and had hitherto been buried. Changes in smaller branches of the Þverá river, also around this time, caused river bank erosion and gave access to the sediment layers in which the trees were rooted. Farmers in the area first discovered these exhumed trees. Markús Runólfsson (of Langagerði) contacted one of the authors,

H. Haraldsson, who first studied the site in 1992 and presented discussions of these findings in Haraldsson (1993).

Eggertsson *et al*. (2004) have carried out dendrochronological work on the Drumbabót trees which indicates that the trees died en masse and that they reached 70–100 years old. They state that the width of the tree rings indicate a similar summer temperature to that recorded in southern Iceland between 1930–1940, the highest temperatures ever registered in Iceland.

Local folklore mentions buried trees at this location (Markús Runólfsson, *pers. comm.* to HH, 1978), which is also supported by the site name (drumbur = tree trunk). Sedimentological studies involving surface analysis and deeper coring experiments were carried out in 1978, prior to the exhumation of the trees, to try to find tree remains. The only organic deposit found at this time was discovered at Teigsaurar, about 3 km east of Drumbabót; a 40 cm thick layer of silty sediments containing remains of plants and birch trees with trunks up to 10 cm in diameter, covered with roughly 3 metres of sand and fine gravel. Haraldsson (1981) radiocarbon dated a sample from the middle of this layer to 1485±65 ^{14}C yr BP (U-2807; calibrates to 1520–1290 cal BP). In many profiles in the coastal plain of Landeyjar where the Markarfljót river and sandur reaches the sea, Haraldsson (1981; 43) found a horizon of fine sand at a similar stratigraphic level in different localities, usually close to the former river channels in the area. Near the farm Hólmar, in south east Landeyjar, peat directly below this sand layer was dated to 1350±65 ^{14}C yr BP (U-4298; calibrates to 1390–1130 cal BP).

a) b) c)

Figure 2. a) Partially exposed birch tree stumps in the eroded flood deposit at Drumbabót. b) Tree trunk found lying horizontally within the deposits and in-situ tree stump exposed in riverbank section. c) In-situ birch tree stump within the flood deposit at Drumbabót. Bark dated to 1230±35 ^{14} C yr BP (AA-48027). – *a) Stubbar af birkitrjám standa að hluta til uppúr flóðaseti sem rofist hefur ofanaf við Drumbabót. b) Trjástofn sem fannst láréttur í setinu og trjástubbur í lífsstöðu í árbakkanum. c) Birkitrjástubbur í lífsstöðu í flóðaseti við Drumbabót. Börkurinn hefur verið aldursgreindur, 1230± 35 C^{14} ár.*

Table 1: Radiocarbon dates used in discussion, including two new dates from Smith (2004). Calibrated dates are calculated at two sigmas (94.5% probability). Dates in brackets are less probable. See Figure 1 for locations of sites. – *Kolefnisaldursgreiningar sem fram koma í greininni, þ.á.m. tvær nýjar frá Smith (2004). Leiðréttur aldur er reiknaður með tveim sigma (94,5% líkindi). Aldur í svigum er ólíklegri. Sjá staðsetningu sýnatöku á 1. mynd.*

Location	**Sample type**	**^{14}C yr BP**	**Cal BP**	**Cal AD**	**Lab Code**	**References**
Teigsaurar	Plant remains from silty sediment layer	1485±65	1520–1290	430–660	U-2807	Haraldsson (1981;36)
Hólmar, Landeyjar	Peat	1350±65	1390–1130 (1110–1090)	560-820 (840–860)	U-4298	Haraldsson (1981;36)
Drumbabót	Buried birch tree bark (AMS)	1230±35	1270–1060	680–890	AA-48027	**New date** from Smith (2004)
SILK YN tephra, Sólheimajökull foreland	Subsamples of a 1cm thick peat layer between SILk YN and overlaying La tephra	1660±12	1575–1525 (1605–1580)	375–425 (345–370)	Weighted mean of 19 dates from GU-7070 to GU-7096	Dugmore et al. (2000)
Layer H tephra, Lambafellsheiði, S. Eyja-fjallajökull	Peat	1540±50	1540–1330	410–620	GU-10383	**New date** from Smith (2004)

RESULTS

Drumbabót trees and flood sedimentology

In the summer of 2000 the authors reinvestigated the Drumbabót site as part of a wider project chronicling the flood history of the Markarfljót valley (Smith 2004).

These trees can still be found extruding through the sandur surface at the site of Drumbabót (around 63°N 42' 43", 019°W 06' 57", Figure 1). Today some of these trees have snapped due to exposure to the elements and now stand between 20 and 60 cm above the sand surface. Others several metres long lie horizontally within and top of the sands. The trees are very well preserved birch trees (*betula penchula*) and their trunks have diameters of up to 25 cm where they are entombed in situ by the sands, most of them leaning slightly to the west or south-west (Figure 2). They show no sign of damage or scouring and are coated in a fine layer of pale silt between their bark and the surrounding sands. Roots up to 5 cm in diameter are found within a grey silt deposit and underlying gravels. This silt layer includes casts of woodland-floor vegetation, some of which are briefly exposed on the surface but are quickly eroded away by the action of the wind. The story behind the demise of these trees is an important puzzle and is the main focus of this paper. They are also important due to their large size compared to present-day Icelandic birch woods, upon which we will briefly touch, and their use as a dendrochronological resource for dating other wood remains in Iceland, as discussed by Eggertsson et al (2004).

Bark from one tree has been dated using AMS radiocarbon dating to 1230±35 ^{14}C yr BP (AA48027, Smith 2004, calibrates to 1270–1060 cal BP). It is considered likely that the sampled tree died some time during the centuries shortly before the eruption of the Landnám tephra, the deposition of which has been dated from correlations to the GRIP Greenland ice core to 871±2 AD (Grönvold *et al.* 1995). The diameter of the tree (∼23 cm) and rough counting of the tree rings indicates that is was 60–80 years old when it died.

Table 2: Electron microprobe analysis of tephra layer 76–2 (see Figure 3 for location of layer). – *Greining á gjóskulagi 76-2 (sjá staðsetningu lags á mynd 3).*

76-2	**SiO_2**	**TiO_2**	**Al_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**Total**
(a)	70.33	0.77	13.67	3.76	0.06	0.52	1.47	4.5	3.34	98.42
(b)	66.51	1.16	14.17	5.64	0.20	1.15	2.95	4.60	2.94	99.31
	66.39	1.25	13.98	5.45	0.09	0.97	2.89	4.44	2.67	98.13
	66.18	1.24	14.05	5.56	0.19	1.11	2.72	4.06	2.72	97.84
	66.12	1.26	14.19	5.89	0.15	1.10	2.76	4.55	3.00	99.02
	66.04	1.31	13.79	5.53	0.15	1.06	2.80	4.48	2.87	98.05
	66.00	1.20	13.69	5.49	0.19	1.04	2.94	4.61	2.78	97.93
	66.00	1.18	14.07	5.75	0.11	1.03	2.76	4.73	2.76	98.39
	65.83	1.28	13.86	5.61	0.16	1.09	2.93	4.52	2.71	97.99
	65.82	1.29	14.05	5.73	0.18	1.10	2.95	4.33	2.57	98.03
	65.65	1.20	13.83	5.43	0.16	1.12	2.83	4.39	2.72	97.33
	65.59	1.21	13.98	5.41	0.10	1.13	2.91	4.39	2.78	97.50
	65.58	1.24	14.05	5.66	0.16	1.06	2.90	4.61	2.81	98.07
mean	*65.98*	*1.23*	*13.98*	*5.60*	*0.15*	*1.08*	*2.86*	*4.47*	*2.78*	*98.13*
s.d.	*0.30*	*0.05*	*0.15*	*0.15*	*0.04*	*0.05*	*0.08*	*0.17*	*0.12*	*0.56*
(c)	47.45	4.50	12.75	15.02	0.18	5.17	10.00	2.24	0.80	98.11
	46.49	4.26	12.70	14.47	0.15	5.05	9.57	3.08	0.79	96.56
	46.39	4.29	12.45	14.20	0.23	5.02	9.74	3.04	0.74	96.08
	46.33	4.36	12.61	14.43	0.23	4.98	9.69	3.08	0.78	96.50
mean	*46.66*	*4.35*	*12.63*	*14.53*	*0.20*	*5.06*	*9.75*	*2.86*	*0.78*	*96.82*
s.d.	*0.53*	*0.11*	*0.13*	*0.35*	*0.04*	*0.08*	*0.18*	*0.41*	*0.02*	*0.89*

Soil and tephra layers stratigraphically below the Drumbabót sand and gravel deposit are exposed within a small hillock at Drumbabót. A pale tephra layer (76-2, Figure 3) within this sequence was analysed using a Cameca Camebax Microbeam electron microprobe using procedures recommended by Larsen *et al*. (1999) and has a geochemical composition very similar to the silicic Katla tephra SILK YN with 67% SiO_2 (Table 2). This tephra layer dips below the Drumbabót bedded deposit indicating that the sand and gravel deposit overlies SILK YN (weighted mean of 19 dates from GU-7070 to GU-7096; 1660±12 ^{14}C yr BP, 1575–1525 cal BP, Dugmore *et al*. 2000).

The deposit which surrounds the Drumbabót trees is a bedded vesicular, black, tephra-rich sand to gravel deposit (Figure 3). The dominant black tephra is basaltic tephra from Katla. Beds rich in gravel (clasts between 0.8 cm and 5 cm) and lithic sands are interbedded with tephra-rich fine to coarse sands. Bedding is predominantly horizontal with some cross-bedding in upper layers. Lenses of fine sand and fine black tephra are found in the base of the deposit. The thickness of this bedded deposit varies but was once somewhat deeper, this overlying material having been eroded in strong winds and by river action (Markús Runólfsson, *pers. comm.*). This means that as well as once being a deeper deposit, the structure and nature

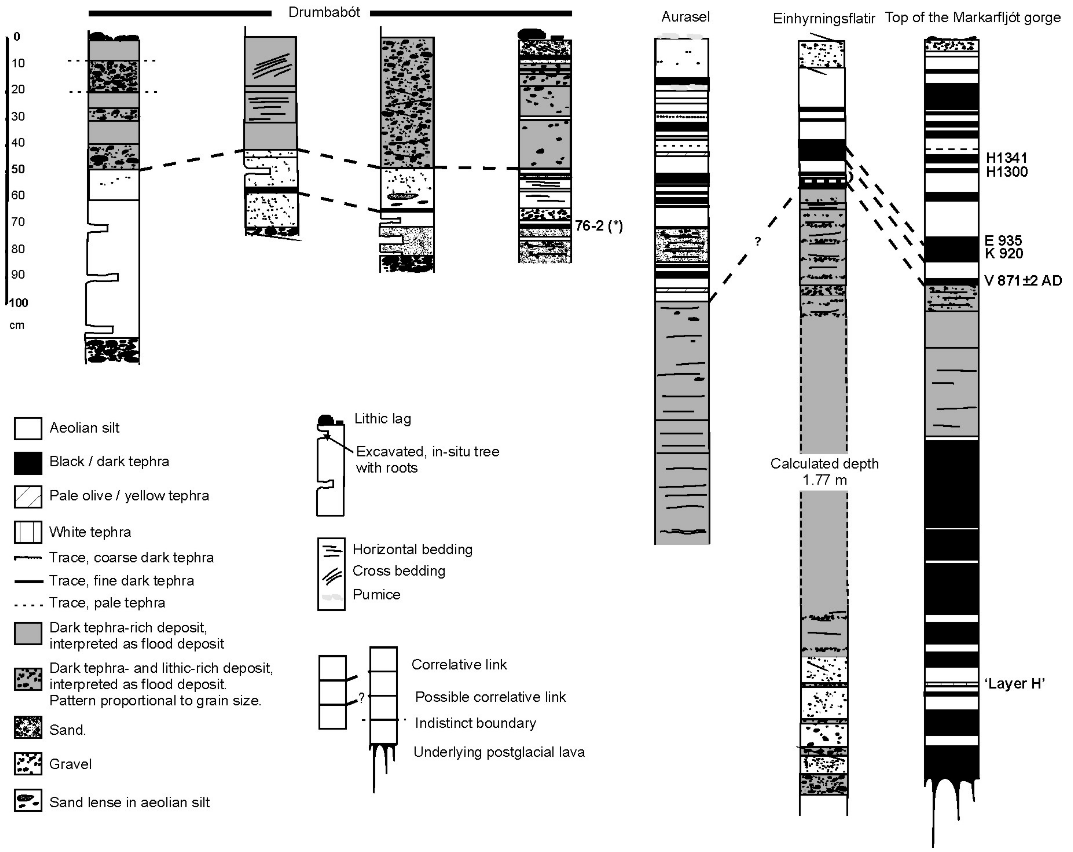

Figure 3. Sedimentary logs illustrating the relationships between the buried trees, surrounding deposits and similar deposits upstream. Tephra layers from historical time have calendar ages and prehistoric dates are stated in ^{14}C years BP (from Þórarinsson 1975, Larsen 1979, Hammer *et al.* 1980, Dugmore 1987, Grönvold *et al.* 1995, Zielinski *et al.* 1995, 1997, Smith 2004). Volcanic systems are: K, Katla; H, Hekla; E, Eldgjá; V, Veiðivötn. Layer H is a tephra layer from Eyjafjallajökull. (*) is location of tephra sample '76-2', see Table 2 (from Smith, 2004). – *Snið setlaga sem sýna tengsl milli trjáleifa, setsins umhverfis þær og sets ofar á Markarfljótsaurum. Gjóskulög frá sögulegum tíma sýna almanaksár og forsögulegur tími er sýndur í C^{14} árum. Eldstöðvakerfi eru: K=Katla, H=Hekla, E=Eldgjá, V=Veiðivötn. Lag H er gjóskulag frá Eyjafjallajökli. (*) sýnir staðsetningu gjóskulagsins "76-2", sjá töflu 2.*

of the uppermost sections of this deposit can no longer be determined. This tephra-rich unit is underlain by pale olive-yellow clay including fine black tephra. Beneath this, the trees, where standing, are rooted in c. 10 cm thick mottled grey-green silt, with underlying clast-supported gravels.

Stratigraphically related deposits

East of Drumbabót, north of the abandoned farm site Aurasel, horizontally bedded granules overlay a coarse tephra-rich sand unit with cross-bedding, ripple laminations and silt drapes. These deposits are deltaic in appearance suggesting deposition into standing water. The increase in grain size up the pro-

Table 3: Sedimentary descriptions (see Figure 1 for locations of sites). – *Lýsingar á setlögum og setgerðum (sjá staðsetningar á mynd 1).*

SEDIMENT SITES (GPS location)	SITE MORPHOLOGY	DESCRIPTION	LITHOFACIES CODES	STRATIGRAPHY
1: DRUMBABÓT 63°N 42' 43"; 019°W 06' 57"	Braided sandur	Bedded coarse black tephra including lithics from fine sand - 0.8 cm clasts, olive brown silt at base, lenses of fine sand, fine black tephra at base. Deposit surrounds mature well-preserved macrofossil trees.	**Sh/Grh**	Below the 'flood' unit: SILK YN[1], exact stratigraphic relationship unclear. Trees have radiocarbon date 1230±35BP
2: North Aurasel 63°N 42' 46"; 020°W 04' 41"	Braided sandur. Riverbank exposure	Horizontally bedded granules overlaying structured fine sands (coarse black tephra and coarse sand lithics) with cross bedding (foresets), ripple laminations and silt drapes. Deltaic structures.	Upper: **Grh** Lower: **Ft (r)**	Above the 'flood' unit: V870 and 4+ black tephra layers. Some may be reworked.
3: Einhyrningsflatir 63°N 43' 46"; 019°W 28' 27"	Rofabard in soil terraces above postglacial lavas	Approximately 2m. Bedded. Occasional layers gravel-rich with clasts up to 0.8–1 cm. Mainly fine to coarse black tephra and lithic sand. Some silt drapes.	**Sh/Gh**	Above the 'flood' unit: V870 and 2 black tephras
4: NORTH ÞÓRSMÖRK 63°N 43' 44"; 019°W 27' 09"	Exposure on the lava surface just above gorge top (305 m)	68 cm thick, 2 units: Upper 14 cm. Bedded coarse black tephra with gravel up to 1 cm. Lower: 34 cm. Crudely bedded coarse black tephra.	Upper: **Gh** Lower: **Sh**	Above the 'flood' unit: V870 Below the 'flood' unit: 5 black tephras and Layer H.

file also represents an increase in flow strength with time. These deposits are found beneath the Landnám tephra (871±42 AD, Grönvold *et al.* 1995) and at least four black tephras.

Fluvial-type deposits (bedded sands, granules, gravels and mud-flow type matrix supported diamicts) have been identified in similar stratigraphic locations in the middle of the valley at Einhyrningsflatir (Figure 3, Table 3) and at the top of the Markarfljót gorge north of Þórsmörk. These deposits are all found beneath the Landnám tephra and/or above Layer H, a prehistoric silicic tephra from Eyjafjallajökull dated to 1540±50 ^{14}C yr BP (Smith 2004, GU-10383, calibrates to 1540-1330 cal BP), although the exact number of black tephras separating them from these key horizons varies.

Upstream deposits at Einhyrningsflatir are approximately 2 metres deep, horizontally bedded black tephra-rich sands with occasional gravel-rich beds with clasts up to 1 cm. This unit is overlain by two black tephra layers and the Landnám tephra layer. A profile just above the top of the Markarfljót gorge, north of Þórsmörk, shows a crudely bedded black tephra-rich deposit with sand-sized lithic grains in the upper layers, just beneath the Landnám tephra and overlying five black airfall tephras and Layer H. There is no evidence of a Katla flood at this time in soil sections in the upper slopes of hills north of Þórsmörk or along Langanes.

DISCUSSION

Trees in the Markarfljót sandur area

These mature buried birch trees at Drumbabót are uncommon in the Markarfljót area and Iceland in general, both in terms of their size in relation to their age and also in the nature of their burial. Comparison of the radiocarbon date for the sampled Drumbabót tree which was probably around 60–80 years old when it was killed (1230±35 ^{14}C yr BP) with Haraldsson's (1981) date for the layer with tree remains at Teigsaurar (1485±65 ^{14}C yr BP) and bearing in mind that gradual vegetational succession means that the underlying surface may have been stable for some 100–200 years before the trees really took hold, suggests that trees were probably growing across the Markarfljót sandur for some centuries prior to burial of the woodland. The biggest tree trunks and the most widespread birch woods in the lower part of the sandur field, Landeyjar, are also of similar age, dating from the mid first millennium AD (Haraldsson 1981). This indicates that burial events of this scale did not happen during this time on decadal or even centurial timescales, but were large-scale, low frequency events.

As yet, no similarly large areas of mature trees have been discovered elsewhere in the valley or other tree remains buried by very thick tephra-rich deposits. Woody fragments and cavities in tephra layers and soils where woody plants once grew are common in low, valley-side prehistoric sediment exposures all along the Markarfljótsaurar margins and in Þórsmörk. Most of these fragments are less than one to five centimetres in diameter but on occasion may reach similar sizes of around 20 cm across. This evidence for woodland extends in most profiles on lower slopes away from the sandur plain right up to the soils directly beneath the Landnám tephra layer. Much work in Iceland indicates that the impact of settlement activities and later climatic deterioration significantly reduced tree cover (as discussed by Dugmore *et al.* 2005), and extensive evidence has been collected for this in the Markarfljót-Eyjafjöll area (e.g. Påhlsson 1981, Buckland *et al.* 1991, Simpson *et al.* 2001). The Drumbabót site is unusual in that mature woodland grew here over a wide area but was extinguished perhaps some centuries prior to the settlement period and that there is no evidence here, or in other riparian zones in Landeyjar, of regrowth of similar woods after the burial event.

Drumbabót flood

The deposits at Drumbabót are most similar to jökulhlaup deposits which make up the sandur surfaces along the south coast of Iceland (e.g. Skógasandur, Sólheimasandur, and Mýrdalssandur; e.g. Jónsson 1982, Maizels 1989, 1991, 1993, Tómasson 1996). Bedding of these sands suggests transport by a water-dominated flow. The lack of discrete bands of lithics or extensive low-flow facies with fine ripples or laminations, combined with the extremely good preservation of the trees suggests rapid emplacement of the sands within one flow event as opposed to normal outwash conditions. Cross bedding and ripple laminations in the deposit at Aurasel suggest low flow water transport perhaps into standing water forming a delta. These two different situations may indicate variation in the type of flow across the area or perhaps represent different time slices during the duration of the event. Perhaps Drumbabót lies closer to the main Þverá flood channel than the deposits north of Aurasel, explaining the difference in thickness of the deposits as well as the different flow regimes represented.

If these deposits at Drumbabót, Aurasel and along the Markarfljót upvalley are indeed the products of a single event they are best explained by a flood originating from close to or perhaps even beneath Mýrdalsjökull passing down the Markarfljót. Haraldsson (1993) interpreted the Drumbabót deposits as the result of a devastating flow caused by a subglacial eruption, a thesis supported by the more recent work presented here. Tephrochronological dating of upstream events places the flood before the deposition of the Landnám tephra (871±2 AD, Grönvold *et al.* 1995) but after the deposition of Layer H (1540±50 ^{14}C yr BP, Smith 2004). No other evidence has been found for this event along the northwest or southern channel margins at Langanes or on the higher slopes north of Þórsmörk giving upper limits to the flow. However, it most probably did overtop the gorge as it entered the wider middle valley flowing across the relatively flat lava surfaces to Einhyrningsflatir, along previously abandoned flood channels and back into the gorge further downstream. As it reached the Markarfljót sandur, at the end of the gorge system by Þórsmörk, the flow was focussed in the centre of the valley, not spreading out to the low slopes along the valley margins at Langanes or the northern Markarfljót banks. This flood became channelled as it reached Fljótshlíð, with tephra-rich flows following the general line of the Þverá, swamping the trees at Drumbabót. It seems likely that over Landeyjar the flow was confined to the main river channels and if any flow extended over the wider areas it was at a lower velocity, mainly water, carrying only finer sediment. Haraldsson (1981; 43) gives a maximum age of 1350±65 ^{14}C yr BP (U-4298, 1390–1130 cal BP) close to river channels in Landeyjar which may have been deposited by overbank flow or wind displacement of fine material from channel deposits. This date compares well with the Drumbabót tree date presented here (1230±35 ^{14}C yr BP, AA-48027, 1270–1060 cal BP, Smith 2004) and suggests that both of these deposits may have been emplaced during the same flood event.

IMPLICATIONS

Consideration of the Drumbabót story presents implications for understanding the environmental impact of medium/small scale flood events and the scale of floods reflected in the Holocene sedimentary record.

This flood at 1230±35 ^{14}C yr BP (Smith 2004) deposited multiple metres of flood sediment within the channel of the Þverá covering much of the sandur area with a thin coating of silt and sand. Woodland was swamped and killed and there is no evidence of reestablishment of similar mature woods. Recovery of vegetation on mudflow and pyroclastic surfaces is related to substrate stability, presence of sufficient organic content and nutrients in the sediment and availability of soil moisture in the period of seedling establishment (Frenzen *et al*. 1986). Although the main tephra-rich sand and gravel deposits would be free-draining and less suitable for colonisation, silt-rich low-flow or windblown deposits outside of the main channels may have been nutrient rich and thus have rapidly become revegetated and stable.

Despite causing a major influx of sediment into the drainage network of the lowlands the Drumbabót c. 1230 ^{14}C yr BP flood did not cause any major channel changes. Major changes in the drainage pattern in the lower part of the region did not occur until 500 years later, around 1200 AD (Haraldsson 1981). Then, probably in a single event, the existing pattern with numerous (at least seven) relatively small courses on the plain was abruptly changed when all courses were combined in a single channel on the eastern part, and peat deposition started in the abandoned courses. The cause of this event is unknown, but may be related to a climate change and increased glaciofluvial activity. So far no sedimentary or historical records have been found for a volcanogenic jökulhlaup at this time.

The majority of the Holocene floods identified in the Markarfljót valley left traces of sediment along the valley margins, filled the approximately 5 km wide valley in the sandur area and filled and overtopped the gorge upstream (Smith 2004, Larsen *et al*. 2005). Gröndal *et al*. (2005) state that such floods had a discharge, if water-dominated, of over around 100–300,000 m^3/sec. Since the Drumbabót flood has mainly been identified based on evidence found in the sandur area and did not seem to extend so far up the valley sides we infer that it was significantly smaller than other floods recorded (less than 100,000 m^3/sec if expressed in the same terms), and has only been recognised because it is a relatively recent event. Such medium and small scale events are not represented in the older Holocene sedimentary records, since their deposits have either been scoured away or buried by subsequent fluvial and flood activity. This lack of evidence however cannot be interpreted as a lack of jökulhlaup activity in the Markarfljót between the biggest Holocene events, meaning that frequencies calculated based on sedimentary records must be understood as minimum estimates only. As can be seen from the Drumbabót story presented here, even smaller scale flood events have overtopped the gorge, washed over the banks of the main river channels on Landeyjar and been catastrophic enough to destroy an entire mature birch wood. Indeed, neither Haraldsson (1981, 40; 1993) nor Påhlsson (1981; 60) found any signs of organic deposits older than around 2000 ^{14}C yr BP from Fljótshlíð down to the coast, which is unusual for presently vegetated areas in Iceland.

This may mean that before that time, the region west of Mýrdalsjökull was relatively frequently overflooded by jökulhlaups depositing sandy and granular sediments, as has been the case with the areas south and east of Mýrdalsjökull in later times (Skógasandur and Mýrdalssandur). Although sedimentary records in the Markarfljót to date do not indicate such high frequency events this may predominantly reflect the low preservation potential of small-scale (Drumbabót-sized) flood sediments and landforms. It is most likely that jökulhlaups of this size flowed westward from the Katla area more often than the terrestrial records found so far can indicate and that these smaller events had a significant impact on shaping the landscape during this time.

CONCLUSIONS

The Drumbabót site in the Fljótshlíð area in the Markarfljót sandur plain is a key site in the story of Markarfljót floods and for understanding issues of flood impact and reconstruction. First studied by Haraldsson during the 1970s–1980s, reconsideration by the authors in 2000 has placed the site in a wider context of Markarfljót floods and relates it to more general issues in palaeoenvironmental reconstruction. This paper presents a new radiocarbon date on a bark sample taken from a tree at Drumbabót south of Fljótshlíð indicating that an extensive mature birch wood was killed at 1230$\pm$35 ^{14}C yr BP, before the deposition of the Landnám tephra and the settlement of Iceland. Evidence from across the sandur area suggests that these trees had been growing across the region for some centuries.

Analysis presented here of the deposits surrounding these trees suggests that they were inundated by a jökulhlaup from Katla travelling down the Markarfljót valley, confirming earlier work by Haraldsson (1993). Importantly the Drumbabót site points out the devastating impact a medium-scale flood event can have on the environment. Holocene records of flood activity predominantly limited to sedimentary evidence at valley margins may underestimate the frequency of such events. Were they to happen today they could present a significant hazard.

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ÁGRIP

Ummerki forsögulegs stórhlaups á Markarfljótsaurum

Fyrir rúmum 1200 árum (1230+35 C^{14} ár) eyddist fullvaxinn birkiskógur sunnan Fljótshlíðar á Suðurlandi af völdum vatnagangs og sandburðar í jökulhlaupi til vesturs frá Kötlu. Þetta hlaup var hið síðasta margra forsögulegra jökulhlaupa sem flætt hafa um Markarfljótsaura og Landeyjar á nútíma. Greiningar á setsýnum benda til að hlaupið hafi tengst gosi í Kötlu, svipuðu jökulhlaupum austar með suðurströndinni sem þekkt eru frá sögulegum tíma. Ný kolefnisaldursgreining, gjóskulagarannsóknir og athuganir á trjástubbum sem eftir standa sýna að birkitrén voru 60–100 ára gömul þegar þau voru færð í kaf. Gróðurfar var sennilega svipað á mestum hluta láglendis í Landeyjum á þessum tíma. Setlög og skúraðar klappir ofar með Markarfljóti, á svipuðum stað í jarðlagaskipaninni, geta tengst þessu hlaupi frá vestanverðum Mýrdalsjökli niður Markarfljótsdal. Með tilliti til áhættu á svæðinu er mikilvægt að hafa staðfestingu á

að slíkir atburðir áttu sér stað í fortíðinni og að gera sér grein fyrir eðli þeirra, áhrifum og umfangi, sérstaklega þar að ummerkin hafa víðast glatast úr eldri setlögum frá nútíma vegna síðari virkni landmótunaraflanna.

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