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A Seismological Image of the Eyjafjallajökull Plumbing System during 2009-2010

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The 2010 flank and summit eruptions in Eyjafjallajökull, S-Iceland, which ended a nearly 200-year-long dormancy of the volcano and caused massive disturbance in flight traffic in Europe during April and May, were preceded by at least 16-18 years of intermittent volcanic unrest, characterized by repeated periods of crustal uplift and enhanced seismic activity.

The aim of our study was to use high-precision earthquake locations to track magma movements within the volcano during the 2009-2010 intrusive and eruptive episode. The earthquakes were recorded by the Icelandic national seismic network, SIL (Icelandic Meteorological Office), and relocated using a double-difference relocation method.

The several deep earthquakes detected near the crust-mantle boundary at the end of March 2009 were the first signs of the reawakening of the volcano. This subtle activity was followed by swarm activity, mainly concentrated at 9-11 km depth just east of the summit, and southward movement of a near GPS-station ($\sim$7 km south of the summit) during the following summer, which indicated the formation of a small intrusion in the upper crust, south of the summit crater. After the seismic activity picked up again in late December same year (again mainly at the 9-11 km deep cluster), it showed, along with complex crustal movements, that magma was again flowing into the upper crust. After mid-February and until 3 March, the partly southward migration of the earthquakes indicates that magma intruded beneath the south and south-eastern flank of the volcano between 4 and 8 km depth but on 4 March this pattern changed along with greatly enhanced seismicity and the foci started to delineate a westward dipping dyke, extending eastwards from the main cluster. Before the earthquake activity partly started to ascend towards the surface on 17 March, it showed activity at two distinct clusters just south and north from the dyke's eastern end. The earthquake distribution recorded during from 17 March until the beginning of the flank eruption on 20 March indicates the gradual ascent of magma from 8 km depth towards the surface along a nearly vertical channel located beneath Eyjafjallajökull's ice-cap but in the uppermost 2-3 kilometres the channel runs nearly 4 km horizontally towards the flank eruption site just east of the ice-cap.

Signs of renewed but very subtle seismicity near the small 2009 intrusion were already detected at 10-12 km depth during the flank eruption. However this activity, now mainly located at 5-8 km depth just SSW of the summit, increased rapidly 2-3 hours before the beginning of the summit eruption, and after a ML=2.3 event earthquake foci also clustered at 0-3 km depth.

The temporal and spatial pattern of the seismicity preceding the two eruptions agrees well with geodetic and petrological studies which show that the flank eruption was fed with primitive basaltic magma but the trachy-andesitic summit eruption was triggered by deeper rooted magma which hit a magma reservoir at shallow depth, located between 3 and 5 km depth according to our findings. Repeated deep seismicity in May followed by changes in the eruptive phase and/or increased plume height also indicates continued magma transport from below during the summit eruption.