A subglacial eruption is a volcanic event that occurs under snow or ice. It could be a volcano that is at high latitude under an ice sheet or glacier, such as the Eyjafjallajökull and Grimsvötn eruptions (Fig. 1, Fig. 2) and it could be an ice-capped volcano at high altitude such as Mt Hood (Fig. 3).

Subglacial eruptions are particularly dangerous, they have all of the hazards of eruptions that take place in open air, but in addition have: 1) high water content, 2) high silica content, 3) the magma water interaction produces large quantities of ash which can destroy BJP and livestock, 4) the sudden melting of ice can create incredibly destructive jökulhlaups (glacial floods) and lahars (mudflows) that can travel for 100’s of km.

Q: Why did Eyjafjallajökull disrupt aviation more than Grimsvötn?
A: Eyjafjallajökull had a higher a Si content which meant that it was highly explosive and so fragmented to produce a very fine-grained ash which was particularly problematic to aircraft.

Figure 1: The Eyjafjallajökull 2010 ash plume

Figure 2: The Grimsvötn 2011 ash plume

Table 1: Information about the volcanoes in this study (colour coded to match Fig. 4)

<table>
<thead>
<tr>
<th>Volcano</th>
<th>Behaviour</th>
<th>Size (km²)</th>
<th>Did it burst through the ice sheet?</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AngelLake</td>
<td>Effusive</td>
<td>0.4</td>
<td>Yes</td>
<td>20,000-0</td>
</tr>
<tr>
<td>Bládhóll</td>
<td>Effusive</td>
<td>0.1</td>
<td>No</td>
<td>95,000-5</td>
</tr>
<tr>
<td>Dalakvísl</td>
<td>Effusive</td>
<td>0.2</td>
<td>Getting close</td>
<td>70,000-1</td>
</tr>
<tr>
<td>Fuji</td>
<td>Explosive</td>
<td>0.4</td>
<td>No</td>
<td>20,000-1</td>
</tr>
<tr>
<td>Gunnuhver</td>
<td>Effusive</td>
<td>0.1</td>
<td>No</td>
<td>20,000-1</td>
</tr>
<tr>
<td>Hekla</td>
<td>Effusive</td>
<td>0.3</td>
<td>Yes</td>
<td>70,000-1</td>
</tr>
<tr>
<td>Katla</td>
<td>Effusive</td>
<td>0.4</td>
<td>Yes</td>
<td>70,000-1</td>
</tr>
</tbody>
</table>

Figure 3: Mt Hood with Portland in the foreground

Figure 4: Water plotted against chlorine. The different colours depict the different volcanoes shown in Table 1. Triangles mark more inclusion data (initial volatile content) and circles mark matrix glass data (final volatile content). The lines mark degassing paths and connect the melt inclusion to the matrix glass for each sample. The two large arrows show the general trends of the explosive and effusive volcanoes.

As a figure demonstrates, our samples show a wide variety of initial water contents (shown by the triangles), ranging from 39% for Angel Lake to 1.5% for Dalakvísl. H2O is the most influential of the volatile species in determining explosive style and and Fig. 4 shows explosive eruptions (shown in red and orange) had higher initial H2O compared to the effusive (non-volcanic) eruptions (in pink and blue) with the exception of just one Bládhóll sample.

What we know already:

1. The size and explosivity of subglacial eruptions is controlled by: 1) the presence of high volatiles (silica content), the more viscous (sticky) the magma and the more explosive the eruption will be; 2) the ice thickness – the more ice there is to melt, the more water is available for violent fluid coolant interactions; 3) the cavity size – subglacial eruptions melt cavities into the base of the ice sheet. The larger the cavity, the more room there is for explosive fragmental behaviour.

What we don’t know: What role do volcanic gases have?

Volcanic gases are a big role in subglacial eruptions. The more volatile there are, the more explosive an eruption is. Imagine shaking up two bottles of pop (one bubbly, one flat) and then removing the tops. In subglacial eruptions, however, it is unclear what role volatile gases play. Some say that volatile contents will reduce explosivity because gas bubbles are compressible so they will absorb some of the force of an explosion (just like shock absorbers on a bike). Other people say that they will increase the explosivity of an eruption because bubbles create a larger surface area for magma-water interaction (Stevenson pers. comm., 2009).

Cue Jacqueline...

We took five subglacial volcanoes from Torfajökull, Iceland (Table 1) that all erupted at very similar times, under very similar thicknesses of ice and have very similar compositions. Four of these five were ever thought to have formed during the same eruption and yet each volcano erupted in a very different way—why? Why?

Samples from each volcano were taken to the Secondary Ion Mass Spectrometry (SIMS) facility at Edinburgh University. This enabled us to measure the H2O (water), Cl (Chlorine) and F (Flurine) content of our samples. Melt inclusions are tiny droplets of melt from the magma chamber that become trapped in crystals as they grow. We thought to record the initial volatile content. By comparing these to the matrix glass (surrounding lava) we can get the full degassing history of our samples.

Figure 5: Cartoons of Eyjafjallajökull (left) and Grimsvötn (right)

Figure 6: The Eystrieyjafjallaglet: 2008 ash plume

There are also different H2O:Cl relationships between the explosive and effusive eruptions. H2O:Cl relationships reveal information about the degassing path, whether volcanoes have been lost on the way to the surface (open system degassing) or whether they have remained in the magma (closed system degassing) to produce a more explosive eruption. In Fig. 4, there is a clear difference between the H2O:Cl trends of the explosive eruptions, which have low gradient degassing paths and the effusive eruptions, which have near vertical degassing paths.

Dalakvísl (in green on Fig. 4) was a mixed eruption that was thought to have started explosively and then became effusive. Two of the samples seem to have very similar volatile data to the explosive volcanic, whilst the third has volatile data more similar to the effusive Bládhóll (in blue). Furthermore, the most volatile rich Dalakvísl sample was collected from an explosive deposit and the volatile poor sample from a more effusive area.

By Jacqueline Owen – a 4th year PhD student Environmental Geosciences Supervised by: H. Tuffen, D.W. McGarvie & L. Wilson

LEG poster day
27th Oct 2011
LANCASTER UNIVERSITY

Why are some subglacial eruptions more explosive than others?