QN Quaternary Newsletter Report QRA Quaternary Research Association

EARLY MEDIEVAL TEPHRA LAYERS AND THE PROXIMAL IMPACTS OF THE ELDGJÁ FISSURE ERUPTION, ICELAND

Conner Morison, School of GeoSciences, University of Edinburgh conner.morison@ed.ac.uk
Andrew J. Dugmore, School of Geosciences, University of Edinburgh
Antony J. Newton, School of Geosciences, University of Edinburgh
Clive Oppenheimer, Department of Geography, University of Cambridge

Introduction

The 939 AD Eldgjá fissure, a north-eastern extension of Katla Volcanic System, produced the largest Icelandic eruption after Settlement (c. 877 AD). It disgorged ~19.7 km^3 of lava (Sigurðardóttir *et al*. 2015), ~1.3 km^3 of tephra (E939; constituting ash, scoriae and bombs), and emitted ~232 Mt of sulphur dioxide (Thordarson *et al*. 2001), which formed a widespread atmospheric haze, confirmed by contemporary observations (Oppenheimer *et al*. 2018). Whilst lava flows represent most of the erupted volume, tephra formed thick deposits across southern Iceland (Larsen 2000). Despite the eruption's great scale, the impacts on the Icelandic environment and society are hitherto unknown, but likely profound. Detailed stratigraphic analysis, at various sites around Mýrdalsjökull ice cap, will address this by evaluating variations in tephra layer morphology and sediment accumulation.

Background, rationale and approach

After Iceland's Settlement, woodland clearance and pastoral farming enhanced erosion, and surviving soils began to thicken rapidly (Dugmore *et al*. 2000). Tephra deposits were buried rapidly so that even tephra layers from near-contemporary eruptions (e.g. Katla ~920 AD and Eldgjá 939 AD) are separated clearly within the stratigraphy. The resulting 'barcode' provides opportunities to track geomorphological change across landscapes and through time (Dugmore & Newton 2012). At present, aeolian soils are found in the highland margins, but an extensive network of erosion fronts have dissected the landscape and expose the stratigraphy.

Tephra layer morphology, created by depositional processes, selective preservation and reworking (Dugmore *et al*. 2019), provides evidence that can help to establish the impacts of, and responses to, volcanic eruptions. Woodlands and isolated shrubs can stabilise initial fallout from remobilisation by wind and precipitation (Morison & Streeter 2022). In addition to considering site altitude, topography and climate, we infer the former presence of woodlands through trace evidence of trunks and roots in pre-877 AD tephra layers. By contrast, deposits that fell on sparse, short-stature vegetation may have been largely reworked and redistributed.

The prime objective of our 2022 fieldwork was to determine whether settlement continued in areas impacted by the Eldgjá eruption. Fieldwork was conducted in June and August at forty sites in the Rangárþing Eystra and Skaftárhreppur municipalities. Selected farms contain archaeological evidence for early (pre-Eldgjá) occupation, where E939 thicknesses range from <1 cm to >1 m.

We recorded thicknesses of E939 (including its constituent phases; Moreland *et al*. 2019) as well as thicknesses and characteristics of younger (e.g. Hekla 1206 AD) and older (e.g. Veiðivötn 877 AD) tephra layers. Estimation of soil accumulation rates between other Settlement-period tephra layers will shed light on woodland extent and soil erosion before, during and after the Settlement period.

We sampled pre- and post-877 AD tephra layers, and also internal phases of E939. Geochemical analysis (major/minor oxides and trace elements) will be used to confirm our tephrochronology by distinguishing tephra from different volcanoes, and different eruptions of the same volcano (Óladóttir *et al*. 2011).

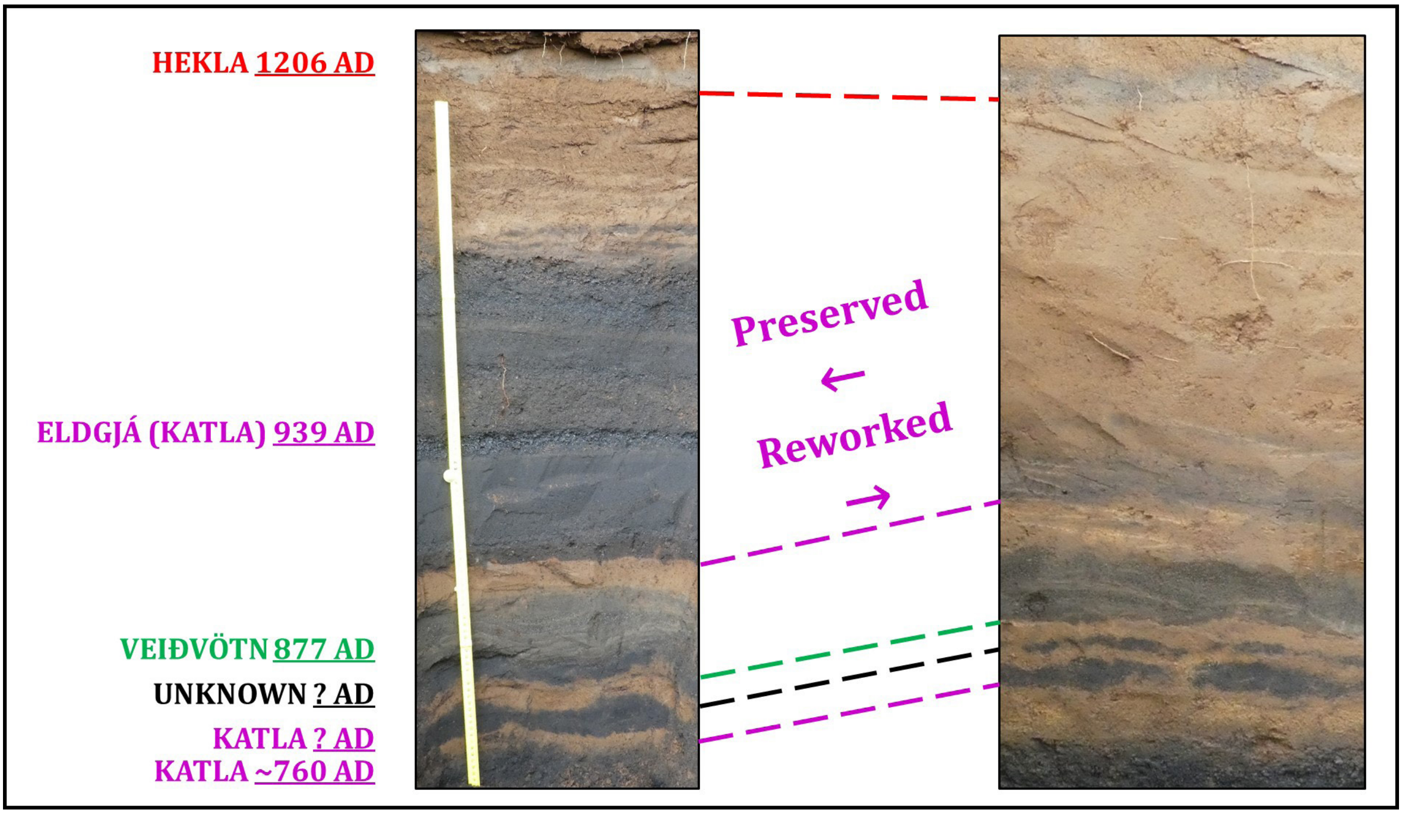

Figure 1. Comparison of two sections, showing the stratigraphy between the suspected Katla ~760 AD (lower contact is below field of view) and Hekla 1206 AD (top) tephra layers. Both sites are in the Skaftártunga area of southern Iceland.

Results and significance

At some sites, preservation of original E939 fallout and internal phases indicates rapid and effective stabilisation of the tephra, indicating the former presence of woodland. At other sites, only vestiges of original tephra fallout remain, its discrete phases having been obliterated by erosion and reworking (Figure 1).

We classify the stratigraphic profiles into three groups. Sites at altitudes greater than ~250 m probably lacked woodlands, even before 877 AD. Some sites had woodlands in 877 AD, but were cleared during the Settlement period to permit farming; thus forming 'occupied' clearings by 939 AD. Other sites had woodlands before 877 AD and after 939 AD.

Trace fossils and disturbance (or absence) of Early Medieval tephra layers imply continuity of human settlement after the Eldgjá eruption. Initial settlers cleared woodlands to establish farms in areas above coastal plains (Dugmore *et al*. 2000), resulting in poor preservation of E939 fallout thicknesses and individual eruptive phases there. Thus, pre-existing local conditions (e.g. short-stature vegetation) would have been ineffective at stabilising fresh deposits from wind erosion. Additionally, farmers may have cleared tephra from fields during the following decades. Lingering snow patches that were buried by fallout would, upon melting, have hindered its preservation further.

The decision not to abandon occupied areas is intriguing because settlement patterns elsewhere in Iceland did adjust during the colonisation period (Vésteinsson *et al*. 2002). Clearance of tephra from field systems may have been easier than creating new fields from surviving birch woodlands, which had stabilised thick tephra deposits. However, archaeological evidence of new structures, built directly on top of E939, suggests that some adaptation did occur in Skaftártunga (Hreiðarsdóttir *et al*. 2013). Woodlands that had survived both the initial 'land-taking' and contemporary eruptions would, if left undisturbed, have continued to stabilise E939. However, if disturbed by later generations in the pursuit of new land, these woodlands could have unleashed great volumes of unconsolidated tephra, perhaps decades to centuries after the eruption.

Acknowledgments

The lead author acknowledges financial fieldwork support from the *New Research Workers' Award*, Quaternary Research Association. This project was also supported by the *Geographical Club Award*, Royal Geographical Society (with IBG), and a grant from the Scottish International Education Trust. The *Geography Centenary Award*, School of GeoSciences (University of Edinburgh) supported airfare costs between the UK and Iceland. Martin Dugmore and the lead researcher's family assisted during fieldwork, whilst Elín Hreiðarsdóttir (Fornleifastofnun Íslands) provided logistical support. Finally, we appreciate the support of landowners at Fljótsdalur, Barkarstaðir, Heiðarsel, Búland, Snæbýli and Flaga.

References

Dugmore, A.J., Newton, A.J. (2012). Isochrons and beyond: maximising the use of tephrochronology in geomorphology. *Jökull* 62, 39-52.

Dugmore, A.J., Newton, A.J., Larsen, G., Cook, G.T. (2000). Tephrochronology, environmental change and the Norse settlement of Iceland. *Environmental Archaeology* 5, 21-34.

Dugmore, A.J., Thompson, P.I.J., Streeter, R.T., Cutler, N.A., Newton, A.J., Kirkbride, M.P. (2019). The interpretative value of transformed tephra sequences. *Journal of Quaternary Science* 35, 23-38.

Hreiðarsdóttir, E.Ó., Hambrecht, G., Streeter, R.T., Dugmore, A.J., Gestsdóttir, H. (2013). *Skaftártunga: Archaeological Investigations in 2013*. Fornleifastofnun Íslands, 75 pp.

Larsen, G. (2000). Holocene eruptions within the Katla volcanic system, south Iceland: characteristics and environmental impact. *Jökull* 49, 1-28.

Moreland, W.M., Thordarson, T., Houghton, B.F., Larsen, G. (2019). Driving mechanisms of subaerial and subglacial explosive episodes during the 10th century Eldgjá fissure eruption, southern Iceland. *Volcanica* 2, 129-150.

Morison, C.A.G., Streeter, R.T. (2022). The influence of vegetation cover on the grain-size distributions and thicknesses of two Icelandic tephra layers. *Volcanica* 5, 227-248.

Óladóttir, B.A., Sigmarsson, O., Larsen, G., Devidal, J-L. (2011). Provenance of basaltic tephra from Vatnajökull subglacial volcanoes, Iceland, as determined by major- and trace-element analyses. *The Holocene* 21, 1037-1048.

Oppenheimer, C., Orchard, A., Stoffel, M., Newfield, T.P., Guillet, S., Corona, C., Sigl, M., Cosmo, N., Büntgen, U. (2018). The Eldgjá eruption: timing, long-range impacts and influence on the Christianisation of Iceland. *Climatic Change* 147, 369-381.

Sigurðardóttir, S.S., Guðmundsson, M.T., Hreinsdóttir, S. (2015). Mapping of the Eldgjá lava flow on Mýrdalssandur with magnetic surveying. *Jökull* 65, 61-71.

Thordarson, T., Miller, D.J., Larsen, G., Self, S., Sigurdsson, H. (2001). New estimates of sulfur degassing and atmospheric mass-loading by the 934 AD Eldgjá eruption, Iceland. *Journal of Volcanology and Geothermal Research* 108, 33-54.

Vésteinsson, O., McGovern, T.H., Keller, C. (2002). Enduring impacts: social and environmental aspects of Viking age settlement in Iceland and Greenland. *Archaeologia Islandica* 2, 98-136.