Title: Geochemical analyses of Icelandic tephra preserved in lake sediments from marine and lacustrine sedimentary archives in the Atlantic sector of the Arctic

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BACKGROUND

These files contain major element geochemical analyses of tephra grains isolated from lake sediment recovered in continuous cores from lakes in Iceland, Svalbard, Arctic Canada, and from marine sediment cores from Greenland and Iceland.

Iceland: Hvítárvatn is a large, proglacial lake adjacent to the eastern margin of Langjökull in central Iceland. The lake is situated 422 m asl, has an area of 28.9 km^2, and a maximum depth of 83 m. Approximately one-third its 820 km^2 watershed is occupied by the ice cap which, through erosion and meltwater transport, governs the sediment flux. Hvítárvatn drains to the southeast and has an average monthly discharge of 45 m^3 s^{-1} with an average suspended sediment load of 35 mg L^{-1}. The outlet stream Hvítá removes roughly half of the sediment delivered to the lake before it settles (Black et al., 2004). Major sediment sources are from two outlet glaciers, Suðurjökull and Norðurjökull, and two meltwater streams that emerge from the glacier farther north. Suðurjökull and Norðurjökull are warm-based outlet glaciers and have catchments of 58 and 61 km^2, respectively. Both outlet glaciers advanced into Hvítárvatn during the Little Ice Age, but have receded from their LIA maxima, which are clearly defined by lateral moraines, trimlines, and multibeam bathymetric data (Geirsdóttir et al., 2008). Suðurjökull receded from the lake ca 60 years ago, whereas Norðurjökull only exited the lake in 2009.

A total of ten sediment cores were recovered from four sites in Hvítárvatn using the DOSECC GLAD-200 core rig (http://www.dosecc.org/). The core locations that were used for establishing the Holocene tephra stratigraphy for Lake Hvítárvatn are given in Larsen et al. (2010; 2012). Offset core pairs (and triplets), drilled from the same sites, ensure continuous sediment recovery, and surface cores were taken at each site to capture the sediment-water interface and undisturbed upper sediments. The recovery of the spliced cores exceeded 95% at each individual coring site

Arctic Canada: Flat Lake (unofficial name) lies within the very gently undulating carbonate terrain of SW Baffin Island, Arctic Canada (64.71682 N; 70.80983 W; 132 m asl; water depth: 5.1 m). It was only deglaciated about 5 ka. Only ~40 cm of postglacial mud was in the basin. Tephra grains were relatively common (2 to 6 shards per cm^3) in the upper 20 cm, but rare (<1 per cm^3) in the more rapidly deposited deeper sediments.

Svalbard: Kongressvatnet is a deep (55 m) meromictic lake with an area of 0.8 km^2 set in carbonate bedrock 120 m asl. The lake was targeted for cryptotephra exploration because of conventional dating problems, and the potential benefit of removing clastic carbonate sediment and organic matter during pretreatment. Kongressvatnet sediment core KL5 (78°01' N 13°57' E) taken in 55 m water depth was selected for a cryptotephra search. The sediment core was sampled continuously in 1-cm^3 increments to 150 cm depth.

Greenland and Iceland Marine Cores Tephra has been isolated and analyzed from marine cores recovered around Greenland and Iceland.

JM96-1215/2-GC was recovered from the Kangerlugssuaq Trough of central East Greenland, middle continental shelf, in deep basin seaward of inner shelf sill. Lat.: 67°2.8' Long.: -30°51.6' Depth (mwd): 668 m

JM96-1213/1-GC was recovered from the Kangerlussuaq Trough of central East Greenland, inner continental shelf, seaward of inner sill. Latitude: 67° 17.30' Longitude: -30° 57.60' Depth (mwd): 557 m

MD99-2322 was recovered from the Kangerlussuaq Trough of central East Greenland. Lat.: 67°8.18' Long.: -30°49.67' Depth (mwd): 714 m

MD99-2323 was recovered from the SW Iceland Slope, Snorri Drift. Lat.: 65°24.93' Long.: -28°19.83' Depth (mwd): 1062 m

MSM 05/03 343300 was recovered at the southwest entrance to Disko Bugt in central West Greenland Lat.: 68°28.311′ Long.: 54°0.118′ Depth (mwd): 518 m

Analytical Procedures (HVT, FLT and marine cores)

Major and minor element compositions in the glass groundmass of individual tephra clasts were determined on polished and carbon coated samples using a Cameca SX100 electron microprobe at the School of Geosciences, University of Edinburgh. The analytical procedures are outlined in Hayward (2012; in press), in which it is demonstrated that the use of small beam diameters in moderately hydrated glasses causes no mobilisation of sodium if appropriately low beam currents (0.5 and/or 2 nA) are used. Concentrations of major elements were determined in energy dispersive spectroscopy (EDS) at accelerating voltage of 15 kV. Counting times for major elements was in 20s on peak and 10s on each background position. Minor elements were measured with counting times of 60s or 40s at 80 nA. Two analytical set-ups were used for the analyses, depending on the size of the areas of glass available. For

the smallest areas, a beam diameter of 3 μm was used and for all other areas, a diameter of 5 μm was used. Sodium was always the first element analysed in order to minimise sodium loss. Internal data reduction was performed using the inbuilt Cameca X-Phi PeakSight software. The instrumental precision and accuracy is ≤1% for each element.

Analytical Procedures (KL5)

Wavelength dispersive X-ray analysis (WDS) was carried out using a Cameca SX-100 electron microprobe at the University of Alberta using methods similar to those of Kuehn et al. (2009), but modified to allow analysis of smaller grains. Analysis conditions included a voltage of 15 KeV, a beam current of 3 nA, and a beam diameter of 5 μm. Preliminary age-depth models based on ^{210}Pb dating and varve counts suggested that the depth with maximum tephra shards might correspond to the age of the Oraefajokull 1362 AD eruption. Consequently, proximal Oraefajokull tephra and secondary standards of known composition were included in the same analytical runs as the unknowns, analyzed under the same instrumental conditions to maximize their direct comparability. Secondary standard values demonstrate a very high degree of consistency between runs. To obtain additional data points on the very small cryptotephra shards, some of the sample mounts were re-polished and re-analyzed. Repolishing removes the near-surface zone of beam damage, which has been depleted in sodium (Nielsen and Sigurdsson, 1981; Humphreys et al., 2006), allowing pristine glass to be analyzed again.

RESULTS

Hvítárvatn tephra database

In total 76 tephra horizons were identified and analysed for their chemical composition in the HVT-cores and the average composition(s) from each horizon is listed in the accompanying data file.

The data are presented in two font types; (1) plain black font, indicating composition of pristine primary tephra and (2) green italics, which designates composition of tephra suspect of being redeposited or reworked. In some instances a horizon contains both categories and indicates co-deposition of primary and secondary tephra. Although we sampled discrete tephra horizons, glacial meltwater always delivers some tephra grains that had been stored in the ice cap for many years.

In some instances individual horizons are typified by distinct compositional range or compositional grouping. In either case, multiple averages are given as a representation of the observed compositional variability. Many Icelandic tephra layers, especially those produced by the Hekla volcano, exhibit a systematic compositional variability (i.e. erupted from a chemically stratified source). Such tephra layers are designated to a single source volcanic system. A number of the tephra horizons are typified by distinct compositional groups that have origin at different source volcanic systems. These either represent tephra from near-simultaneous eruptions at two or more source volcanoes (indicated by plain black font) or horizon of redeposited/reworked tephra (green *italic* font) or a mixture of the two.

Column A indicates source core(s) for the analysed samples and the sample depth within corresponding core section.

Column B gives an arbitrary number assigned to each horizon, counting from top down, indicating its stratigraphic position within the Hvítárvatn lake sediment archive.
Column C designates the number of analysis behind each average. Each analysis corresponds to one tephra grain.
Columns D to N show averaged major and minor element concentrations for the compositional groups identified in each tephra horizons.
Column O reports the averaged sum of the alkali metal (Na_2O+K_2O) concentration in each group.
Column P records the designated rock type name.
Column Q records the designated rock suite.
Column R indicates the source volcanic system for individual compositional groups or tephra layers.

The reported uncertainty is $\pm 1\sigma$.

Marine tephra database
One hundred and fifty-six tephra shards extracted from 10 levels in five different marine cores have been analysed

Flat Lake tephra database
Twelve separate shards were suitable for analyses. The shards were very small 15 to 30 μm, and highly irregular, limiting the number of suitable shards on a polished surface. One shard was analysed twice.

Kongressvatn tephra database
Only 5 shards of suitable dimensions were isolated for analyses, coming from two adjacent depths in the core. Most of these were analysed 3 to 4 times.

RELEVANT PUBLICATIONS

Larsen, D. J., Miller, G.H., Geirsdóttir, Á., and Thordarson, T., 2011. A 3000-year varved record of glacier activity and climate change from the proglacial lake Hvítárvatn, Iceland, *Quaternary Science Reviews*, 20: 2715-2731. doi:10.1016/j.quascirev.2011.05.026.

Larsen, D.J., Miller, G.H., Geirsdóttir, Á, and Ólafsdóttir, S., 2012. Non-linear Holocene climate evolution in the North Atlantic: a high-resolution, multi-proxy record of glacier activity and environmental change from Hvítárvatn, central Iceland. *Quaternary Science Reviews*, in revision

Gudrún Eva Jóhannsdóttir, 2007. Mid Holocene to late glacial tephrochronology in west Iceland as revealed in three lacustrine environments (Gjóskulagatímatal Vesturlands á sí›jöklatíma og fyrri hluta nútíma byggt á rannsóknum á stö›uvatnaseti / Reykjavík, 2007. Unpublished MS thesis University of Iceland 182pp.