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Seismic Signs of Magma intruding from the Crust-Mantle Boundary preceding and during two Intrusion Episodes in the Eyjafjallajökull Volcano, south Iceland

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The Eyjafjallajökull volcano is situated in south Iceland in the southeastwards propagating eastern volcanic zone. The volcano, which is elongated in the east-west direction and partly covered by an icecap, lies only a few kilometers west of another and larger icecap-covered volcanic system, Katla. Only two eruptions are known to have occurred in Eyjafjallajökull for the past 1000 years, in 1612 and 1821-23, and unlike Katla the volcano was fairly quiet seismically prior to the 1990's, when the SIL-network started detecting its activity. Between 1991 and August 2006 a total of 860 earthquakes were recorded in Eyjafjallajökull by the Icelandic SIL-seismic network. Three swarms occurred during the observation period: in 1994, 1996 and 1999-2000. The 1994 and 1999-2000 activity was accompanied by uplift centered at the southern rim of the ice cap and has been modeled using geodetic data, which inferred intrusion formation at 4.5-6.3 km depth. No deformation was detected during the increased seismic activity in 1996. The aim of this research is to analyze the seismic activity within Eyjafjallajökull to study the processes which caused the heightened seismicity and intrusion formations. The earthquakes are relocated using a multi event double-difference method and their mechanisms are analyzed.

The original locations formed a 3-km-wide chimney between 2 and 10 km depth beneath the northern flank of the volcano. A smaller cloud of events from the 1996 swarm was also apparent between 19 and 24 km depth and 2 km west of the main

cluster. After relocating the earthquakes, the chimney narrowed somewhat and shortened and the main activity separated into two depth ranges, 2-4.5 km and 8.5-11 km, where the event distribution formed a horseshoe like pattern. The deep activity also collapsed to a narrower formation between 20.5 and 23.5 km which is near the crust-mantle boundary of the velocity model used for the relocations.

Mechanisms have been recalculated based on the improved locations. The distribution of P- and T-axes of the optimum solutions was examined as a function of depth. There is considerable variation in the azimuthal direction of the axes, but dip is more stable. The T-axis is near horizontal in all but the shallowest depth interval (1.5-5 km). The P-axis also has a small dip in the deeper intervals, but its dip increases as the surface is approached. The deep cluster above the Moho shows a combination of strike-slip and normal motion mechanisms, with the T-axis predominantly oriented in the horizontal E-W direction and the P-axis in the N direction, indicating that divergence is the dominant factor close to the crust-mantle boundary. The Gutenberg-Richter relation was also examined as a function of depth. b-values for events occurring between 7 and 13 km depth was between 1.3 and 1.4, whilst the b-value for 17-26 km was much higher, between 2.4 and 3, probably reflecting the higher temperature at the bottom of the crust.

We suggest that the overall pipe-like pattern of the seismicity displays a feeding channel through the crust and that the deepest seismicity in 1996 indicates a period of intruding material from below, which fed the intrusion in the upper crust three years later, in 1999. Such deep seismicity is not common in Iceland but has been observed under the Heimaey fissure that erupted in 1973 (Westman-Islands), during the last year at Upptyppingar in the (northern volcanic zone) and recently close to the table mountain Hjörleifshöfði, only 25 km southeast of the Katla caldera. There, 10 microearthquakes were recorded at 23-24 km depth on 7 December 2007. Similar to Eyjafjallajökull, this deep seismicity may be indications of future intrusive activity beneath Hjörleifshöfði, or even magma movement towards the active Katla system, which already is overdue.