Quaternary Geochronology 46 (2018) 59–76

Contents lists available at ScienceDirect

Quaternary Geochronology

journal homepage: www.elsevier.com/locate/quageo

Research paper

Provenance, stratigraphy and chronology of Holocene tephra from Vestfirðir, Iceland

David J. Harning[a,b,*], Thor Thordarson[a], Áslaug Geirsdóttir[a], Kate Zalzal[a,b], Gifford H. Miller[b]

[a] Faculty of Earth Sciences, University of Iceland, Reykjavík, Iceland
[b] INSTAAR and Department of Geological Sciences, University of Colorado Boulder, CO, USA

ARTICLE INFO

Keywords:
Iceland
Holocene
Lake sediment
Tephrochronology
Hekla
10 ka Grímsvötn tephra series

ABSTRACT

Tephrochronology facilitates the interpretation and correlation of terrestrial and marine paleoclimate records in and around Iceland. The Holocene tephra record on the Vestfirðir peninsula has until now been poorly known. Based on detailed analysis of major element chemistry, we present a holistic tephra stratigraphy and chronology (n = 30) generated from four lakes located on northeastern Vestfirðir. Key markers are Tv-3, the 10 ka Grímsvötn tephra series along with the Hekla VF, Katla EG, Hekla T, Hekla 4 (intermediate component) and Hekla 3 (intermediate component), Snæfellsjökull-1, Landnám (basalt and rhyolite), Katla 920, Hekla 1693 and Bárðarbunga 1716 tephra layers. Notably, we also document two early Holocene intermediate tephra from the Hekla volcano, the oldest yet identified. Imperfections in the continuity of tephra records between lakes indicate gaps produced by either variable ash plume trajectories or periodic ice coverage (glacier or seasonal) of the lakes. The northernmost lake, Skorarvatn, archives three tephra layers consistent with the 10 ka Grímsvötn tephra layer series formed by eruptions in the same time frame as the well-known Saksunarvatn tephra from the Faroe Islands. Radiocarbon-dated macrofossils bounding Skorarvatn's upper and basal tephra layers from the 10 ka series indicate that they were produced by at least three large, successive eruptions from Grímsvötn over ~240 years. The composite Vestfirðir tephra stratigraphy and chronology presented here will enable better age control and synchronization between paleoclimate records in the northern North Atlantic.

1. Introduction

Tephrochronology has evolved into a highly valuable tool for the temporal constraint of various Icelandic sedimentary records (i.e. climatology, oceanography and archeology) since the seminal work of Thorarinsson (1944). The deposition of tephra layers is instantaneous on geologic timescales making them valuable stratigraphic isochrons (Haflidison et al., 2000; Larsen and Eiríksson, 2008), and diagnostic geochemical fingerprints of tephra allow the identification of their respective source (e.g. Larsen et al., 1999; Óladóttir et al., 2011a). Other traditional methods for dating sedimentary records, such as radiocarbon, are commonly less reliable in Iceland due to the mobilization of older organic material into lake environments (Sveinbjörnsdóttir et al., 1998; Geirsdóttir et al., 2009). As such, detailed tephrochronologies from numerous marine and terrestrial sedimentary archives in Iceland have demonstrated the efficacy of providing or aiding in secure age control (Eiríksson et al., 2000a; Jóhannsdóttir, 2007; Kristjánsdóttir et al., 2007; Gudmundsdóttir et al., 2012; Larsen et al., 2011, 2012; Geirsdóttir et al., 2013; Blair et al., 2015). The wealth of known age tephra layers in the marine realm also allows direct correlation between marine and lacustrine records (Larsen et al., 2002; Eiríksson et al., 2004; Gudmundsdóttir et al., 2016) and better synchronization between paleoclimate proxy datasets (Ólafsdóttir et al., 2013).

The goal of this paper is to improve the current Icelandic tephra record by constraining the provenance, stratigraphy and chronology of Holocene age tephra from Vestfirðir lake sediment. Various studies have identified key tephra markers from lake and soil sections on Vestfirðir (Hjort et al., 1985; Caseldine et al., 2003; Principato et al., 2006; Thordarson and Höskuldsson, 2008; Langdon et al., 2011; Schomacker et al., 2016; Harning et al., 2016a; b; Brader et al., 2017), yet none have been presented in a holistic stratigraphic framework. We expand upon these previous studies by systematically identifying additional tephra horizons and detailing the Holocene chemistry and chronology of all currently known tephra on Vestfirðir. This record will be available for future application in dating and correlating between sedimentary archives in Iceland and throughout the northern North Atlantic.

* Corresponding author. Faculty of Earth Sciences, University of Iceland, Reykjavík, Iceland.
E-mail address: David.Harning@colorado.edu (D.J. Harning).

https://doi.org/10.1016/j.quageo.2018.03.007
Received 31 October 2017; Received in revised form 19 March 2018; Accepted 21 March 2018
Available online 28 March 2018
1871-1014/

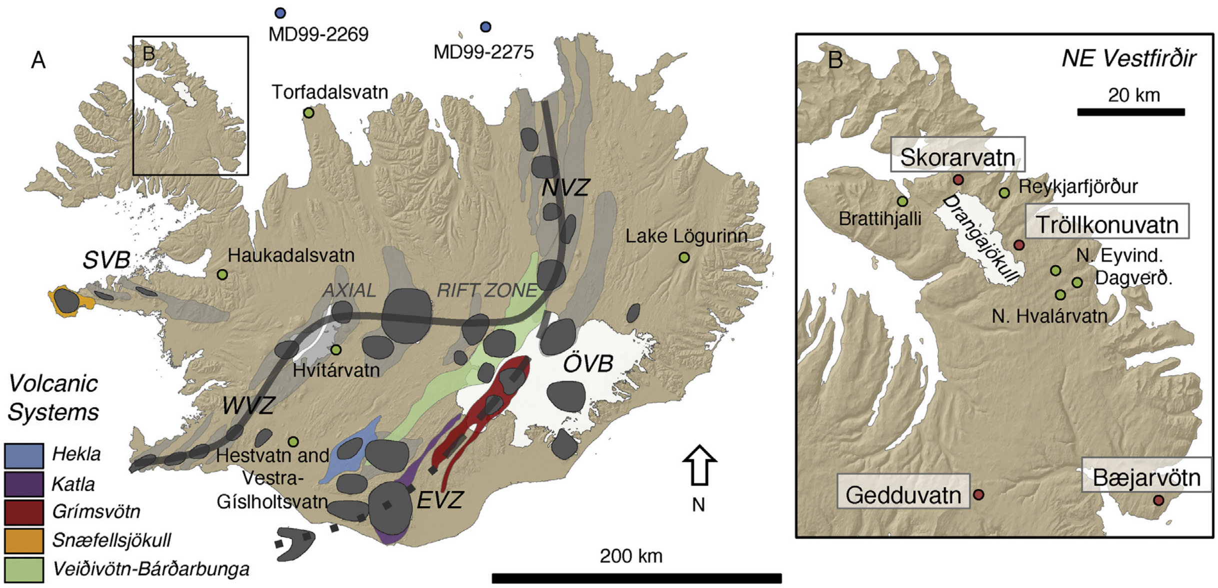

Fig. 1. Location maps. A) Overview of Iceland showing the volcanic systems and central volcanoes (dark gray, Catalogue of Icelandic Volcanoes). Colored volcanic systems reflect those that generated tephra found on Vestfirðir. Solid gray line delineates the axial rift. Dashed gray line marks the tholeiitic portion of the propagating rift, whereas the dotted gray line marks the alkalic/transitional portion of the propagating rift. Also labeled are key lake (green circles) and marine sites (blue circles) mentioned in text. B) Locations of this study's lakes (red circles) and other key lake sites (green circles, Schomacker et al., 2016) on northeastern Vestfirðir. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

2. Regional setting

2.1. Vestfirðir peninsula

Vestfirðir comprises Iceland's northwesternmost extension into the North Atlantic Ocean. The peninsula is the oldest subaerial sector of Iceland dating back to over 15 Ma and lies outside the current active volcanic zones and belts (Fig. 1A, Moorbath et al., 1968; McDougall et al., 1984; Harðarson et al., 1997). Regional bedrock is primarily composed of Neogene basaltic lava successions intercalated with relatively thin sedimentary horizons of mostly aeolian and fluvial origin. Rhyolite outcrops indicate the presence of relic central volcanoes near the local ice cap, Drangajökull (Harðarson et al., 2008). Upland surfaces on the plateau surrounding Drangajökull are characterized by discontinuous andosols and vitrosols, low in organic content and sparsely covered with vegetation (Arnalds, 2004). At lower elevations, low-lying heath vegetation prevails but it is scattered and tends to clump in small tussocks atop soil patches.

The prevailing westerlies in the upper troposphere and lower stratosphere are the main control on ash plume trajectories in Iceland (Lacasse, 2001), which commonly results in net north to eastward dispersal of the plumes produced by explosive eruptions in Iceland. This, in conjunction with the location of volcanic zones and belts in Iceland in relation to Vestfirðir (Fig. 1A), implies that relatively few tephra plumes reach the Vestfirðir peninsula (e.g. Thordarson and Höskuldsson, 2008). Thus, only explosive eruptions that are large and/or take place during spring/summer when the prevailing westerlies shift toward weak easterlies (Lacasse, 2001) have the potential to deposit primary tephra into Vestfirðir's lakes.

2.2. Study lakes

The Vestfirðir peninsula hosts a multitude of over-deepened lake basins remnant from prior glaciations (Principato and Johnson, 2009). The continuous sedimentation in most of these lakes since the last deglaciation has allowed the preservation of organic matter interspersed with discrete Icelandic tephra (Caseldine et al., 2003; Thordarson and Höskuldsson, 2008; Langdon et al., 2011; Schomacker et al., 2016; Harning et al., 2016a, b). Four lakes ranging in elevation from 140 to 470 m asl on northeastern Vestfirðir were selected for this study (Fig. 1B). Bæjarvötn and Gedduvatn are located over 30 km from Drangajökull's extant margin, whereas Tröllkonuvatn and Skorarvatn are located within 3 km of the ice cap. Thus, the distribution of sampled lakes includes vegetated low-elevation coastal locations, sparsely vegetated highlands, and lakes currently influenced by Drangajökull.

3. Methods

3.1. Lake sediment coring and inspection

Bæjarvötn, Gedduvatn, Tröllkonuvatn and Skorarvatn (Fig. 1B) were cored during the winter of 2010 and 2014. Sediment cores were recovered from each lake's deepest basin(s) using a percussion driven piston corer. The presence of deglacial sediment at the base of each core confirms that the entire sedimentary sequence since local deglaciation of proto-Drangajökull was captured from each lake (Fig. 2; Harning et al., 2016b). All cores were subsequently split, sedimentology described, and visually inspected for pristine tephra horizons at the University of Minnesota's LacCore facility (2010 cores) and the University of Iceland (2014 cores).

3.2. Major-elemental analysis of pristine tephra

Tephra layers located by visual inspection in split cores halves (Figs. 2 and 3) are fine to medium ash comprised of glassy tephra grains (> 98% grain population) in addition to a trace of accidental lithics. These layers are clean and do not include any of the surrounding sediments or any other foreign material indicative of reworking (Fig. 3A–C). Hence, each of the tephra layers is pristine (i.e. primary and not reworked) and deposited directly from ash plumes overhead. The fact that the tephra shards feature small and delicate protrusions (Fig. 3D), which would not survive fluvial transport, underpins the above assertion. Each tephra sample was sieved to isolate glass fragments between 63 and 250 μm and then embedded in epoxy plugs, exposing 100s-1000s of grains (depending on the exact grain size distribution of the tephra separates), from which ~20 randomly selected