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High-precision mapping of seismicity in the 2014 Bárdarbunga volcanic episode

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The Bárdarbunga volcano and its associated fissure swarm in Iceland's Eastern volcanic zone is a highly active system with over 20 eruptions in the last 11 centuries. The location of this active volcano and much of the fissure swarm under several hundred metres thick ice gives rise to multiple hazards, including explosive, subglacial eruptions and associated subglacial floods (jökulhlaups), as well as fissure eruptions extruding large volumes of lava.

After a decade of increasing seismic activity, volcanic unrest at Bárdarbunga suddenly escalated into a minor subglacial eruption on 16 August 2014. In the following weeks seismic activity soared and surface deformation of tens of cm were observed, caused by rifting and a dyke intrusion, which propagated 48 km northward from the central volcano (Sigmundsson et al., 2014). The dyke propagation stopped just outside the glacial margin and ended in a fissure eruption at Holuhraun at the end of August. At the time of writing the eruption is ongoing, having extruded a lava volume of over 1 km3 and released high rates of SO_2 into the atmosphere. Over twenty thousand microearthquakes have been recorded. Initially most were in the dyke, but after the first two weeks the activity around the caldera rim increased and over 70 shallow earthquakes with MW > 5 have been located along the caldera rim accompanied by caldera subsidence.

At the onset of the unrest on 16 August, the seismicity was located in the caldera and north of the caldera rim, but already in the first few hours the activity propagated out of the caldera to the SE. Still, the activity continued for a few days in the fissure swarm to the NE of the rim. High-precision earthquake locations in the propagating dyke have revealed its very detailed, planar rifting segments, with the events distributed over a 3-4 km depth range, and mostly between 6 and 9 km. These very planar event distributions are highly unusual in volcanic areas and strongly suggest rifting of unbroken crust as the magma intruded. The lateral propagation direction of the seismicity abruptly changes direction along each new segment, sometimes by up to 90 degrees and the propagation was sporadic, advancing with varying speed and sometimes stopping for periods of time. During these times of arrest, continuous low-frequency seismic tremor was sometimes recorded for several hours. A few days following these episodes, depressions appeared on the ice surface, confirming initial assumptions that the tremor was revealing temporary magma-ice interaction on the surface below the glacier.

Relative locations of microearthquakes around the caldera rim are much less constrained and their distribution is more diffuse. However, along the southern caldera rim, the events follow the linear trend of the rim and extend to a few km depth. At the northern caldera margin the distribution is more diffuse and appears to dip towards north.

An overview will be given of the high-precision locations in the dyke and around the caldera rim and estimation of absolute location accuracies in horizontal and vertical direction discussed. A joint interpretation of the best fitting focal mechanisms with the rifting planes, as defined by the event distribution in the dyke, will also be presented to show the lateral variation in the stress field orientation along the dyke. The high relative, lateral location accuracy in the dyke allows detailed examination of the temporal propagation so some examples of the temporal dyke advance will also be shown.

Sigmundsson and 36 others. 2014. Segmented lateral dyke growth in a rifting event at Bárðarbunga volcanic system, Iceland. Nature. doi:10.1038/nature14111.