Geofile Online
SEPTEMBER 2011
646

Jane Dove

The Icelandic volcanic ash hazard, 2010

In the spring of 2010, a volcano erupted under the Eyjafjallajökull ice cap in south east Iceland. The eruption, although relatively small, had a huge impact on air travel across northern Europe. This **Geofile** examines:

- the causes and nature of the eruption
- the impacts on Iceland
- why European air space was closed, and the impacts of the flight ban
- the eruption in the context of past volcanic events in Iceland
- lessons for the future.

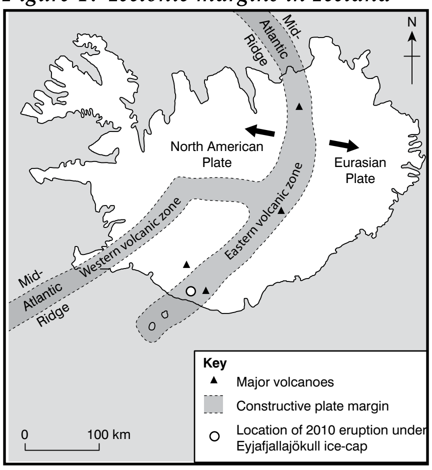
Figure 2: End of the eruption

Source: Emma Jones

Iceland is located in a tectonically active area. Tourists visit the island to view its dramatic volcanic landscapes, and geothermal resources supply almost a quarter of the country's energy needs. Volcanic eruptions, however, create multiple natural hazards.

The island is bisected by the northern part of the Mid-Atlantic Ridge, a constructive plate margin which is diverging by about 23 mm per year. Magma periodically rises between the plates to emerge at the surface as basaltic lava flows. Volcanic eruptions also produce large quantities of tephra – fragmented solid rock, ranging in size from large volcanic bombs to small particles of ash. Gases which exsolve from the magma, including water vapour, carbon dioxide and sulphur dioxide, are also released during eruptions, together with small quantities of hydrogen sulphide, carbon monoxide, hydrogen chloride and hydrogen fluoride.

Figure 1: Tectonic margins in Iceland



Volcanic activity is carefully monitored in an effort to reduce the hazards associated with eruptions. The measures include:

- observing changes in the temperature and composition of hot springs, groundwater and volcanic gases, which often alter before an eruption
- monitoring seismic activity, which increases prior to an eruption
- measuring ground deformation, ie alterations in the shape of the land surface which may suggest that magma is recharging the volcano
- studying past patterns of volcanic activity to identify recurrence intervals, ie likely time periods between eruptions.

Cause and nature of the 2010 eruption

The Eyjafjallajökull is an ice cap which partly covers a gently sloping, strato-volcano ie a cone composed of alternating layers of ash and lava, rising to 1666 m. This volcano and its nearby larger neighbour, Katla, are located in the Eastern Volcanic Zone, which forms part of the Mid- Atlantic Ridge (Figure 1). Not only is Iceland located on a plate margin, but it is also on a hot spot, ie an area where an abnormally hot volcanic plume of magma from the asthenosphere (upper mantle) rises to the surface.

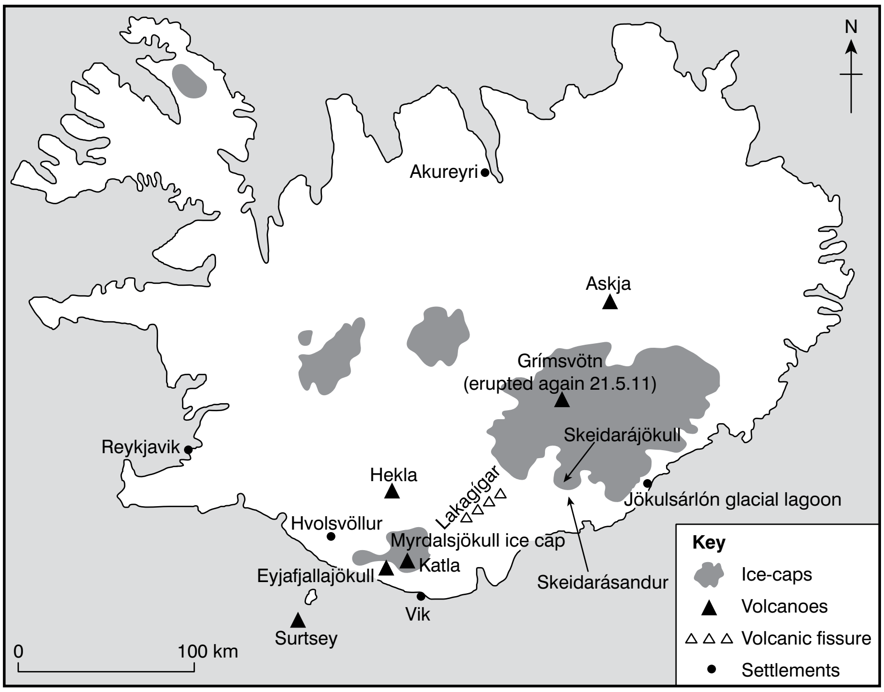
The Eyjafjalljökull volcano has erupted several times in the past, the previous major eruption occurring between 1821 and 1823. In the past, these episodes had been often followed by an eruption of Katla, a much more dangerous volcano.

Increased seismic activity in December 2009 was the first indication that the volcano was becoming more active. In February 2010, ground deformation was detected which suggested that magma was moving towards the surface, and earthquake activity continued to increase, supporting this supposition. The first eruption occurred on 20 March. Magma rose to the surface and was emitted from a number of vents on the flanks of the volcano in the form of lava flows.

Increasing seismic activity heralded the main eruption which began on 14 April. Unlike the March event, the second eruption occurred under the ice cap, which significantly increased its explosive power. The reasons for this were that heat from the eruption melted ice, which rapidly vaporised, and also ice quickly chilled the molten lava, causing it to fragment into highly abrasive, glass-like shards of ash, which were then carried up in the eruption plume. The explosive power of the eruption was sufficient to carry the ash 9 km into the atmosphere. The eruption was rated at level four on the Volcanic Explosivity Index (VEI), which has a range of zero to eight.

The eruption continued intermittently until 21 May, after which time lava stopped flowing and only steam was released (Figure 2). The eruption was officially declared to have finished on 28 October 2010.

Figure 3: Settlements, ice caps and volcanoes mentioned in the text



Impacts of the eruption on Iceland

The impacts on Iceland were:

- Flooding – heat from the eruption melted vast amounts of ice under the ice cap. Meltwater subsequently emerged from the edge of the ice cap as a glacial burst (or jökulhlaup), causing flooding. Local roads beside the Markarfljót river were washed away and 800 local people were evacuated because of the risk of flooding. During the main eruptive phase the road between Hvolsvöllur and Vík (Figure 3) was closed for several days. Engineers in some cases opened gaps in the road to allow meltwater to escape, to protect bridges from collapsing under the surge of floodwater.
- Disruption to farming – in order to prevent livestock eating grass or drinking water poisoned by fluorine-tainted ash, farmers were advised to keep their animals indoors. Pastures, which were just beginning to grow again after the winter, suffered where ash-fall was deep – more than 10 cm. Lighter ash-falls, however, were soon washed away by rain and caused little damage to the vegetation. In the longer term, nutrients released from the ash may improve soil fertility.
- Airport closure – ash-fall closed Keflavik (Reykjavík) airport from 23 April for several days, and a further shut-down occurred in mid-May. Passengers instead had to be bussed to Akureyri airport on the north coast of the island, which remained open – a long journey.
- Decline in air-quality – heavy ash-fall on 7–8 May caused schools in southern Iceland to close. People living in areas subject to heavy ash-fall were also told to remain indoors. Some people experienced minor health problems as a result of the ash-fall, such as eye irritations and dry throats. Those vulnerable to respiratory conditions such as asthma were advised to be vigilant. The effects, however, were short-lived.
- Mudslides (lahars) – ash mixed with meltwater and rain created mudslides or lahars. Mudslides falling into rivers raised channel beds, increasing the flood risk. Later in the summer, heavy rain falling on ash caused renewed concerns about flooding.
- Tourism – the impacts on tourism were mixed. Initially the eruption in March attracted tourists to Iceland. Tourist organisations quickly exploited the situation by offering helicopter, bus and jeep tours to view the eruption. By the end of March, 10,000 people had visited the eruption. Other attractions also benefited, for example at the glacial lagoon at Jökulsarlón (Figure 4), increased visitation was reported. After the main eruption on 14 April the ring road, as previously mentioned, was closed temporarily, which adversely affected attractions such as the waterfall and folk museum at Skógar and hotels and guest houses at Vík. However, day tours from Reykjavík to view the eruption, albeit from a safe distance, continued. The main impact was that the eruption closed air space across mainland Europe, preventing European visitors from going to Iceland.

Closure of European air space

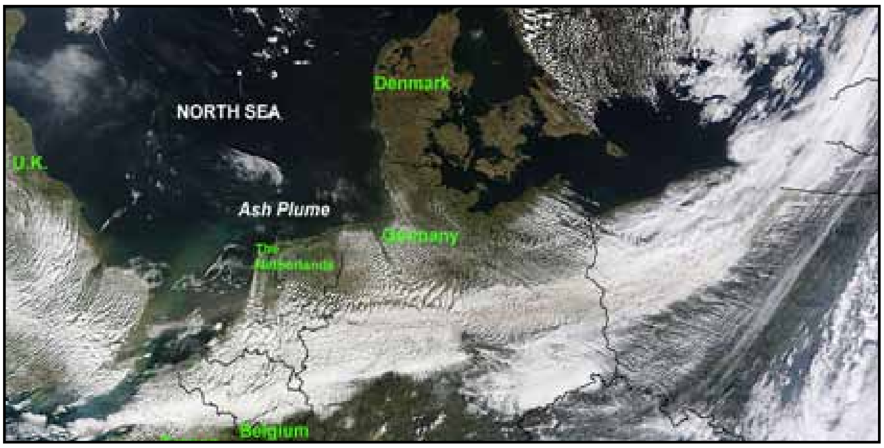
Cause of closure

The explosive force of the eruption carried the ash up into the path of the jet stream, a band of very fast, high altitude winds. The jet stream was particularly stable at the time, and the winds carried the ash in a south-easterly direction towards mainland Europe, into one of the busiest air spaces in the world. Civil Aviation

Figure 4: Glacial lagoon at Jökulsarlón with Vatnajökull in background

Source: Emma Jones

Figure 5:Satellite image of ash cloud over Europe, 16 April, 2010



Source: NASA

Authorities took the decision to close this air space because of concerns that the highly abrasive volcanic ash would damage aircraft engines, perhaps causing engine failure. The volcanic ash can also sandblast windscreens, reducing visual navigation. Over 20 countries closed their air spaces at some point, and the flight ban extended east to Russia and south to Spain (Figure 5).

Air space was closed over much of northern Europe between 15 and 20 April, causing severe travel disruption. Skies were opened again after the 20th as the result of more favourable winds, a decline in volcanic activity and intense lobbying by the airlines. Some further intermittent disruption, however, followed as winds again temporarily changed direction, which affected airports in Scotland and Ireland. As the main ash cloud drifted south over northern Spain, transatlantic flights had to be re-routed over Greenland, or south around Spain.

Impacts of the flight ban

The closure of air space had both economic and environmental impacts. While many businesses lost money, some profited from the situation. Although many of the effects of the flight ban were negative, some were also positive. The main impacts were:

- Losses in productivity – about 7 million passengers worldwide were stranded as the result of airport closures. Many of these were on holiday and unable to return to work, which left businesses without employees. One estimate put the loss in productivity at £400 million a day. The no-fly ban in Britain coincided with the end of the Easter holiday, and many teachers and pupils were unable to return to school at a time when public examinations were approaching.
- Air freight losses – most goods are transported by road, rail and sea, because of the high cost of air transport, and therefore were unaffected. Nevertheless, products such as pharmaceuticals, just-in-time deliveries of electronic devices, flowers and some exotic foodstuffs suffered. Hot-house flowers, for example, destined for European markets and worth an estimated £1.3 million, rotted in warehouses in Kenya.
- Tourism – the airline industry suffered large losses, estimated by the International Air Transport Association at £1.2 billion worldwide over six days. Airlines had no passenger revenue and also had to cover the cost of re-routing planes and paying for the care of stranded customers. In contrast, companies who offered alternative transport to stranded passengers, such as rail companies eg Eurostar, and cross-channel ferries, gained from the disruption. Car rental firms, taxis and bus companies also saw an increase in business.
- Tourist destinations, such as Florida, although receiving few European arrivals, still had stranded passengers unable to get home, who continued to spend money on accommodation and meals.
- Travel agents in the UK lost an estimated £6 million in business each day. The impacts continued into the summer period as potential travellers delayed booking holidays. Resorts in Greece, Spain and Portugal were particularly affected by reticent potential customers.
- Sporting fixtures and concerts were also cancelled, because players and performers were unable to reach their venues.
- Decline in aircraft air and noise pollution – the flight ban reduced aircraft carbon emissions over Europe. Some carbon dioxide was, however, released into the atmosphere as the result of the eruption. Britain at the time of the flight ban was experiencing anticyclonic weather conditions and blue skies. The blue colour of the sky appeared deeper than normal, because water vapour normally emitted from aircraft as contrails, which expands into cirrus clouds, was absent. Aircraft noise

near airports was also dramatically reduced, to the delight of local residents.

- Respiratory concerns – initially there were concerns that the ash would cause problems for people with respiratory conditions such as asthma. In the event, however, few cases were reported, because the dust was trapped too high in the atmosphere to cause ill health.

The 2010 eruption in context

In the context of previous volcanic eruptions in Iceland, that of 2010 was a relatively small-scale event. It took place, however, against a background of growing air traffic, and therefore caused massive travel disruption.

In comparison with the 2010 event, past Icelandic eruptions, from volcanoes such as Hekla, Katla, Grímsvötn and Askja (Figure 3), have been both more powerful and devastating. These eruptions have caused:

- Widespread loss of life and famine – eg in 1783–4, the Lakagígar fissure eruption killed 10,000 people – one-fifth of the Icelandic population – who died from inhaling poisonous gases, drowning, or later famine. Fluoride-tainted ash, which contaminated grazing land and water supplies, also resulted in the loss of 50% of the island's cattle and 75% of its sheep. Winds carried the ash cloud and poisonous gases across northern Europe, causing an estimated 20,000 deaths in Britain during the summer of 1783 due to famine.
- Just under 100 years later, the eruption of Askja, a strato-volcano in the central highlands, buried farms in ash and lava, contaminated grazing land and caused widespread famine and emigration from Iceland.
- Temporary falls in global temperatures – eg the winter which followed the Lakagígar eruption was exceptionally cold in both Europe and North America. Cooling occurred because sulphur dioxide produced by the volcano rose into the stratosphere, where it combined with water vapour to produce small droplets of sulphuric acid which then reflected and scattered solar radiation. Ash in the atmosphere, by scattering and absorbing incoming solar radiation, also had a cooling effect, but not to the same extent as the sulphuric acid droplets. The eruption in 2010 under Eyjafjallajökull did not, however, cause a decline in surface temperatures, because sulphur dioxide was not carried high enough into the stratosphere to have a cooling effect.
- Extensive flooding – eg in 1996, a fissure eruption melted ice under the Vatnajökull ice cap and water drained southwards through underground tunnels forming a lake in the Grímsvötn caldera. The lake subsequently overflowed and water moved sub-glacially to eventually break out of the ice margin at the snout of the Skeidarárjökull glacier. Fast-flowing water, laden with blocks of ice, then moved downstream, causing flooding. The bridge over the River Skeidará, part of an extensive outwash plain, was severely damaged by flooding, closing the ring road to Vík, a key regional centre. Fortunately there was no loss of life, the road having been closed as a precaution prior to the glacial burst.

The Grimsvötn volcano erupted again on 21 May 2011. Ash in the atmosphere resulted in the closure of Iceland's main airport and flight cancellations in Scotland and Germany, but travel disruption was short-lived.

Lessons for the future

Volcanic eruptions will continue to affect Iceland. The last major eruption of Katla occurred in 1918. It has a recurrence interval of between 40 and 80 years, which means another eruption is overdue. Katla and Eyjafjallajökull are symbiotic: in the past, if one erupts, the other tends to follow. In 2010 this was not the case. In 1918 it produced lava flows 10 times as great as those of 2010. Moreover, Katla is partly covered by the Mýrdalsjökull glacier, which means that a major eruption would be likely to generate huge quantities of ash and cause jökulhlaups (glacial floods).

Civil aviation authorities were criticised by airlines for closing air space too hastily and for too long during the 2010 eruption. They, however, argued that they had little choice, citing incidents over Java in 1982 and Alaska in 1989, when volcanic ash caused aircraft engine failure. The 2010 eruption has, however, encouraged research into:

- engine design
- the level of ash concentrations in the atmosphere deemed safe for aircraft to fly
- meteorological forecasting of ash movements during eruptions..

Insurance companies and airlines have also reviewed their policies regarding obligations to customers should a similar event occur again.

Should a future eruption coincide with a period of upper north-westerly air flow, it is probable that northern Europe will again witness major air travel disruption, the extent of which will depend on the scale and location of the eruption, the level of preparedness and research findings on ash cloud and engine design.

References

Einarsson, P. and Douglas, G. (1994). *The Geology of Iceland: Rocks and Landscape*, Iceland: Mal Og Menning.

Smith, K. and Petley, D. N. (2009) Chapter entitled 'Tectonic hazards: volcanoes' in *Environmental Hazards*, London: Routledge.

www.icenews.is/index.php/2010/04/16/general-update-on-the-volcanic-eruption
Icelandic newspaper documenting the eruption, 16 April 2010.

www.earthice.hi.is
Institute of Earth Sciences, University of Iceland – follow links to Eyjafjallajökull eruption.

Focus Questions

1. Summarise the hazards in Iceland associated with the 2010 eruption.

2. What are the wider impacts of Icelandic eruptions on the rest of Europe?

3. What were the similarities and differences between the 2010 event and past major volcanic eruptions in Iceland?