Why it is important to improve our understanding of Katla

Katla

A ticking time bomb?

By
Jacqueline Owen (Fig. 1)
Hugh Tuffen

Figure 1: Me (Jacqui), sitting facing Katla (photo taken from a tuya in Torfajökull)

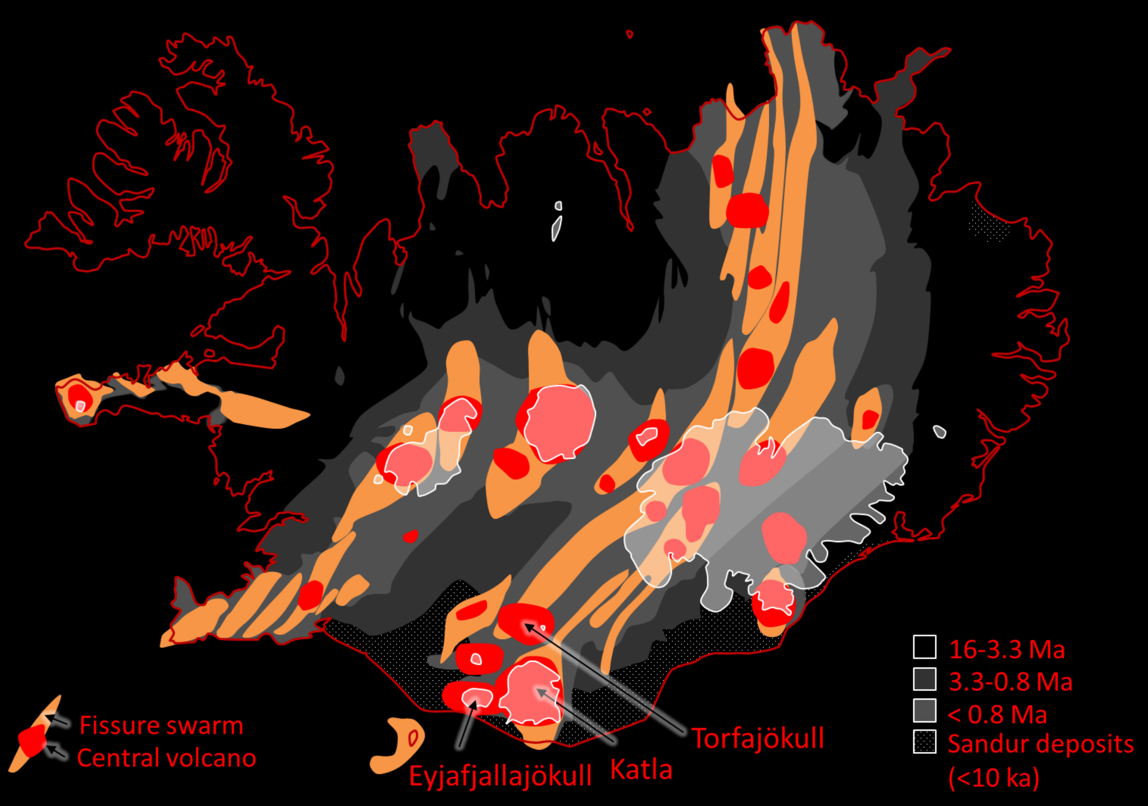

Figure 2: A map of Iceland showing the locations of central volcanoes. Based on Einarsson, (1994); Tentler and Temperley, (2007) and Thordarson and Larsen, (2007).

Is Katla ready to erupt?

Katla (Figs. 1, 2) is one of Iceland's most active volcanoes. However, she has not erupted since 1918. This is the longest gap in Katla activity within historical records (Óladóttir et al., 2005). On average, she erupts twice per century. In fact, for the past several hundred years, Katla had erupted at the end of the 2nd and 6th decade of every century, give or take 5 years… until the 20th century (Thorarinsson, 1960) (Fig. 3).

Katla also seems to have a connection with Eyjafjallajökull. Every time Eyjafjallajökull has erupted within historical records, Kata has erupted within a year or two (Fig. 3). However, it has now been nearly 4 years since the 2010 eruption of Eyjafjallajökull and there has still not been a significant Katla eruption.

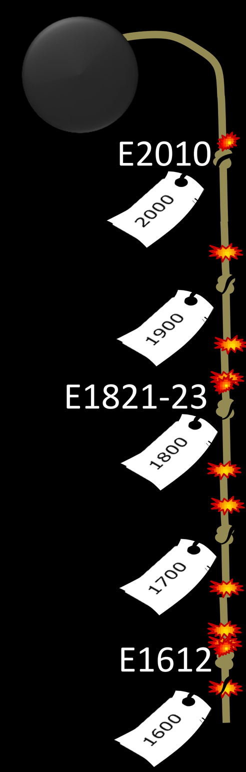

Figure 3: A timeline of eruptions from Eyjafjallajökull (prefixed E) and Katla (prefixed K) for the past 500 years. Based on Sturkell et al., (2010) and Thorarinsson, (1960).

Katla is, however showing signs of unrest. It is even possible that there have been small, entirely subglacial eruptions in 1955, 1999 and 2011 based on the occurrence of small jökulhlaups and ice cauldron formation. However, it is also possible that these were caused by geothermal heating at the glacier base (Dugmore et al., 2013). There have also been earthquake swarms in 1999, 2002-2004 and 2011 (Icelandic Met Office). Some of these, at least, were likely caused by dyke intrusion, as 2000-2004 also saw considerable inflation at Katla (Sturkell et al., 2010). However, it is possible that some of the earthquakes were caused by glacial movement (Jónsdóttir et al., 2009).

It is therefore unclear, whether an eruption at Katla is imminent. We may have a long wait, on the other hand, she may erupt tomorrow!

Katla eruptions

What are eruptions at Katla like?

Although, Katla has, on occasion, produced lava flows during fissure eruptions (including the 934 AD Eldgjá eruption, which at 14 km^3, is one of the largest lava flows in recorded history; Larsen et al., (2001)) and silicic tephra, by far the most common eruption type is explosive subglacial basaltic eruptions from within the ice-clad caldera. This is particularly true for eruptions within the most recent millennia (Larsen, et al., 2001, Óladóttir et al., 2008). Consequently, the biggest Katla hazards are tephra dispersion (Fig. 4) and glacial floods (Fig. 5).

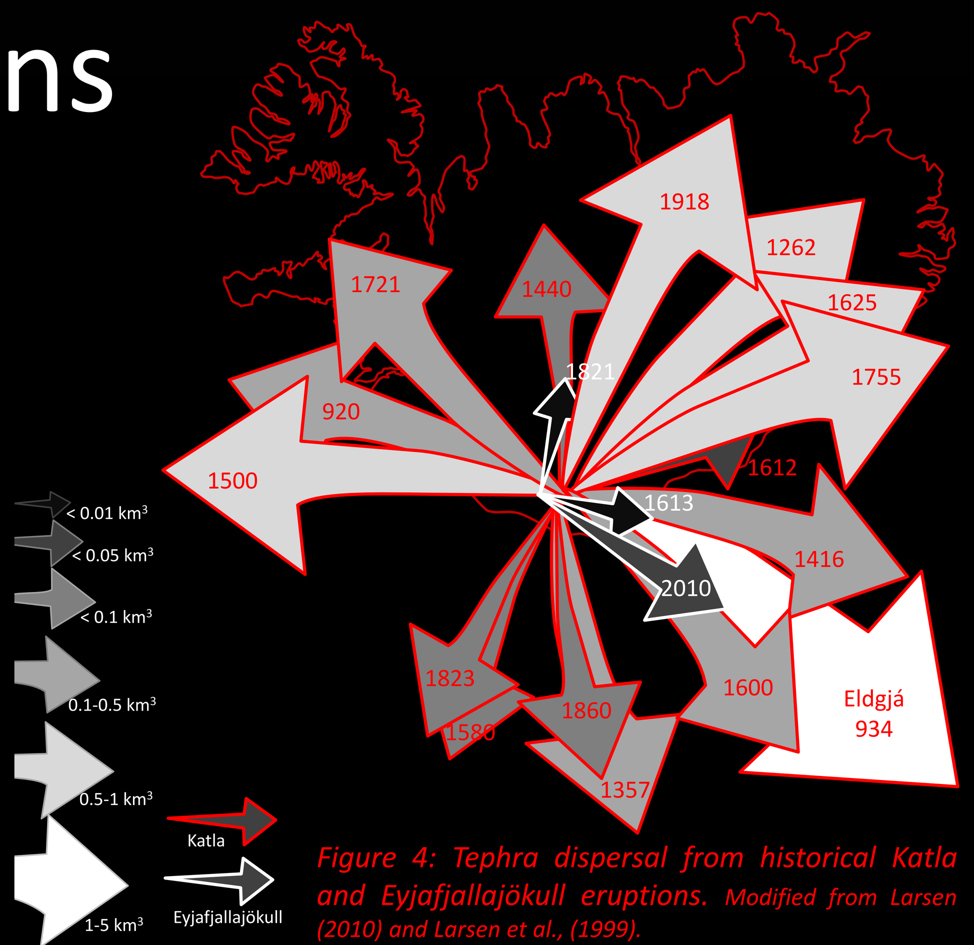

Figure 4: Tephra dispersal from historical Katla and Eyjafjallajökull eruptions. Modified from Larsen (2010) and Larsen et al., (1999).

Figure 5: Areas at risk from Katla floods. (Bird, 2010)

Katla 1918

The last eruption of Katla occurred in 1918 (Fig. 6). It was comparable in style to the 2010 Eyjafjallajökull eruption, however it was more powerful (Table 1, Fig. 4). Eyjafjallajökull 2010 produced both an ash cloud (that caused the worst disruption to aviation since WW2) and a jökulhlaup (glacial flood), which destroyed roads in south Iceland (Gylfason et al., 2012). The 1918 Katla eruption produced a bigger plume, but also one of the world's largest ever floods (O'Conner and Costa, 2004). Peak discharge exceeded 300,000 m^{3}s^{-1} (more powerful than the Amazon river), within 2 hours and flooded an area 6 times the size of Paris. Sediment transported by the flood (Fig. 7) extended the coastline by 3 km (Tómasson, 1996).

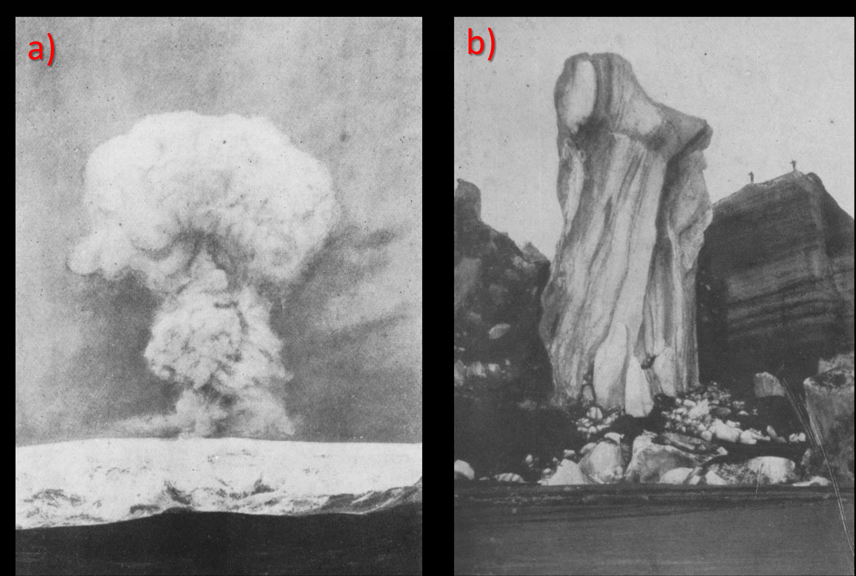

Figure 6: Photographs of the 1918 Katla eruption; a) the plume, b) an iceberg transported by the flood. Photos by Kjartan Guðmundsson (Jóhannsson, 1919).

Figure 7: Hugh Tuffen jumping on a ~1400 tonne boulder that was carried > 15 km by the 1918 flood. Based on information in Jónsson (1980)

Table 1: Comparing the eruption of Katla 1918 with Eyjafjallajökull 2010

	Katla 1918	Eyjafjallajökull 2010
Date of commencement	12th Oct 1918 [A]	14th Apr 2010 [G]
Duration of eruption	24 days [A]	39 days [G]
Composition	Basalt (47% SiO_2) [B]	Benmoreite and trachyte [H]
VEI	4 (at least) [C]	4 (upgraded from 3) [C]
Total erupted volume (DRE)	1 km^3 [D]	0.2 km^3 [H]
Max plume height	14 km [A]	10 km [H]
Volume of airborne tephra	0.7 km^3 [D]	<0.3 km^3 [H]
Area of tephra fall on land	50,000 km^2 [A]	12,000 km^2 [I]
Thickness of ice over eruption site	400 m [D]	200 m [H]
Volume of subglacial lavas	0.2 km^3 [E]	0.02 km^3 [H]
Time taken to melt overlying ice	2 hours [E]	3-4 hours [H]
Jökulhlaup volume	>8 km^3 [E]	<0.06 km^3 [I]
Flooded area	600-800 km^2 [F]	57.5 km^2 [I]
Max discharge rate of jökulhlaup	>300,000 m^3 s^{-1} [E]	2,600 m^3 s^{-1} [I]
Volume of flood transported tephra	0.7-1.6 km^3 [F]	0.03 km^3 [H]

A: Larsen (2010); B: Óladóttir et al., (2008); GVP (2013); D: Sturkell et al., (2010); E: Tómasson, (1996); F: Larsen (2000); H: Guðmundsson et al., (2012); I: Gylfason et al., (2012)

The project

My aims

I have just started a 2 year project to get under Katla's skin. Why does she behave the way she does? What triggers her violent outbursts?

We have collected various samples of 1918 Katla ash (Figs. 8,9). We shall analyse them in a number of ways to determine:

- Grain size distributions
- Bubble characteristics
  - Vesicularity
  - Vesicle size distributions
  - Bubble number densities
  - Vesicle shape
  - Connectivity
- Mineralogy
  - Mineral identification
  - Crystal volume distributions
  - Crystal number densities
  - Relationships between bubbles and crystals
- Volatile content
  - Pre-eruptive
  - Matrix glass
- Geochemistry
  - Pre-eruptive
  - Matrix glass

This will help us answer the following key questions (Table 2)

Figure 8: Location map. Locations in red also appear in Fig. 2. Yellow pins represent sampling locations (see Fig. 9 for more detail). The dark grey area to the SE of the large glacier (Mýrdalsjökull) are jökulhlaup deposits from Katla 1918. Modified from Google Earth.

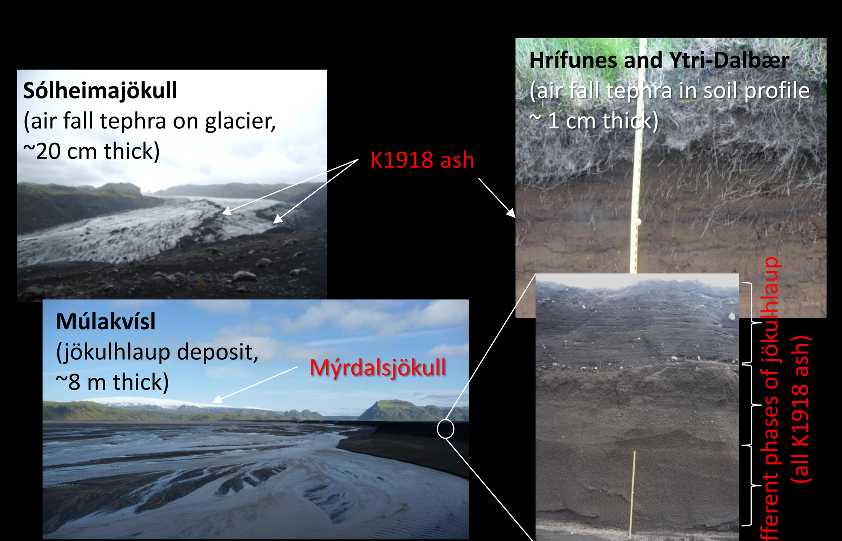

Figure 9: Photos of sampling locations (see also Fig. 8)

Table 2: Some key project aims

Key question relating to Katla 1918	Implications for the next Katla eruption
How deep was magma stored prior to eruption?	This will help us to interpret seismic data and distinguish between earthquakes caused by magma vs ice movement
What was the rise speed of the magma?	Assuming there are precursory earthquakes, how much time until the magma reaches the surface?
Was fragmentation driven by magmatic or phreatomagmatic processes?	Will there only be potential for explosive fragmentation when there is sufficient volcano-ice interaction?
How much gas was released into the atmosphere?	Could there be detrimental effects to climate/livestock/vegetation etc. due to volcanic emissions?

Lessons learnt from PhD

My PhD was investigating the role of volatiles in determining the explosivity of subglacial rhyolite at Torfajökull (Fig. 2). We also reconstructed the palaeo-ice thickness for various edifices using dissolved volatile contents (Owen et al., 2012, 2013a). There was no correlation between ice thickness and eruption style. However, there was evidence for rapid decompression at Dalakvísl, which seemed to accompany a change in eruptive behaviour (Owen et al, 2013b). Furthermore, the more explosively formed edifices had significantly higher pre-eruptive H_2O contents and showed evidence of closed-system degassing (Fig. 10). By comparison, effusive edifices were water-poor and showed evidence of open-system degassing (Owen et al., 2013a, 2013b). Will the same relationships hold true in basaltic subglacial systems such as Katla?

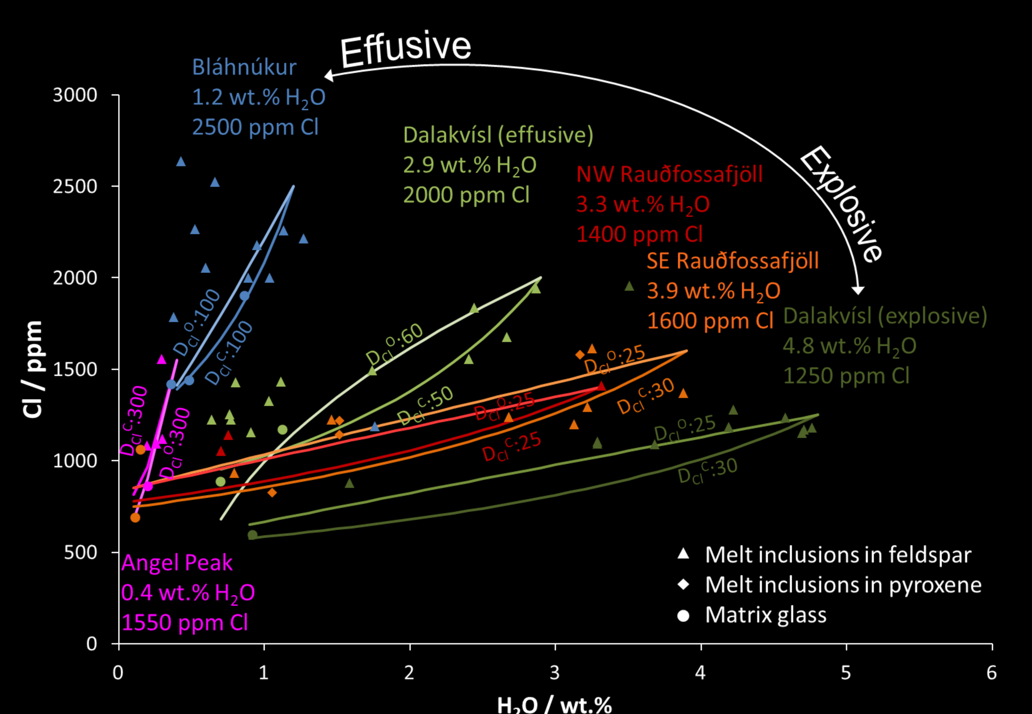

Figure 10: Secondary ion mass spectrometry (SIMS) measurements of H_2O vs Cl. We assigned an initial H_2O and Cl content (as labelled) and used this to model open-system (pale line) and closed-system (dark line) degassing. Numbers overlying each degassing path show the chlorine distribution ratio (D_{Cl}) used to create the best fit to our data; superscripts C and O represent closed- and open-system degassing, respectively. Modified from Owen et al., (2013a).

Preliminary data

The project is in early days but preliminary data showing a high fraction of particles < 63 µm (Fig. 11) suggests that phreatomagmatic fragmentation may have played an important part in fuelling explosivity. Volatile data next…

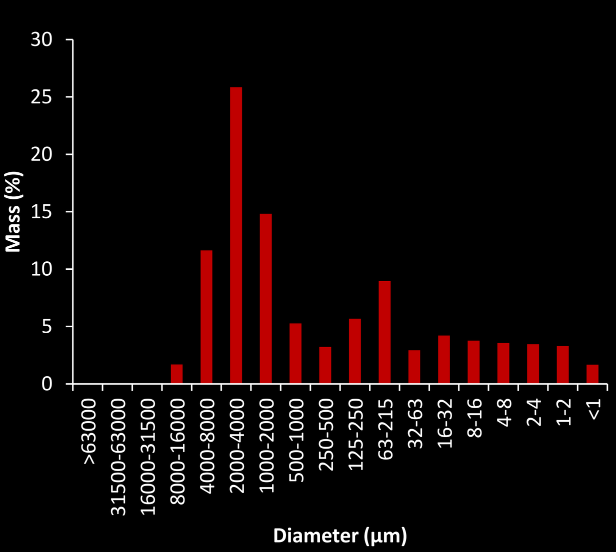

Figure 11: A grain size distribution for Katla 1918

References

Bird (2010) Science blog: risk of further eruptions in Iceland, http://www.smc.org.au/2010/04/science-blog-risk-of-further-eruptions-in-iceland/

Dugmore et al., (2013) Tephrachronology and the late Holocene volcanic and flood history or Eyjafjallajökull, Iceland, *J Quaternary Sci*, 28(3): 237-247

Einarsson (1994) *Geology of Iceland: Rocks and Landscape*, Mál og menning, Reykjavík, 309 p.

Guðmundsson et al., (2012) Ash generation and distribution from the April-May 2010 eruption of Eyjafjallajökull, Iceland, *Sci Rep, 2(572)*

GVP (2013) Smithsonian Institution, National Museum of Natural history, Global Volcanism Program, http://www.volcano.si.edu/search_volcano.cfm

Gylfason et al., (2012) The 2010 Eyjafjallajökull eruption, *Iceland Report to ICAO - June 2012* IVATF/4-IP/3, Icelandic Meteorological Office, Reykjavík.

Höskuldsson and Sparks (1997) Thermodynamics and fluid dynamics of effusive subglacial eruptions, *B Volcanol*, 59: 219–230

Icelandic Met Office: http://en.vedur.is/

Jóhannsson (1919) Kötlugosið 1918, Bókaverzlun Ársæls Árnasonar, Reykjavík

Jónsdóttir et al., (2009) Glacial long period seismic events at Katla volcano, Iceland, *Geophys Res Lett,* 36(L11402)

Jónsson (1980) Um Kötluhlaup, *Náttúrufræðingurinn,* 50(2): 81-86

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

Larsen (2010) Katla: tephrachronology and eruption history, *Dev Quaternary Sci,* 13: 23-49

Larsen et al., (1999) Geochemistry of historical-age silicic tephras in Iceland, *The Holocene,* 9(4): 463-471

Larsen et al., (2001) Geochemistry, dispersal, volumes and chronology of Holocene silicic tephra layers from the Katla volcanic system, Iceland, *J Quaternary Sci*, 16(2): 119-132

O'Connor and Costa (2004) *The world's largest floods, past and present - their causes and magnitude*. US Geological Survey Circular 1254, 13p.

Óladóttir et al., (2005) The Katla volcano S-Iceland: Holocene tephra stratigraphy and eruption frequency, *Jökull*, 55: 53-74

Óladóttir et al., (2008) Katla volcano, Iceland: magma composition, dynamics and eruption frequency as recorded by Holocene tephra layers, *B Volcanol*, 70: 475-493

Owen et al., (2012) Using dissolved H_2O in rhyolitic glasses to estimate palaeo-ice thickness during a subglacial eruption at Bláhnúkur (Torfajökull, Iceland), *B Volcanol*, *74*(6), 1355-1378

Owen et al., (2013a) Explosive subglacial rhyolitic eruptions in Iceland are fuelled by high magmatic H_2O and closed system degassing, *Geology*, *41*(2), 251-254

Owen et al., (2013b) Pre-eruptive volatile content, degassing paths and depressurisation explaining the transition in style at the subglacial rhyolitic eruption of Dalakvísl, South Iceland, *J Volcanology Geoth Res*, *258*, 143-162.

Photovolcanica, Eyjafjallajökull volcano, http://www.photovolcanica.com/VolcanoInfo/Eyjafjallaj%C3%B6kull/Eyjafjallaj%C3%B6kull.html

Sturkell et al., (2010) Katla and Eyjafjallajökull volcanoes, *Dev Quaternary Sci,* 13: 5-21

Tentler and Temperley (2007) Magmatic fissures and their systems in Iceland: A tectonomagmatic model, *Tectonics*, *26*(5), TC5019

Thorarinsson (1960) On the predicting of volcanic eruptions in Iceland, *B Volcanol,* 23(1): 45-52

Thordarson and Larsen (2007) Volcanism in Iceland in historical time: Volcano types, eruption styles and eruptive history, *J Geodyn*, *43*(1), 118-152

Tómasson (1996) The jökulhlaup from Katla in 1918, *Ann Glaciol*, *22*, 249-254

j.owen2@lancsater.ac.uk

@jacquelineowen

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