Reviewed research article

Holocene marine tephrochronology on the Iceland shelf: An overview

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Abstract – *Currently the Late-glacial and Holocene marine tephrochronology on the shelf around Iceland comprises 130 tephra layers from 30 sediment cores ranging in age from 15,000 years cal. BP to AD 1947. A vast majority of the cores and tephra layers are from the North Iceland shelf. Much fewer tephra layers have been found on the South and West Iceland shelf. The early Holocene Saksunarvatn ash and Vedde Ash are the only tephra layers identified on all investigated shelf areas. For the last 15,000 years correlated tephra layers from the shelf sediments around Iceland to their terrestrial counterparts both in Iceland and overseas are 40 of which 26 are terrestrially dated tephra markers. Thirty correlations are within the last 7050 years. The terrestrially dated tephra markers found on the shelf have been used to constrain past environmental variability in the region, as well as marine reservoir age. The marine tephra stratigraphy on the North Iceland shelf has revealed variations in volcanic activity in Iceland further back in time than terrestrial records in Iceland. The numerous tephra layers identified in the sediments on the shelf demonstrate the potential of marine tephrochronology for dating purposes, land-sea correlation, marine reservoir estimations and reconstruction of past volcanic activity of Icelandic volcanoes.*

INTRODUCTION

The application of tephrochronology is twofold; as a tool in volcanology, deciphering volcanic history and as a stratigraphic dating tool, using layers of tephra as time parallel marker horizons. In recent times tephrochronology (*sensu lato*) has been adopted as a general term used broadly to describe all aspects of tephra studies (Lowe, 2011). The term tephra was brought to modern terminology by Sigurður Þórarinsson in 1944 and is a collective term for all airborne pyroclasts produced in volcanic eruptions regardless of size and shape.

Tephrochronology has been a growing field in geology. The reason for the increased interest in tephrochronology is the unique ability of the method to precisely link and date geological, palaeoecological, palaeoclimatic or archaeological sequences or events. Not many methods if any can match the precision it offers temporally and spatially (Lowe, 2011). Tephrochronology has proven to be one of the principal chronological tools for dating Quaternary sequences. This is demonstrated in globally important projects such as INTIMATE (Integrating ice-core, marine and terrestrial global records 60,000 to 8,000 years ago) (Turney *et al.*, 2004; Davies *et al.*, 2012) SMART (Synchronizing marine and ice-core, marine records using tephrochronology) (Abbott *et al.*, 2011; Abbott and Davies, 2012), SUPRAnet, (Studying uncertainty in palaeoenvironmental reconstructing – a net) (Lowe, 2008), HOLSMEER, Millennium (Eiríksson *et al.*, 2011) and VAST (Larsen *et al.*, 2011, 2012) where tephrochronology plays an important role. In addition to serving as a dating tool and fixing points in geological archives, tephrochronology or tephra stratigraphy is a key factor in the study of data on the geochemistry and eruption frequency of volcanoes and the interrelationships between eruption sequences both spatially and temporally (e.g. Thorarinsson, 1967; Larsen *et al.*, 1998; Shane, 2000, 2005; Thordarson and Larsen, 2007; Óladóttir *et al.*, 2008, 2011a).

Dr. Sigurður Þórarinsson was a pioneer in tephra studies and laid the foundation of tephrochronology in the 1930's. His focus was on Holocene tephra layers in terrestrial Iceland. Since the work of Þórarinsson, substantial research on tephrochronology in Iceland as well as in other parts of the world, where tephra layers exist, has been carried out (Lowe, 2011). Considerable knowledge on Holocene tephra stratigraphy and tephrochronology has been gathered from terrestrial archives in Iceland especially in the southern, northern and central parts (e.g. Thorarinsson, 1958,1967, 1976; Larsen, 1984, 2000; Larsen *et al.*, 2001; Óladóttir *et al.*, 2005, 2008, 2011a,b).

With increased research emphasis on climate and climate change the studies of tephrochronology have stretched into the marine realm which has enabled reliable dating and secure land-sea correlations of various climate archives. Knowledge on tephra stratigraphy and tephrochronology in the marine realm, especially in the North Atlantic region, has been continually increasing (e.g. Kvamme *et al.*, 1989; Sejrup *et al.*, 1989; Sjøholm *et al.*, 1991; Lacasse *et al.*, 1998; Eiríksson *et al.*, 2000; Lacasse and Garbe-Schönberg, 2001; Knudsen and Eiríksson, 2002; Andrews *et al.*, 2002; Rasmussen *et al.*, 2003; Wastegård *et al.*, 2005; Kristjánsdóttir *et al.*, 2007; Brendryen *et al.*, 2010, 2011; Thornallay *et al.*, 2011; Gudmundsdóttir *et al.*, 2011a,b, 2012; Davies *et al.*, 2010, 2012).

In this paper we present an overview of the current knowledge on Holocene marine tephrochronology on the Iceland shelf, (Figure 1 and Table 1). Marine tephrochronology in the North-Atlantic extends as far back as 5–6 Ma (Lacasse and Garbe-Schönberg, 2001) but the focus here will be on the last 15,000 years. The shelf around Iceland presents a unique opportunity to study tephrochronology based on explosive eruptions of volcanoes in Iceland. During the Holocene several hundred tephra layers have been recorded in terrestrial environments (e.g. Larsen, 2000, 2010; Óladóttir *et al.*, 2005, 2008, 2011a; Jóhannsdóttir, 2007; Larsen and Eiríksson, 2008a,b; Thordarson and Höskuldsson, 2008) and over 100 tephra layers in marine archives on the shelf (e.g. Andrews *et al.*, 2002; Larsen *et al.*, 2002; Eiríksson *et al.*, 2000, 2002, 2004, 2011; Kristjánsdóttir *et al.*, 2007; Gudmundsdóttir *et al.*, 2012). The number of Icelandic Holocene tephra layers is, however, not completely known but existing terrestrial records give a rate of 6.5 tephra layers per century. The estimated number of postglacial explosive eruptions in Iceland is close to 2000 (Thordarson and Höskuldsson, 2008).

APPLICATION OF MARINE TEPHROCHRONOLOGY

Application of marine tephrochronology is mainly threefold; i) as a tool for dating and correlating different environments, ii) for estimating marine reservoir ages iii) and in volcanology i.e. to gather information on explosive eruption frequency and history of volcanic systems.

Dating and correlation

Tephra studies have become increasingly important in Quaternary research as tephrochronology is one of a few techniques that have the potential to address chronological uncertainties. In the North Atlantic region, Greenland and western Europe, Icelandic tephra layers have played an important role in dating and synchronizing different environments and archives (e.g. Mangerud *et al.*, 1986; Kvamme *et al.*, 1989; Dugmore *et al.*, 1995a; Turney *et al.*, 1997; Wastegård *et al.*, 1998; Davies *et al.*, 2001, 2003; van den Bogaard and Schmincke, 2002; Chambers *et al.*, 2004; Pilcher *et al.*, 2005; Wastegård, 2005; Blockley *et al.*, 2007; Wastegård and Davies 2009; Haflidason *et al.*, 2000; Eiríksson *et al.*, 2000a, 2004; Andrews *et al.*, 2002; Knudsen and Eiríksson 2002; Larsen *et al.*, 2002; Kristjánsdóttir *et al.*, 2007; Davies *et al.*, 2010, 2012; Gudmundsdóttir *et*

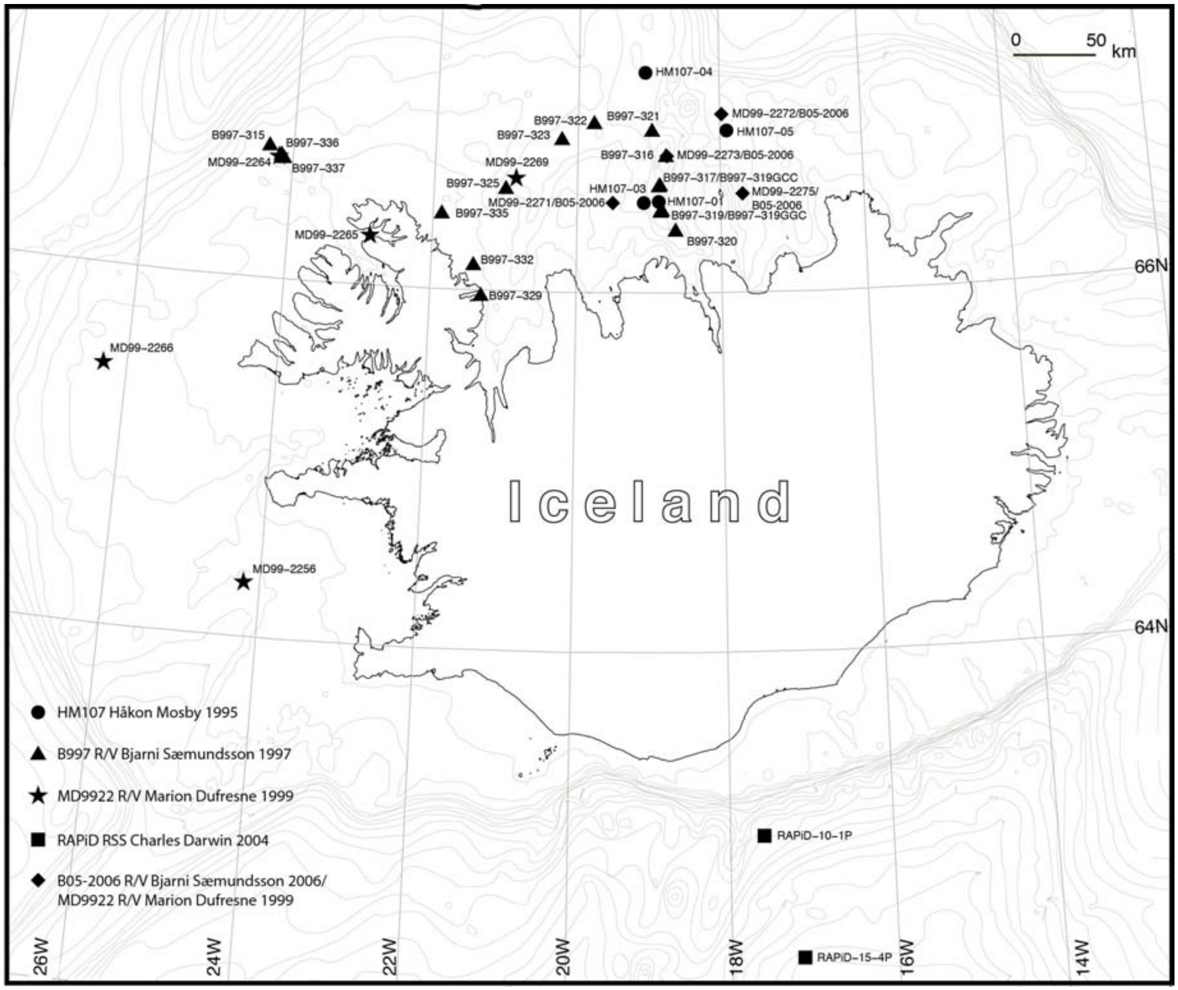

Figure 1. Map showing locations of cores on the Iceland shelf where Holocene tephra layers have been identified. Circles represent cores collected on the R/V Håkon Mosby in 1995, triangles, cores collected on the R/V Bjarni Sæmundssson in 1997, stars, cores from 1999 collected on the R/V Marion Dufresne, squares, RAPiD cores collected on the R/V Charles Darwin in 2004 and diamonds, cores from Bjarni Sæmundsson in 2006 and Marion Dufresne in 1999. – *Staðsetning kjarna á landgrunninu þar sem gjóskulögum frá Hólósen hefur verið lýst. Hringir sýna kjarna sem teknir voru á rannsóknarskipinu Håkon Mosby 1995, þríhyrningar, kjarna á Bjarna Sæmundssyni árið 1997, stjörnur, kjarna frá Marion Dufresne, 1999, ferhyrningar, kjarna frá Charles Darwin, 2004 og tíglar, kjarna frá Bjarna Sæmundssyni, 2006 og Marion Dufresne, 1999.*

al., 2011, 2012). Examples of Icelandic tephra layers that have been used as marker horizons are the basaltic V1477 tephra from Veiðivötn-Bárdarbunga volcanic system, the silicic tephra layers from Hekla volcano (Hekla 1104, Hekla 3, Hekla 4, Hekla 5), the basaltic Saksunarvatn ash from Grímsvötn volcanic system and the bimodal Vedde Ash from Katla volcanic system. All these tephra layers have been found in sediments on the Iceland shelf enabling dating of palaeoclimatic and -oceanographic events

Table 1. Core numbers, locations and references of marine cores on the Iceland shelf where Holocene tephra layers have been described. – *Kjarnanúmer, staðsetning og heimild um sjávarsetkjarna þar sem gjóskulögum, frá Hólósen tíma, hefur verið lýst á landgrunni Íslands.*

Core number	Latitude	Longitude	Reference
North Iceland shelf			
HM107-01	66°30'29"N	18°51'54"W	Eiríksson *et al.*, 2004
HM107-03	66°30'09"N	19°04'20"W	Eiríksson *et al.*, 2004
HM107-04	67°13'38"N	19°03'00"W	Eiríksson *et al.*, 2000
HM107-05	66°54'08"N	17°54'19"W	Eiríksson *et al.*, 2000
MD99-2271	66°30.09'N	19°30.34'W	Eiríksson *et al.*, 2000; Knudsen and Eiríksson, 2002; Søndergaard, 2005; Gudmundsdóttir *et al.*, 2011
MD99-2272	66°59.57'N	17°58.49'W	Eiríksson *et al.*, 2000
MD99-2273	66°45.78'N	18°45.02'W	Eiríksson *et al.*, 2001; Eiríksson *et al.*, 2003, 2011
MD99-2275	66°33.06'N	17°41.59'W	Larsen *et al.*, 2002; Knudsen *et al.*, 2008; Eiríksson *et al.*, 2011; Gudmundsdóttir *et al.*, 2011, 2012
MD99-2269	66°37.53'N	20°51.16'W	Andrews *et al.*, 2002; Kristjánsdóttir *et al.*, 2007
B05-2006-MC03B	66°45.79'N	18°44.98'W	Eiríksson *et al.*, 2011; Knudsen *et al.*, 2011
B05-2006-MC04	66°33.189'N	17°42.02'W	Eiríksson *et al.*, 2011; Knudsen *et al.*, 2011
B05-2006-GBC03B	66°33.189'N	17°42.02'W	Eiríksson *et al.*, 2011
B997-316	66°45.00'N	18°46.87'W	Jónsdóttir, 2001
B997-320	66°20.10'N	18°39.04'W	Jónsdóttir, 2001
B997-322	66°56.29'N	19°46.55'W	Andrews *et al.*, 2002; Andrews and Helgadóttir, 2003
B997-323	66°50.79'N	20°13.64'W	Andrews *et al.*, 2002; Andrews and Helgadóttir, 2003
B997-325	66°34.03'N	20°59.99'W	Andrews *et al.*, 2002
B997-329	65°58.00'N	21°17.91'W	Andrews *et al.*, 2002
B997-332	66°08.19'N	21°25.08'W	Andrews *et al.*, 2002
B997-317	66°35.27'N	18°51.85'W	Andrews *et al.*, 2002
B997-319GGC	66°26.82'N	18°50.24'W	Andrews *et al.*, 2002
B997-321	66°53.47'N	18°58.47'W	Kristjánsdóttir, 1999
B997-319	66°26.82'N	18°51.06'W	Kristjánsdóttir, 1999
West Iceland shelf			
B997-315	66°43.96'N	24°20.13'W	Andrews *et al.*, 2002
B997-335	66°25.00'N	21°52.82'W	Andrews *et al.*, 2002
B997-336	66°41.21'N	24°09.70'W	Andrews *et al.*, 2002; Geirsdóttir *et al.*, 2002
B997-337	66°40.16'N	24°07.63'W	Andrews *et al.*, 2002
B997-339	66°01.16'N	22°48.03'W	Andrews *et al.*, 2002; Geirsdóttir *et al.*, 2002
MD99-2256	64°18.19'N	24°12.40W	Geirsdóttir *et al.*, 2002
MD99-2264	66°40.74N	24°11.76W	Geirsdóttir *et al.*, 2002
MD99-2265	66°16.63N	22°51.47'W	Geirsdóttir *et al.*, 2002; Jóhannsdóttir, 2003
MD99-2266	65°26.65N	26°18.94'W	Andrews *et al.*, 2002
South Iceland shelf			
RAPiD-10-1P	62°58.53'N	17°35.37'W	Thornalley *et al.*, 2011
RAPiD-15-4P	62°17.58'N	17°08.04'W	Thornalley *et al.*, 2011
RAPiD-12-1K	62°05.43'N	17°49.18'W	Thornalley *et al.*, 2011

recorded in sediment proxies, and correlation between the marine and terrestrial regimes (Larsen *et al.*, 2002; Kristjánsdóttir *et al.*, 2007; Gudmundsdóttir *et al.*, 2011a,b, 2012). For example, using palaeoceanographic proxies and tephrochronological age models, Knudsen *et al.* (2009) were able to reconstruct the relative strength of Arctic and Atlantic water masses on the North Iceland shelf throughout the last millennium. Foraminifera and diatom assemblages show increased influence of Atlantic water masses during the time interval ca. AD 800–1300 (the so-called Medieval Warm Period or Medieval Climatic Anomaly), whereas the interval ca. AD 1300–1910 (encompassing the Little Ice Age) was characterized by decreased sea surface temperatures due to intensified influence of Arctic waters of the East Icelandic Current. These climate changes were then compared with records in e.g. Greenland ice cores, documentary records from Iceland, as well as terrestrial evidence of sea-ice, glaciation extent and vegetation changes. The comparison shows that the palaeoceanographic record on the North Iceland shelf reflect regional rather than local climate signals and they demonstrate that it is possible to study leads and lags in the atmosphere-ocean interactions when the marine records can be reliably dated with tephrochronology.

Ocean reservoir age variability

Marine tephra layers have been used to estimate changes in the ocean reservoir age (e.g. Austin *et al.*, 1995; 2011; Haflidason *et al.*, 2000; Eiríksson *et al.*, 2000, 2004, 2011; Jennings *et al.*, 2004; Sejrup *et al.*, 2010, 2011; Thornalley *et al.*, 2011). The marine reservoir age is the difference between a terrestrially dated sample and material dated from the marine environment. This difference is on average about 400 years (Stuiver and Braziunas, 1993). This apparent age difference is caused by delay in exchange rates between atmospheric CO_2 and dilution effect caused by mixing of surface waters with upwelled deep waters (Mangerud, 1975). By correlating terrestrially ^{14}C dated tephra markers to their counterpart in marine environments the reservoir age at that time can be evaluated. On the Iceland shelf tephra layers erupted from Icelandic volcanoes have been used to collect information on changes in reservoir ages of the water masses around Iceland during the Late glacial and the Holocene (Eiríksson *et al.*, 2000, 2004, 2011; Jennings *et al.*, 2002; Thornalley *et al.*, 2011). The discrepancy between reservoir corrected radiocarbon dates of marine material and tephrochronological age models is reflected in deviation of tens to hundreds of years as observed on the North Iceland shelf (Jennings *et al.*, 2002; Eiríksson *et al.*, 2000, 2004, 2011; Kristjánsdóttir, 2005). Determining the reservoir ages of the ocean through the geological record is very important because reservoir age correction needs to be applied to a conventional marine ^{14}C age to correct for growth in a non-atmospheric (i.e. marine) carbon reservoir (Stuiver *et al.*, 1986). As previously noted correction of 400 years is used but recent research has shown that an additional correction is needed for certain time intervals of the geological record. Thus to enable a better comparisons of marine and terrestrial palaeoclimatic proxies knowledge on temporal and spatial variations in the ocean reservoir age is important. Moreover changes in reservoir ages may give information on palaeoceanographic changes through time as demonstrated from studies on the North Iceland shelf were higher reservoir ages are interpreted to represent influence of cold Artic water (East Icelandic current) but lower reservoir ages warmer Atlantic waters (Irminger current) (Eiríksson *et al.*, 2004, 2011).

Eruption history

Tephra layer frequency has been used in Iceland to infer explosive eruption frequency and history of volcanic systems (e.g. Thorarinsson 1967; Larsen *et al.*, 1998; Larsen and Eiríksson 2008a,b, Óladóttir *et al.*, 2008, 2011a). Correlation of Late-glacial and Holocene high-resolution marine tephra stratigraphy from the North Iceland shelf to high-resolution terrestrial tephra stratigraphy in Iceland reveals the same trend in tephra layer frequency in both regimes indicating that the marine tephra stratigraphy can in fact be used to gather information on past explosive volcanic activity in Iceland (Gudmundsdóttir *et al.*, 2012).

IDENTIFICATION, ORIGIN AND INTEGRITY OF MARINE TEPHRA LAYERS

Various methods are used to identify tephra layers in marine environments. The methods that are most commonly used are visual inspection, X-ray photographs, magnetic susceptibility (MS), grain size analyses and counting of glass grains (e.g. Lacasse *et al.*, 1996, Eiríksson *et al.*, 2000; Jennings *et al.*, 2002; Austin *et al.*, 2004; Kristjánsdóttir *et al.*, 2007; Brendryen *et al.*, 2010; Gudmundsdóttir *et al.*, 2011a, 2012; Davies *et al.*, 2012). A majority of the marine tephra layers are not visible to the naked eye and often referred to as cryptotephra (Lowe and Hunt, 2001; Turney *et al.*, 2004). The shelf sediments around Iceland have a dominant volcanogenic origin adding to the complexity of locating and identifying tephra layers. Whole core methods such as MS and X-ray photographs have proven not to be very effective in detecting tephra layers in marine sediments (Kristjánsdóttir *et al.*, 2007; Gudmundsdóttir *et al.*, 2011a) whereas grain counting and grain size analyses have been effective (Gudmundsdóttir *et al.*, 2011a). Origin of Icelandic tephra layers can be traced to individual volcanic systems based on their chemical composition (e.g. Jakobsson, 1979; Larsen, 1981, 1982; Larsen *et al.*, 1999; Óladóttir *et al.*, 2008, 2011b) (Figure 2). Moreover, microprobe analyses have proven to be very useful to distinguish between a primary tephra layer and reworked tephra in the marine sediments. A primary tephra layer manifests itself by a dominant glass composition whereas reworked tephra consists of grains of variable chemical composition (Gudmundsdóttir *et al.*, 2011a, 2012).

The distinction between a primary tephra layer and reworked tephra is the prerequisite to be able to use tephra layers as tool for dating and synchronization. Primary tephra layers are formed by transport and fall-out during a volcanic event. Reworking and secondary deposition of tephra in marine environments are caused by processes such as tephra fall-out on sea ice and ice sheets that causes a time lag between eruption and deposition from months to years or centuries to millennia respectively (e.g. Bond

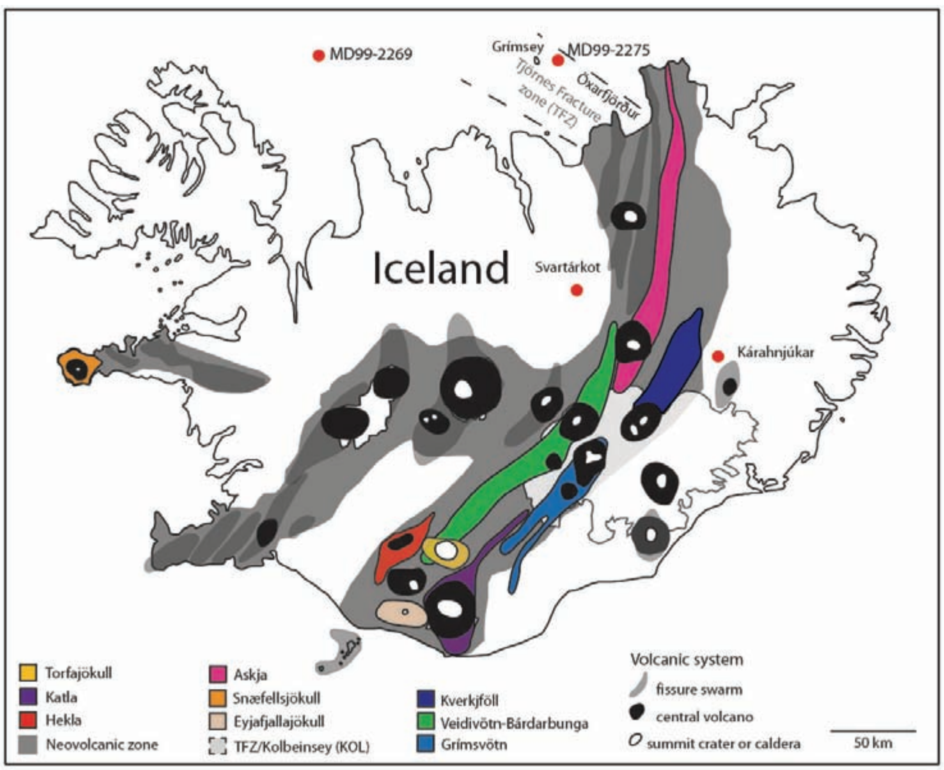

Figure 2. Map showing the volcanic systems of Iceland (modified from Óladóttir *et al.*, 2011; Jóhannesson and Sæmundsson, 1998). The relevant volcanic systems are shown in colors that refer to specific chemical composition of each system. Offshore volcanic systems except Vestmannaeyjar are not shown. Red dots indicate locations of cores MD99-2269 and MD99-2275 and the Svartárkot and Kárahnjúkar soil sections. – *Kort sem sýnir gosbelti og eldstöðvakerfi á Íslandi (breytt frá Óladóttur o.fl., 2011; Jóhannessyni og Sæmundssyni, 1998). Eldstöðvakerfum á landgrunninu er sleppt nema Vestmannaeyjum. Eldstöðvakerfi sem gjóska hefur fundist frá í sjávarseti eru sýnd í litum sem vísa til einkennandi efnasamsetningar gosefna. Rauðir punktar sýna staðsetningu kjarna MD99-2269 and MD99-2275 og jarðvegssniða við Svartárkot og Kárahnjúka.*

et al., 1993; Ruddiman and Glover, 1972; Lackschewitz and Wallrabe-Adams, 1997; Austin *et al.*, 2004; Brendryen *et al.*, 2010). Other processes known to influence tephra deposition in marine environments included reworking by currents, bioturbation and mass movements (Brendryen *et al.*, 2010). Sea ice or iceberg transported tephra may contain ice rafted detritus (IRD) as additional components of grains of different provenance (Lackschewitz and Wallrabe-Adams, 1997) and poorly sorted tephra grain size distribution (Austin *et al.*, 2004). Signs of bioturbation are indistinct boundaries of the tephra layers, especially the lower boundary (Ruddiman and Glover, 1972). Reworking by currents and mass movements are reflected in grain size distribution and most likely grain morphology where remobilized grains display rounded form. Results from morphological measurements on tephra layers in marine sediments from the North Iceland shelf show that fresh glass grains are more rugged and/or elon- gated than the background material. This demon- strates the usefulness of grain morphology measure- ments in determining whether a tephra horizon is a primary deposit or a layer of reworked tephra (Gudmundsdóttir *et al.*, 2011a).

Defining cryptotephras in marine environments, i.e. their boundaries and the isochrone position, is dependent on grain counting or shard concentration and grain size analyses (e.g. Lacasse *et al.*, 1996; Hafliðason *et al.*, 2000; Jennings *et al.*, 2005; Austin *et al.*, 2004; Kristjánsdóttir *et al.*, 2007; Gudmundsdóttir *et al.*, 2011a; Davies *et al.*, 2012). In a volcanogenic environment, where the majority of the inorganic material is volcanic glass as on the Iceland shelf, additional methods such as grain morphology and geochemistry are needed to define the boundaries and isochrone position (Gudmundsdóttir *et al.*, 2011a). Determining the exact stratigraphical position of the time signal the tephra layers provide is a prerequisite for using them as chronostratigraphic horizons or isochrones. In general the peak concentration or first abundance peak is considered to reflect the exact timing of the volcanic eruption (Ruddiman and Glover, 1972; Jennings *et al.*, 2002; Davies *et al.*, 2012). A multi-parameter study of tephra layers from marine sediments on the Iceland shelf suggest that the exact timing is were the rate of change in these parameters, grain concentration, grain size, grain morphology and chemical composition, is greatest from background levels below the tephra (Gudmundsdóttir *et al.*, 2011a). In some cases vertical shard concentration profiles are complicated if there is no distinct peak or there are more than one (e.g. Davies *et al.*, 2007; Pyne-O'Donnell *et al.*, 2008). Therefore, detailed grain counting, grain size, grain morphology and chemical analyses in addition to careful consideration of sedimentation processes are needed when working with marine tephra layers.

TEPHRA LAYERS ON THE ICELAND SHELF

The number of tephra layers identified on the shelf around Iceland so far, is about 130 spanning the Late glacial and Holocene where the oldest tephra layer is about 15,000 cal. BP and the youngest from AD 1947 (Kristjánsdóttir, 1999, 2007; Eiríksson *et al.*, 2000, 2004, 2011; Jónsdóttir, 2001; Andrews *et al.*, 2002, 2003; Geirsdóttir *et al.*, 2002; Søndergaard, 2005; Knudsen *et al.*, 2008, 2011; Thornalley *et al.*, 2011; Gudmundsdóttir *et al.*, 2011a,b, 2012). However it can be expected that sediments on the shelf of Iceland extend back to the Miocene time period (Verhoeven *et al.*, 2012) and thus older tephra layers can be anticipated within the shelf sediments.

Tephra layers in the shelf sediments around Iceland have been identified in 30 marine cores (Figure 1, Tables 1 and 2) obtained in five research cruises; the BIOICE cruise in 1995 (HM107-) with R/V Håkon Mosby (Eiríksson *et al.*, 2000), in 1997 with R/V Bjarni Sæmundsson (B997-) (Helgadóttir, 1997), in 1999 on MD114 IMAGES V cruise (MD9922-) with the R/V Marion Dufresne (Labeyrie, 2003) and in 2004 on RAPiD cruise (RAPiD-) with RSS Charles Darwin (McCave, 2005). The IMAGES cores MD99-2271, -2272, -2273 and -2275 were supplemented with multicores and box cores (B05-2006) during the Millennium cruise with the R/V Bjarni Sæmundsson in 2006 (Eiríksson and Bartels-Jónsdóttir, 2006). Tephra layers have been identified in multicores B05-2006-MC03, at the location of core MD99-2273, and B05-2006-MC04 at core site MD99-2275. The

Table 2. Holocene tephra layers in marine sediments on the Iceland shelf. Bold tephra layers are absolutely dated tephra layers or tephra markers. Shaded tephra layers are tephra layers identified in more than one core on the shelf. – *Gjóskulög í sjávarseti á landgrunni Íslands. Feitletruð gjóskulög eru aldursákvörðuð, svokölluð gjóskuleiðarlög. Skyggðum gjóskulögum hefur verið lýst í fleiri en einum kjarna á landgrunninu.*

Age (cal.) (BP)	Volcanic system	Tephra markers	1-6	7	8-11	12	13	14	15	16	17	18-19	20	21	22	23	24	25	26	27	28	29-30	31	32
3	Hekla	H1947										X										X		
70	Vei-Bár																					X		
70	or R.nes																					X		
75	Vei-Bár																					X		
111	Vei-Bár																					X		
119	Vei-Bár																					X		
119	or REY																					X		
153	Vei-Bár	**V1797**																				**X**		
168	Hekla	**H1766**										**X**												
168	Vei-Bár	**V1766**										**X**												
175	Vei-Bár																					X		
215	Vei-Bár																					X		
233	Vei-Bár	**V1717**										**X**										**X**		
264	Hekla	**H1693**										**X**												
293	Grímsvötn	**G1640**										**X**												
336	Vei-Bár																					X		
373	Grímsvötn	**G1500**										**X**												
380	Grímsvötn	**G1480**										**X**												
392	Hekla	H **1300**										**X**										**X**		
406	Hekla																					X		
439	Vei-Bár																					X		
473	Vei-Bár	**V1477**																				**X**		
539	Vei-Bár																					X		
580	KOL	**KOL1372**					**X**				**X**			**X**			**X**							
650	Vei-Bár	**V1410**																				**X**		
850	Hekla	**H1104**					**X**		**X**	**X**	**X**	**X**		**X**	**X**	**X**		**X**	**X**			**X**		
995	Vei-Bár																					**X**		
1025	Katla																					X		
1075	Vei-Bár+	**Settlem.**																				**X**		
1075	Torfaj.	**layer**																				**X**		
1091	Katla	**K 9th cent.**																				**X**		
1186	Katla	**Hrafnkatla**																				**X**		
1229	Grímsvötn																					X		
1395	Katla						X																	
1405	Hekla																					X		
1447	Vei-Bár																					X		
1698	Grímsvötn																					X		
1714	Grímsvötn																					X		
1815	Snæfellsj.	**Sn-1**					**X**			**X**												**X**		
2337	Katla+																					X		
2337	Vei-Bár																					X		
2436	Vei-Bár																					X		
2450	Katla					X																		
2473	Katla																					X		
2525	Vei-Bár																					X		
2551	Grímsvötn																					X		
2598	Vei-Bár																					X		
2629	Vei-Bár																					X		
3000	Hekla	**Hekla 3**					**X**			**X**	**X**	**X**		**X**	**X**			**X**	**X**	**X**		**X**		

1. **MD99-2256**; 2. **MD99-2266**; 3. B997-315; 4. **MD99-2265**; 5. B997-337; 6. B997-336; 7. **MD99-2264**; 8. B997-330; 9. B997-329; 10. B997-332; 11. B997-325; 12. B997-323; 13. **MD99-2269**; 14. B997-322; 15. HM107-04; 16. **MD99-2271**; 17. HM107-03; 18. **MD99-2273**; *19. B05-2006-MC03; 20. B997-317; 21. HM107-01; 22. B997-319GGC; 23. B997-319; 24. BB97-316; 25. B997-320; 26. B997-321; 27. **MD99-2272**; 28. HM107-05; 29. **MD99-2275**; 30. *B05-2006-MC04; 31. RAPiD-10-1P; 32. **RAPiD-15-4P**. Cores in bold are longer than 10 m and cores with asterisk are multi-cores, spanning approximately the last 150 years. For core locations see Figure 1.

Table 2. Holocene tephra layers in marine sediments on the Iceland shelf cont. – *framhald.*

Age (cal.) (BP)	Volc. syst.	Tephra markers	1-6	7	8-11	12	13	14	15	16	17	18-19	20	21	22	23	24	25	26	27	28	29-30	31	32
3014	Vei-Bár																					X		
3085	Unkn.																					X		
3508	Grímsvötn																					X		
3880	Vei-Bár																					X		
4200	Hekla	**Hekla 4**					**X**			**X**	**X**	**X**										**X**		
4307	Vei-Bár																					X		
4586	Vei-Bár+																					X		
4586	Grímsvötn																					X		
4649	Vei-Bár																					X		
4747	Vei-Bár+																					X		
4747	Grímsvötn																					X		
4870	Grímsvötn						X																	
5220	Vei-Bár+																					X		
5220	Grí																					X		
5264	Grímsvötn																					X		
5284	Vei-Bár+																					X		
5284	Grí																					X		
5352	Vei-Bár+																					X		
5352	Grí																					X		
5416	Grímsvötn																					X		
5713	Vei-Bár																					X		
5762	Vei-Bár																					X		
5811	Vei-Bár																					X		
5824	Grímsvötn						X																	
5831	Grímsvötn																					X		
5850	Vei-Bár																					X		
5948	Grímsvötn																					X		
6026	Grímsvötn																					X		
6060	Hekla+	**Hekla-Ö/**																				**X**		
6060	Grímsvötn	**Grímsvötn**																				**X**		
6175	Grímsvötn																					X		
6208	Grímsvötn																					X		
6378	Grímsvötn																					X		
6411	Katla																					X		
6543	Grímsvötn																					X		
6567	Grímsvötn																					X		
6629	Katla																					X		
6650	Hekla	**Hekla-DH**																				**X**		
6672	Grímsvötn																					X		
6681	Katla+																					X		
6681	Grímsvötn																					X		
6717	Katla																					X		
6747	Katla						X																	
6766	Hekla?																					X		
6783	Grímsvötn																					X		
6792	Katla																					X		
6872	Grímsvötn																					X		
6908	Vei-Bár+																					X		
6908	Grí																					X		
7028	Grímsvötn																					X		
7046	Grímsvötn																					X		
7050	Hekla	**Hekla 5**																				**X**		
7054	Grímsvötn																					X		
7080	Grímsvötn						X																	
7425	Vei-Bár																					X		
7614	Katla																					X		

1. **MD99-2256**; 2. **MD99-2266**; 3. B997-315; 4. **MD99-2265**; 5. B997-337; 6. B997-336; 7. **MD99-2264**; 8. B997-330; 9. B997-329; 10. B997-332; 11. B997-325; 12. B997-323; 13. **MD99-2269**; 14. B997-322; 15. HM107-04; 16. **MD99-2271**; 17. HM107-03; 18. **MD99-2273**; *19. B05-2006-MC03; 20. B997-317; 21. HM107-01; 22. B997-319GGC; 23. B997-319; 24. BB97-316; 25. B997-320; 26. B997-321; 27. **MD99-2272**; 28. HM107-05; 29. **MD99-2275**; 30. *B05-2006-MC04; 31. RAPiD-10-1P; 32. **RAPiD-15-4P**. Cores in bold are longer than 10 m and cores with asterisk are multi-cores, spanning approximately the last 150 years. For core locations see Figure 1.

Table 2. Holocene tephra layers in marine sediments on the Iceland shelf cont. – *framhald.*

Age (cal.) (BP)	Volc. syst.	Tephra markers	1-6	7	8-11	12	13	14	15	16	17	18-19	20	21	22	23	24	25	26	27	28	29-30	31	32
8000	Katla	**Suduroy**					**X**															**X**		
8243	Grímsvötn																					X		
8200	Grímsvötn																							X
8394	Eyjaf.j.																					X		
8400	Katla																							X
8485	Grímsvötn																					X		
9909	Grímsvötn						X																	
10055	Grímsvötn						X																	
10218	Grímsvötn																					X		
10300	Grímsvötn	Saks.vatn	**X**	**X**	**X**		**X**		**X**	**X**			**X**		**X**					**X**	**X**	**X**	**X**	**X**
10319	TFZ or KOL																					X		
10334	TFZ or KOL																					X		
10422	Vei-Bár						X																	
10457	Vei-Bár																					X		
10620	TFZ or KOL																					X		
10650	TFZ or KOL						X															X		
10764	Vei-Bár						X																	
11000	Askja	**Askja-S**								**X**														
11058	TFZ or KOL						X															X		
11107	TFZ or KOL						X															X		
12045	Vei-Bár																					X		
12120	Katla	**Vedde Ash**		**X**		**X**		**X**	**X**	**X**										**X**	**X**	**X**	**X**	**X**
12165	Vei-Bár																					X		
12210	Katla																					X		
12600	Katla																						X	
12667	Grímsvötn																					X		
12999	Vei-Bár																					X		
13429	TFZ or KOL																					X		
13600	Katla																						X	
14000	Katla																						X	
14389	Vei-Bár																					X		
14360	KOL								X												X			
14550	Unknown	**Borrobol**						**X**	**X**	**X**											**X**	**X**		
14600	Grímsvötn																						X	X
15000	Grímsvötn																						X	X

1. **MD99-2256**; 2. **MD99-2266**; 3. B997-315; 4. **MD99-2265**; 5. B997-337; 6. B997-336; 7. **MD99-2264**; 8. B997-330; 9. B997-329; 10. B997-332; 11. B997-325; 12. B997-323; 13. **MD99-2269**; 14. B997-322; 15. HM107-04; 16. **MD99-2271**; 17. HM107-03; 18. **MD99-2273**; 19. *B05-2006-MC03; 20. B997-317; 21. HM107-01; 22. B997-319GGC; 23. B997-319; 24. BB97-316; 25. B997-320; 26. B997-321; 27. **MD99-2272**; 28. HM107-05; 29. **MD99-2275**; 30. *B05-2006-MC04; 31. RAPiD-10-1P; 32. **RAPiD-15-4P**. Cores in bold are longer than 10 m and cores with asterisk are multi-cores, spanning approximately the last 150 years. For core locations see Figure 1.

RAPiD cores are outside the shelf but are nevertheless included here to give a better overview. Table 2 shows the number of tephra layers identified on different parts of the Iceland shelf.

North Iceland shelf

On the North Iceland shelf there are evidence of sediments containing tephra layers as old as about 50,000 years (Haraldsson, 2004; Telesinski, 2010).

The majority of sediment cores are located on the North Iceland shelf (Figure 1) which was targeted for coring because of high sedimentation rates and convergence of cold and warm air- and water masses in the area, which make it very sensitive to climate change and thus an interesting area to study oceanographic and atmospheric changes. As a consequence the greatest number of tephra layers have been found on the North Iceland shelf (e.g. Eiríksson *et al.*, 2000, 2004, 2011; Larsen *et al.*, 2002; Kristjánsdóttir *et al.*, 2007; Knudsen *et al.*, 2004, 2008; Gudmundsdóttir *et al.*, 2011a, 2011b, 2012) (Table 2) because the density of available cores varies between regions and tephra layers in other cores have not been analysed in the same detail as core MD99-2275 (Table 2, Figures 1 and 3). Core MD99-2275 has the most reported tephra layers, over 100, so far (Søndergaard, 2005; Gudmundsdóttir *et al.*, 2012).

South- and west Iceland shelf

Little research on other areas around the shelf of Iceland has been undertaken in terms of identifying tephra layers systematically. On the western part of the shelf only two tephra layers, the well known tephra markers Saksunarvatn ash and Vedde ash, have been identified until now (Table 2) (Andrews *et al.*, 2002; Geirsdóttir *et al.*, 2002; Jóhannsdóttir, 2003). This is not to say there are no tephra layers in marine sediments in the west but rather they have not been looked for in detail. However it would be expected that relatively fewer tephra layers would be identified on the western shelf compared to the northern shelf, due to prevailing wind directions in Iceland. The east flowing jet stream dominates at 10–15 km heights (Jónsson, 1990) and most explosive eruptions in Iceland produce plumes reaching such heights (Gudmundsson *et al.*, 1992; Lacasse *et al.*, 2004; Oddsson *et al.*, 2012) promoting east and northeastward distribution. This is evident from terrestrial archives in western Iceland where tephra studies have revealed a marked decrease/drop in number of tephra layers compared to north, east and south Iceland (Jóhannsdóttir, 2007; Thordarson and Höskuldsson, 2008). South of the Iceland shelf nine tephra layers have been described in the sediments spanning late glacial and early Holocene and one with an age of about 23,400 years (Thornalley *et al.*, 2011). Among these are the tephra markers Saksunarvatn ash and Vedde Ash (Table 2). No tephra stratigraphical investigation on marine cores has yet been carried out for the Holocene time period. Hitherto no cores have been collected on the East Iceland shelf and no information is available on tephra layers there.

Sources of tephra layers on the Iceland shelf

The vast majority of the marine tephra layers identified are basaltic originating from the most active volcanic systems in Iceland; Grímsvötn, Veiðivötn-Bárðarbunga and Katla (Figure 2 and Table 2). The Grímsvötn volcanic system has been the most productive during the Holocene with about seven eruptions per century followed by Veiðivötn-Bárdarbunga and Katla (Óladóttir *et al.*, 2005, 2008, 2011a). This is reflected in the marine tephra stratigraphy where tephra layers from Grímsvötn are the most common and then Veiðivötn-Bárdarbunga and Katla volcanic systems (Gudmundsdóttir *et al.*, 2012 and unpublished data). Other systems that have produced tephra deposited on to the Iceland shelf are Hekla, Eyjafjallajökull, Öræfajökull, Askja, Snæfellsjökull and Kolbeinsey ridge (KOL) or the Tjörnes fracture zone (TFZ) (Figure 2). Tephra layers from the KOL/TFZ are found in sediment cores; MD992269, -2271 and -2275; HM107-01, -01, -03, -04 and -05 (Eiríksson *et al.*, 2000, 2004; Knudsen *et al.*, 2004, 2008; Kristjánsdóttir *et al.*, 2007; Gudmundsdóttir *et al.*, 2012).

TEPHRA MARKERS

One of the applications of tephra studies, as mentioned previously, is dating and correlations. For that purpose tephra markers are used. Tephra markers should be relatively easily recognizable, either by macro- and microscopic characteristics (such as colour, grain type, crystal content) or chemical characteristics, be traceable over large areas and well dated (e.g. Larsen and Eiríksson, 2008a). Ideally a tephra marker should have all these qualities. Tephra markers are the foundation of a tephrochronological framework. Examples of tephra layers that have been used as markers in Icelandic tephra stratigraphy are the silicic tephra layers, H1104, Hekla 3, Hekla 4 and Hekla 5, large explosive eruptions from the Hekla volcanic system. These tephra layers have specific characteristics such as color, grain morphology and chemical composition and have been found in various environments, soil, lakes, marine and glacial ice within and out side terrestrial Iceland (e.g. Thorarinsson, 1967, 1971; Larsen and Thorarinsson, 1977; Dugmore *et al.*, 1995b; Dugmore and Newton, 1998; Eiríksson *et al.*, 2000, 2004; van den Bogard and Schmincke, 2002; Zillén *et al.*, 2002; Boygle, 2004; Pilcher *et al.*, 2005; Wastegård, 2005, Jóhannsdóttir, 2007; Kristjánsdóttir *et al.*, 2007; Sejrup *et al.*, 2011; Larsen *et al.*, 2011, 2012; Gudmundsdóttir *et al.*, 2012). These tephra layers have been used for dating the marine shelf sediments off north Iceland and for correlation between areas on the shelf and terrestrial Iceland as will be discussed later.

The majority of the known tephra markers in Icelandic tephra stratigraphy are either silicic or intermediate in chemical composition. They generally have more distinct characteristics, they often have wider distribution due to the nature of the eruptions and are not as abundant as basaltic tephra layers. The vast number of basaltic tephra, the similar appearance and chemical composition of layers from the same system makes it challenging to use them as marker layers or isochrones. Moreover the basaltic tephra layers tend to be more spatially confined making them less suitable as marker layers. Nevertheless widespread Icelandic basaltic tephra markers do exist such as Saksunarvatn ash, Mjáuvötn tephra, Settlement layer, Hrafnkatla, V1477 and V1717 (Table 2). Due to their limited number in marine sediments, basaltic tephra layers from Katla have a potential as tephra markers in marine sediments north off Iceland. Basaltic tephra layers also have the potential to be tephra markers as a part of a spectra or series of tephra layers (Gudmundsdóttir *et al.*, 2012). The age of the marine tephras on the North Iceland shelf is based on correlation with terrestrially dated tephras and dated volcanic events.

POTENTIAL TEPHRA MARKERS IN THE MARINE ENVIRONMENT

One of the aims of tephra and tephrochronological studies is to increase the number of tephra layers that can be used as marker horizons. Identification of a tephra layer with distinct characteristics, found in several locations that can be absolutely dated has the potential to become a tephra marker. Known local and regional markers in terrestrial tephrochronology in Iceland are about 40 (e.g. Larsen *et al.*, 1999; Larsen and Eiríksson, 2008a; Óladóttir *et al.*, 2011a). A portion of these markers has been traced into the marine sediments on the Iceland shelf (e.g. Larsen *et al.*, 2002; Kristjánsdóttir *et al.*, 2007; Gudmundsdóttir *et al.*, 2012) (Table 2). In general tephra layers with volumes more than 0.1 km^3 can be expected to be deposited in marine sediments around Iceland and overseas. Large tephra layers exceeding volumes of 10 km^3, such as the Hekla 4 and 3, can be expected to have regionally extensive deposition. Less voluminous tephra layers can be expected to have limited distribution depending on the weather conditions at the time of the eruption. They commonly tend to be strongly limited laterally downwind (Larsen and Eiríksson, 2008b). Holocene silicic, intermediate and basaltic tephra layers in the 0.1–1 km^3 category that are likely to occur sporadically outside Iceland and have not been reported in marine sediments on the shelf are shown in Table 3. All of these tephra layers have been used as tephra markers in Icelandic terrestrial tephrochronology and most of them are silicic or intermediate. Holocene basaltic tephra layers that have been mapped fall within the 0.01–1 km^3 category but a few reach a volume of 10–20 km^3 (Larsen and Eiríksson, 2008b and references therein). Recent additions to the marine tephra marker assemblage are Hekla 1947, V1797, Hrafnkatla, Hekla DH, Hekla Ö and Askja S (Eiríksson *et al.*, 2011; Gudmundsdóttir *et al.*, 2011, 2012).

CORRELATING MARINE AND TERRESTRIAL TEPHRA STRATIGRAPHY

High-resolution studies have enabled the establishment of a detailed marine tephrochronological framework, which has been correlated to high-resolution terrestrial tephra stratigraphy in Iceland. Land-sea correlation between marine core MD99-2275 and three soil sections in north and east Iceland has resulted in correlation of over 30 tephra layers within the last 7,050 years (Gudmundsdóttir *et al.*, 2012). For the last 15,000 years 40 tephra layers from shelf sediments around Iceland have been correlated to their terrestrial counterparts both in Iceland and overseas. Thereof 26 are absolutely dated tephra layers, i.e. tephra markers. The tephra markers Hekla 1947, V1717, KOL 1372, H1104, Sn-1, Hekla 3, Hekla 4, Suduroy tephra, Saksunarvatn ash, Vedde Ash and tephra with Borrobol affinity have been identified in more than one core on the North Iceland shelf in addition to four tephra layers from the Kolbeinsey Ridge (KOL) or Tjörnes Fracture Zone (TFZ); KOL3-2269/3373, KOL2-2269/2912, KOL1-2269/2780 and KOL-GS-2 (Eiríksson *et al.*, 2000;

Table 3. Holocene silicic, intermediate and basaltic tephra layers in the 0.1–1 km^3 volume range that have not been reported in marine sediments on the Iceland shelf and are potential tephra markers. *The volumes for tephra layers HM and HN are calculated within 0.5 cm isopach. – *Súr, ísúr og basísk gjóskulög, í 0,1–1 km^3 stærðarflokki, sem ekki hefur verið lýst í sjávarseti á landgrunninu fram að þessu og eru möguleg gjóskuleiðarlög. *Rúmmál gjóskulagana HM og HN er reiknað út frá 0,5 jafnþykktarlínum.*

Silicic and intermediate tephra layers	Basaltic tephra layers	Volcanic system	Age cal. BP (before 1950)	Volume (km^3) uncomp.	Tephra distrib.	Reference
Askja 1875		Askja	75	2	E	Thorarinsson, 1963
	K-1755	Katla	195	∼1	E, SE	Thorarinsson, 1975; Larsen, 2010
	K-1721	Katla	229	0.33	W, NW	Thorarinsson, 1955; Larsen, 2010
	K-1625	Katla	325	0.5	E, SE	Thorarinsson, 1981; Larsen, 2010
H-1597		Hekla	353	0.29	S, SE	Thorarinsson, 1967; Larsen *et al.*, 1999
H-1510		Hekla	440	0.32	S	Thorarinsson, 1967
	K∼1500	Katla	450	0.5	W	Thorarinsson, 1969; Larsen, 2000
H-1389		Hekla	561	0.15	SE	Larsen *et al.*, 1999
Ö-1362		Öræfajökull	588	10	S, SE	Thorarinsson, 1958
H-1341		Hekla	609	0.18	SE	Larsen *et al.*, 1999
	K-1262	Katla	688	0.48	NE	Larsen, 2010
H-1206		Hekla	744	0.4	SE	Larsen *et al.*, 1999
H-1158		Hekla	792	0.33	NE	Thorarinsson, 1967; Larsen *et al.*, 1999
	Eldgjá 934	Katla	1016	∼4.5	S, SE	Hammer *et al.*, 1980; Larsen, 2000, 2010
Grákolla (G)		Torfajökull	1950±45		NE	Larsen and Eiríksson, unpubl.
Askja (A)		Askja	1950±45		S, SE	Larsen and Eiríksson, unpubl.
H-X		Hekla	∼ 2300	0.45	E, NE	Larsen and Vilmundardóttir, 1992; Óladóttir *et al.*, 2011a
H-A		Hekla	2540	0.55	W	Róbertsdóttir, 1992; Róbertsdóttir *et al.*, 2002b; Sigurgeirsson and Sveinbjörnsdóttir, 1999
H-Y		Hekla	∼ 2600	0.6	E	Larsen and Vilmundardóttir, 1992; Óladóttir *et al.*, 2011a
H-B		Hekla	∼ 2740		W	Róbertsdóttir, 1992
SILK-UN		Katla	2850±50	0.29	E, NE	Larsen *et al.*, 2001
H-C		Hekla	2800±70		NW	Thorarinsson, 1964; Róbertsdóttir, 1992
H-M		Hekla	2970	0.46	SE	Larsen et al, 2002b; Óladóttir *et al.*, unpubl.
H-N		Hekla	3040	0.66	SE	Larsen et al, 2002b; Óladóttir *et al.*, unpubl.
SILK-LN		Katla	3390±70	0.22	NE	Larsen *et al.*, 2001
H-S		Hekla	3800±120	2	E, SE	Larsen *et al.*, 2001; 2012
Sn-2		Snæfellsjökull	4400±160		N, NE	Steinthórsson, 1967; Jóhannesson *et al.*, 1981
SILK-A8		Katla	∼7350		SE	Larsen *et al.*, 2001
Sn-3		Snæfellsjökull	>8000		N, NE	Jóhannesson *et al.*, 1981
A13		Torfajökull	∼8350		SE	Larsen *et al.*, 2001; Óladóttir *et al.*, 2008

Søndergaard, 2005; Kristjánsdóttir *et al.*, 2007). The Saksunarvatn ash and Vedde Ash are the only tephra layers that are found on all of the shelf areas that have been investigated, i.e. north, west and south (Figure 1, Table 2). Other tephra markers have only been identified, until now, in a single core (Table 2).

A transect from the western part of the North Iceland shelf to east Iceland is shown in Figure 3, where marine cores MD99-2269 and MD99-2275 are correlated to the Svartárkot soil section in north Iceland (Larsen *et al.*, 2002 and unpublished data) and Kárahnjúkar in east Iceland (Óladóttir *et al.*, 2011a) (Figure 2) (Gudmundsdóttir *et al.*, 2012). Nine tephra layers can be correlated between cores MD99-2269 and MD99-2275. Here four of these tephra layers, KOL1372, KOL3-2269/3373, KOL2-2269/2912 and KOL1-2269/2780 are correlated based on age and chemical composition. These tephra layers could be potential regional tephra markers on the shelf as they originate from KOL or the TFZ. In addition to these nine tephra layers correlated between cores MD99-2269 and MD99-2275, 21 and 22 layers, identified in

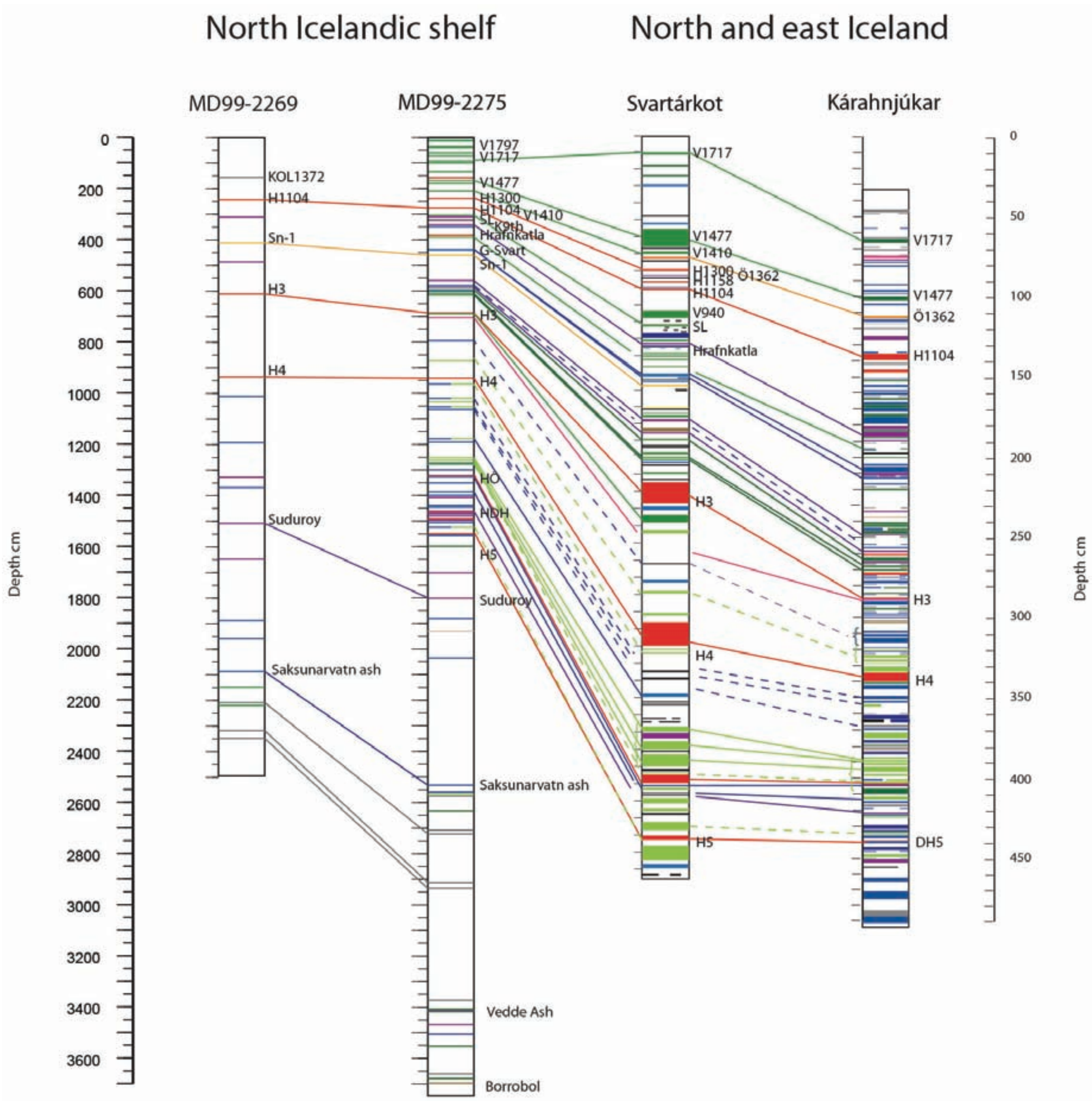

Figure 3. Tephra stratigraphy of marine cores MD99-2269 and MD99-2275 correlated to tephra stratigraphy of the Svartárkot and Kárahnjúkar soil sections. The colors of the tephra layers refer to a specific volcanic system (Figure 2). Broken lines refer to less certain correlations and discontinuous lines represent correlations that can only be made between core MD99-2275 and Kárahnjúkar soil sections. The thickness of the tephra layers in the soil sections are shown proportionally. – *Gjóskulagaskipan í sjávarkjörnum MD99-2269 og MD99-2275 tengd við gjóskulagaskipan í jarðvegsniðum við Svartárkot og Kárahnjúka. Litir gjóskulaga vísa til eldstöðvakerfa skv. 2. mynd. Brotalínurnar endurspegla meiri óvissu í tengingu og slitnar línur eru tengingar sem einungis hefur verið unnt að gera milli kjarna MD99-2275 og jarðvegssniðsins í Kárahnjúkum.*

core MD99-2275, have been correlated to the Svartárkot and Kárahnjúkar soil sections, respectively (Figure 3) (Gudmundsdóttir *et al.*, 2012). Further details on correlations of core MD99-2275 with these soil sections are presented in Gudmundsdóttir *et al.*, 2012. Tephra layers from Katla volcanic system in core MD99-2269 between the Hekla 1104 and Hekla 3 tephra markers could possibly be correlated to some of the Katla tephra layers in core MD99-2275 and Svartárkot and/or Kárahnjúkar soil sections (Figure 3). A Katla tephra layer with an age of 2450 years BP in core MD99-2269 could be correlated to two Katla tephra layers with an age of 2337 years or 2473 years (Table 2). Such a correlation, however, would be rather weak because the tephra stratigraphy of core MD99-2269 has not been fully documented, with every 10 cm investigated for tephra layers versus every cm in core MD99-2275. Therefore other potentially undiscovered Katla tephra layers in core MD99-2269 of similar age could be a better correlation. Good stratigraphic and chronological control is of utmost importance when correlating tephra layers, in particular basaltic tephra layers where appearance and chemical composition is similar within a particular volcanic system. The same applies for correlation of basaltic Grímsvötn and Katla tephra layers in the interval between the Hekla 4 and Saksunarvatn ash marker layers in core MD99-2269, a more detailed tephra stratigraphy is needed to make a robust correlation.

High-resolution and systematic studies of tephra layers in marine sediments on the Iceland shelf opens up the possibility of high-resolution layer-by-layer correlations with centennial to decadal resolution within certain time intervals (Gudmundsdóttir *et al.*, 2012). This is especially valuable in areas where frequent shifts in climate/atmosphere-oceanographic system may have occurred and where synchronicity of leads and lags between such events needs to be established. Correlating marine tephra stratigraphy with terrestrial (including ice core) tephra stratigraphy is critical because dates can be obtained from the terrestrial setting. In many cases, this will also add to the available information on its distribution outside Iceland.

CONCLUDING REMARKS

Tephra studies on the Iceland shelf show that the marine sediments are a good preserver of tephra layers from Icelandic volcanoes facilitating robust correlation and dating of various proxy archives for paleoenvironmental and climatic research. High-resolution marine tephrochronology, allows detailed layer by layer correlation were centennial to decadal resolution may be possible for certain time periods. Tephra studies on the North Iceland shelf have revealed new tephra layers, such as the Hrafnkatla, Hekla Ö and Hekla DH, that can be used as markers or isochrones on the Iceland shelf and possibly in the North Atlantic region.

Marine tephrochronology also provides an independent control on marine radiocarbon dates, and assessment of marine reservoir age. The marine tephra stratigraphy on the North Iceland shelf captures general trends of explosive volcanic activity, providing an important supplement to the high-resolution terrestrial record on volcanism in Iceland. In addition, the marine record extends further back in time than the terrestrial record. Regional identification of specific tephra layers in marine sediments, ice cores and soil, will improve understanding of the frequency and dispersal directions of Icelandic tephra. However, it is important when working with marine tephra layers to carefully consider sedimentation processes that can influence the integrity of a tephra layer such as reworking by bioturbation, currents and mass movements and the presence of sea ice during a tephra fall.

Development of tephrochronology in marine archives on the Iceland shelf is still in its infancy. Much of the work has been carried out on the North Iceland shelf while the west, south and east Iceland shelf areas await further investigation. The numerous tephra layers identified on the North Iceland shelf demonstrate the potential of the marine record around Iceland for tephra studies.

Acknowledgements

We thank Prof. Haflidi Haflidason, University of Bergen, Norway, and dr. Peter Abbott, University of Swansea, UK, for valuable comments and suggestions on the manuscript and the editors for their patience.

ÁGRIP

Fram til þessa hafa verið borin kennsl á 130 gjóskulög í setlögum á íslenska landgrunninu frá nútíma og síðjökultíma. Elsta gjóskulagið er um 15.000 ára gamalt og það yngsta frá árinu 1947. Gjóskulög hafa fundist í 30 sjávarsetkjörnum. Flestir kjarnanna eru á norðanverðu landgrunninu og meirihluti gjóskulagana hefur fundist þar. Á vestan- og sunnanverðu landgrunninu hefur mun færri gjóskulögum verið lýst. Af þessum 130 gjóskulögum hefur verið hægt að tengja 40 gjóskulög við gjóskulög á landi, bæði hérlendis og erlendis og þar af eru 26 tímasett gjóskuleiðarlög. Flestar tenginganna spanna síðustu 7050 ár. Saksunarvatn og Vedde gjóskulögin eru einu lögin sem lýst hefur verið á öllum þeim svæðum landgrunnsins sem hafa verið rannsökuð. Gjóskuleiðarlög hafa gegnt mikilvægu hlutverki í að meta umhverfisbreytingar í hafinu, þ.a.m. breytingar í sýndaraldri sjávar við strendur landsins. Gjóskulagaskipanin á norðanverðu landgrunni Íslands gefur upplýsingar um eldvirkni íslenskra eldfjalla lengra aftur í tímann en gjóskulagaskipan á landi og er því mikilvæg viðbót við þekkingu á gossögu Íslands.

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