

# Observations of the Eyjafjallajökull eruption

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May 2010

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The now-infamous Eyjafjallajökull volcano (pronounced A-ya-fyat-la-yok-utl) lies under one of Iceland's smaller glaciers in the south of the island (Figure 1). Since human settlement in 874, eruptions have occurred in 920, 1612 and from 1821 to 1823.

The Eyjafjallajökull volcanic event has so far exhibited four different stages: an effusive stage followed by a brief quiescence, an explosive stage and a further quiescent stage.

Following a sharp increase in seismic activity in late 2009 and ground deformation in February 2010 an effusive eruption from Eyjafjallajökull volcano began on 20 March 2010. This first effusive stage - known locally as the 'tourist eruption' - lasted until 12 April and was characterised by fountaining of basaltic lava from fissures in between the Eyjafjallajökull and Mýrdalsjökull glaciers (Figure 1). Ash ejection from this stage was small (< 4km column height) with an explosive force estimated to be no more than 1 on the Volcanic Explosivity Index (VEI)<sup>1</sup>.



Figure 1: Map showing the location of the two stages of the Eyjafjallajökull event, Katla volcano and the Red Cross support centre locations.

The explosive stage of the eruption began under the Eyjafjalla glacier in the early hours of 14 April with the eruption plume breaking through around 250m of ice approximately five hours later. The eruption was initially phreato-magmatic as ice was melted, with a steam plume coincident with the ash plume. The eruption later became purely magmatic

<sup>1</sup> The Volcanic Explosivity Index (Newhall and Self, 1982) provides a composite estimate of the explosive character of volcanic eruptions. VEI range from 0 to 8 on a logarithmic scale so that a VEI 5 eruption is ten times more explosive than a VEI 4 eruption. The volume of pyroclastic ejecta, duration and column height of the eruption alongside qualitative observations are employed to determine an eruption's VEI classification.

erupting more silicic and viscous trachy-andesite magma. Column heights in this stage have reached above 9km height with an estimated VEI of 4. A VEI 4 eruption may be expected to occur somewhere in the world every few years (Simkin and Siebert, 1994) and is not unusually powerful. On 23 May the Icelandic Meteorological Office reported that ash was no longer being ejected and the eruption appeared over. Seismographic data indicates that volcanic tremor has decreased almost to pre-eruption levels and GPS sensors indicate a continued horizontal displacement toward the centre of the volcano. This has been interpreted as showing no replenishment of magma is taking place; however further eruptions cannot be ruled out. The last Eyjafjallajökull event in December 1821 produced heavy ash falls in the first week of the event with intermittent ash emission over the next year until January 1823.

Long-duration ash emissions are common in the geological and historical record (Jenkins et al., 2007). The eruption of Soufriere Hills on Montserrat (1995-2003 and continuing) serves to highlight the devastating impact such an eruption can have on a community and economy. Today more than half of Montserrat, including the capital, remains an exclusion zone. Long-duration ash emissions from Eyjafjallajökull, including periods of quiescence, may similarly result in the abandonment of affected areas as well as the long-term disruption of aviation travel across Europe, with associated costs.

What made the Eyjafjallajökull volcanic activity so disruptive to air travel was the location of the volcano under the Jet Stream, the relative stability in wind conditions blowing ash towards Europe and the explosivity of the eruption. The glass-rich fine-grained ash was carried by the Jet Stream directly over northern Europe and into some of the busiest airspace in the world. Given the significant uncertainties associated with forecasting eruptions and wind conditions, reducing disruption to aviation in future ash emissions requires aircraft and engine manufacturers to better establish what level of ash their products can safely tolerate.

### **Our findings**

From 5 to 11 May, I travelled to Iceland as part of a Cambridge team investigating impacts associated with the explosive stage of the Eyjafjallajökull event. Our objectives were: 1) to investigate potential health impacts; 2) to collect water and ash samples for analysis and 3) to consider the impacts and emergency response associated with long duration continuous ash emissions. Assessment of eruption impacts and recovery over time is rare following volcanic events. One of the most important aspects of such studies is to collect baseline data: a further objective of our visit. We worked in collaboration with the Nordic Volcanological Institute, Icelandic Meteorological Office, Government departments of Civil Protection and Emergency Management, Agriculture and Air Pollution in Reykjavík, as well as local doctors, vets and farmers in the affected area. Here I provide an informal review of the eruption impacts and issues that I found interesting<sup>2</sup>.

Since the start of the explosive stage, winds have predominantly blown ash to the south and southeast of the volcano: directly towards Europe but away from most of Iceland and its population. The most affected strip of land is therefore relatively small, approximately 10km wide and 50km long. This area is home to around 200 farms and Vík, a town of approximately 400. The maximum depth of ash fall on affected farms around the volcano was a few centimetres (Figure 2).

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*Figure 2: Vegetation beginning to push through ash fall deposits in Seljavellir, approximately 10km southeast of the volcano.*

#### *Agricultural impacts*

For the farmers in the area, the timing of this explosive eruption has been particularly bad. May is one of the driest months of the year and ash resuspension by winds has been a major problem. The area needs rainfall to suppress the ash and to remove ash from grazing land, however there are also concerns that rain may generate lahars (mudflows of volcanic deposits) from the steep hills above many farms (Figure 3). Recent heavy rainfall on ash covered land led to a lahar in the Svaðbælisheiði river on 19 May which resulted in the greatest discharge at the Markarfljót river since the initial meltwater floods of 15 April.



*Figure 3: A farm approximately 8km from the vent with steep hills above that may generate lahars during heavy rainfall. Three hours and a wind change separate the two photos.*

During May Icelandic farmers work long hours lambing, calving and preparing fields for crops to be grown for next winter's feed. Farmers face the dilemma of sowing and fertilising all their seed assuming no return to eruptive activity or sowing less now and saving money to pay for winter feed assuming eruptive activity will continue.

Under normal conditions livestock and their new offspring would be put out to graze the higher lands over summer. With the ash fall this has not been possible and so livestock are currently kept indoors in increasingly crowded conditions. Due to controls on sheep movement because of disease it is not possible to relocate stock to another area in Iceland. An estimated 5% of livestock may be expected to die from overcrowding if they are kept in their winter dwellings; however there is no estimate of the percentage that would die if they were let out onto ash-covered pastures. Concerns for livestock health on pastures or water supplies exposed to ash fall arise from ingestion of ash or fluoride and the abrasive and chemical action of ash on skin or eyes.

By far the most important question for farmers has been: when will the eruption end? Should this quiescent stage mark the end of the eruption, rain will clean ash off the vegetation and life may return to normal rather quickly. However, if the Eyjafjallajökull event were to continue intermittently for months or even years farmers would need to slaughter significant amounts of livestock and it may quickly become economically (and psychologically) unfeasible to farm the area.

Following previous natural disasters in Iceland (avalanches in January and October 1995 that killed 34; earthquakes in June 2000 and May 2008 that injured more than 30), the Civil Protection department has developed a protocol for help centres to be set up in affected areas. The purpose of such help centres is to provide necessary equipment, such as facemasks, goggles and shovels in the case of eruption, and to offer advice: officials such as doctors, air pollution experts and members of Civil Protection frequent the centres. One of the most important accomplishments of the centres may be the support they offer the small, close-knit communities. Help centres have been established in Heimaland and Vík (Figure 1) with the support of the Red Cross and local volunteers. These help centres are considered a success with large daily attendance.

### *Health impacts*

The government has advised against being outdoors during ash falls and always to wear facemasks outdoors where ash has fallen. Some of the ash produced in the explosive stage of the Eyjafjallajökull event has an unusually fine-grained component, with more than 10% of the plume comprising particulate matter less than 10 microns ( $PM_{10}$ ) and 7% of the plume less than 2.5 microns in size ( $PM_{2.5}$ ).  $PM_{10}$  is considered an approximate size threshold for particles breathed into the thoracic (chest) area, with  $PM_{2.5}$  particles able to penetrate further into the respiratory system. As well as the particle size of ash, the electrical charge, presence of crystalline silica and toxic substances on the particle surfaces are important for human health impacts. Analysis of the ash is currently in progress. Finer respirable particles are likely to be the most toxic (Horwell and Baxter, 2006) and can increase the irritancy of ash in the airways and the likelihood of long-term respiratory impacts. Fortunately, facemasks were stockpiled in Iceland in anticipation of the swine flu epidemic and so suitable protection against breathing in ash particles is readily available and these have been distributed in the affected areas. Homes in Iceland are well sealed against the cold and so infiltration of ash is low. To limit ash resuspension in the town of Vík, efforts include wetting roads and imposing a speed limit. Exposure to ash over long periods, typically years to decades, may result in long-term respiratory effects. There are therefore concerns for the health of children and outdoor workers such as farmers should long-duration ash emissions continue from this volcano.

### *Infrastructure impacts*

Infrastructure damage is limited. Meltwater from the glacier flowed mostly to the north of the volcano down the Markarfljót river (Figure 1). Mitigation plans were already in place for meltwater floods of up to 400,000m<sup>3</sup> in this river following an eruption from Katla. Construction machinery for quarrying aggregate in the Markarfljót area were re-applied to preparing for the flood: levees were built to prevent flooding of local agricultural areas and roads were bulldozed to provide channels and to prevent adjacent (expensive) bridges being damaged. Impacts were therefore limited, with the main road rebuilt within days. Corrosion of metal from the toxicity of ash particles was limited to the initial phase of the eruption with very minor damage to machinery (Figure 4).



*Figure 4: Corrosion of new ploughing machinery at Porvaldseyri farm, approximately 8km southeast of the volcano. This corrosion took place overnight.*

### *The ominous neighbour*

Links between eruptions at Eyjafjallajökull and its much larger neighbour, Katla, have been suggested with the Icelandic President Ólafur Grímsson saying "the time for Katla to erupt is coming close ... it is high time for European governments and airline authorities all over the world to start planning for the eventual Katla eruption". In fact, while the three most recent eruptions of Eyjafjallajökull have been closely followed (< 1 year) by an eruption from Katla; a further 16 Katla eruptions have occurred without any eruption from Eyjafjallajökull. There is currently no change in activity at Katla, however the possibility for activity at Katla or for long-duration activity at Eyjafjallajökull and the consequences for aviation and the Icelandic population must be considered.

### **References**

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