Jenny Jenkins

Daði Harðarson

Explosive Earth

Earthquakes and volcanoes in Iceland

The eruption of Bárðarbunga volcano in Iceland, July 2014

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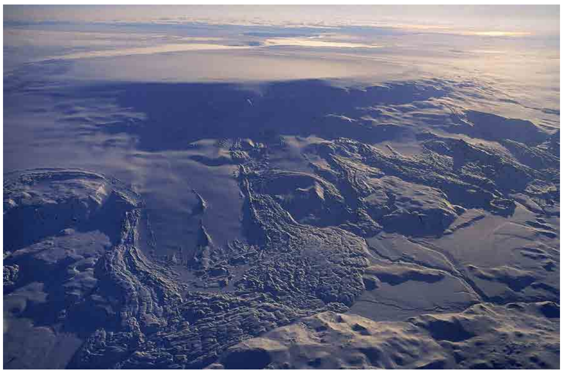
Bárðarbunga is a massive volcano located in central Iceland. It sits under 800 m thick ice of the largest glacier in the country. In July 2014 Bárðarbunga erupted but instead of lava erupting out of the top of the volcano the molten rock moved underground for nearly 50 km, and came to the surface on a sandy river flood plain.


The volcano of Bárðarbunga beneath the glacier

The eruption was spectacular, forming huge fire fountains as the molten rock was thrown over 150 m high into the air, glowing yellow-red due to its high temperature (over 1000 degrees). Lava was not erupted from a single central vent, but all the way along a crack in the Earth called a fissure. This was the largest eruption in Iceland in over 200 years with as much energy released as dropping a Hiroshima-sized bomb, not just once but every 2 minutes, hour after hour, day after day for 6 full months before the eruption finally stopped. By the time it was finished a massive area of 84 km^2 was covered by the fresh cooling lava flow – large enough to cover the whole of Manhattan. However this eruption was not very explosive or even particularly dangerous, since it happened in a deserted area of the Icelandic highlands.

Molten rock is known as magma when it is underground and lava when it comes to the surface.


Ragnar_Th_Sigurdsson
The fire fountain eruption of Bárðarbunga


Ragnar_Th_Sigurdsson
The extent of the lava flow from Bárðarbunga

For several weeks before the eruption, scientists knew Bárðarbunga volcano was restless and there was molten rock moving deep beneath the surface. We tracked the molten rock using tiny earthquakes as it moved from the volcano out to where it eventually erupted.

Tracking molten rock underground using earthquakes

When magma moves underground it cracks and fractures a path, forcing its way through the solid rock, causing thousands and thousands of tiny earthquakes. These are not the kind of earthquakes reported on the news that knock down houses and cause lots of damage, in fact they are so tiny a person can't even feel them. For earthquakes that small even to know they are happening we need very sensitive instruments called seismometers, which measure tiny changes in the motion of the ground.

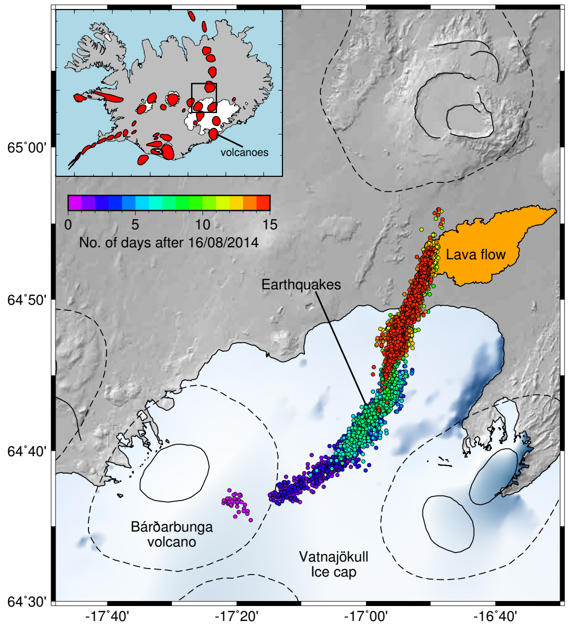
Setting up seismometers near the volcano

By recording the same earthquake with many different seismometers we can calculate where the earthquake must have originated. When an earthquake happens, seismic energy is released, causing the ground to shake. Vibrations spread outwards from the centre in all directions, just like when you drop a stone in a pond and see the ripples spreading out. By measuring how long it takes these seismic waves to reach different seismometers we can tell which ones are close to where the earthquake started and which are further away, and can pinpoint a location for the earthquake. Locating multiple earthquakes in this way can show us where molten rock is moving underground as it cracks its way forward.

Seismometers in Iceland

In Iceland around Bárðarbunga volcano the University of Cambridge had a network of around 70 seismometers used to record earthquakes. When the unrest at Bárðarbunga first started, teams of scientists rushed out over the rugged terrain using off-road vehicles to put out extra instruments, even flying up onto the glacier by helicopter to bury some in the ice.

From about two weeks before the eruption started our seismometers recorded over 30 000 tiny earthquakes. These earthquakes moved northwards over time allowing us to track the molten rock as it moved underground from under the volcano out to the eruption site. When the melt eventually came to the surface it erupted right in the middle of our instruments. This was very useful for getting really accurate locations of where the earthquakes come from. Unfortunately it also meant that two of our seismometers had to be quickly removed, to save their precious data from the advancing lava flow.



Earthquake locations tracking the underground movement of magma

Rescuing a seismometer as the lava flow approaches

Can we predict a volcanic eruption?

Predicting exactly when a volcanic eruption will happen is very difficult, because there are so many different factors which control how an eruption may develop, many of which are poorly understood. Even as molten rock was tracked using the locations of the earthquakes its movement produced, scientists didn't know how far it would go before coming to the surface to erupt or when that would be. Indeed it was possible that no eruption would happen and the melt would stay in the ground where it would slowly cool and solidify, becoming an igneous intrusion.

An igneous intrusion is rock formed from magma which has cooled underground without erupting to the surface.

Scientists couldn't say exactly when the magma would stop moving, but knowing whether it would erupt beneath the ice of the glacier or would travel far enough away that it could erupt outside the ice would have resulted in completely different styles of eruption. Being able to tell authorities what type of eruption is likely to occur and what sorts of hazards they need to be prepared for is extremely important, even if it's not possible to say exactly when it will happen.

The photograph on pages 10-11 shows an aerial view of lava flowing when Bárðarbunga erupted.


Daði Harðarson

Catalyst
www.catalyststudent.org.uk

A light aircraft carries scientists and their measuring equipment over the lava flow as Iceland's Bárðarbunga volcano erupts.

The earthquake magnitude scale – how big is a big one?

The size of an earthquake is defined by the magnitude scale. Big damaging earthquakes are usually magnitude 6 or larger, whereas the tiny earthquakes caused by magma movement are only around magnitude 1. This might not sound a lot smaller than a magnitude 6 but the earthquake magnitude scale is logarithmic. This means each time earthquake magnitude increases by one, 32 times more energy is released. So a magnitude 6 earthquake doesn't release 6 times as much energy as a magnitude 1, but around 33.5 million times as much.

Different eruptive styles

Molten rock in Iceland is usually very runny and fluid, which means gases in the magma can easily escape, leading to effusive fire-fountain style eruptions which are not very explosive or dangerous. But when an eruption happens under ice, everything changes.

Eruptions that happen beneath glaciers bring very hot magma into contact with very cold ice. The ice instantly melts or turns to steam and expands. In contrast, the hot magma is suddenly cooled and solidified into volcanic glass which is instantly shattered into tiny fragments by the expanding steam and thrown into the air. These tiny fragments of volcanic glass are what form volcanic ash. Glacial melt water can also cause catastrophic glacial outburst floods.

Lava can emerge from many points during an eruption.

Therefore the difference between an eruption happening underneath a glacier or at the surface can mean a change between an ash heavy explosive eruption and major flooding, or a gently effusive fire fountain type eruption. By tracking the magma movement from Bárðarbunga we could try and determine which of these scenarios was more likely.

Jenny Jenkins is a seismologist at the University of Cambridge studying the deep structure of the Earth beneath Iceland.

Just a handful of volcanic dust

Volcanic ash produced in sub-glacial eruptions doesn't seem very dangerous, it just looks like a handful of fine grey dust. But when ash in the air gets inside aeroplane engines it can become a major hazard. Plane engines can reach very high temperatures causing the volcanic ash to melt forming magma droplets. These droplets can get stuck to plane turbines and re-solidify, which can potentially stall the engine. Thus planes cannot fly through heavy ash eruptions.

This happened during another eruption in Iceland in 2010 when the volcano Eyjafjallajökull (pronounced: AY-JAH-FYAT-LA-YOK-KULT) exploded. Just like Bárðarbunga, Eyjafjallajökull sits beneath a glacier, but unlike Bárðarbunga the magma erupted out of the centre of the volcano beneath the ice, creating a very ash-heavy eruption. Winds blew ash from Iceland over European airspace which was forced to close. Over 100 000 flights were cancelled, leaving around 10 000 000 people stranded or unable to fly, and costing the aviation industry around $1.7 billion.

The Eyjafjallajökull eruption in 2010 caused widespread flight cancellations.

Look here!

Find out about volcanoes, earthquakes, and Iceland and what it's like to be a volcano seismologist on the Cambridge Volcano Seismology group webpage: *http://tinyurl.com/zyp4m9c*