ANATOMY OF MELT INTRUSION AT 15–18 KM DEPTH BENEATH UPPTYPPINGAR, ICELAND

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Abstract

An extended sequence of micro-earthquakes at 14–22 km depth near Upptyppingar in the northern volcanic rift zone of Iceland has been attributed to the injection of melt into the crust (Jakobsdóttir *et al.*, 2008). The main sequence lasted more than 2 years, starting in February 2007 and extended over an area of ~50 km^2. A reduced level of activity continues to the present day. We use data from a detailed array of 26 seismometers deployed around Upptyppingar to investigate one of the most intense periods of seismic activity during July–August 2007.

Upptyppingar is located within the NW edge of the fissure swarm that occupies part of the Kverkfjoll volcanic system. The crustal thickness is ~30 km, (Darbyshire *et al.*, 2000), with the thick crust caused by the underlying Iceland mantle plume. The deep earthquakes occur in the normally ductile and aseismic region of the crust in response to locally high strain rates created by melt injection.

We deployed and operated a network of twenty broadband (0.03–50 Hz) Güralp 3-component CMG-6TD seismometers, supplemented by six Icelandic SIL network 3-component Lennartz LE5 seismometers (0.2–40 Hz). The Continuous Microseismic Mapping algorithm (Drew, 2009) was used to search in time and space using a signal onset function for event detection and initial location. A linear velocity-gradient crustal model was derived from seismic profiles within the Askja region and RRISP results (Angenheister *et al.*, 1980; B. Brandsdóttir, pers. comm.) supplemented by surface wave analysis of noise recorded across the seismometer array (Drew, 2009).

Over 2,000 events were detected between 6 July – 22 August 2007. The largest was a *M*L 2.2 earthquake on 21 July, at a depth of 15.5 km. The fault plane solution of the largest earthquake shows a thrust event on an east-west plane which is dipping southward at 55º. This is the same as the orientation of the dyke inferred from the hypocentres over a much longer period, and over a bigger depth range than our snapshot in July–August 2007. Numerous other fault plane solutions show the same thrust orientation on this southward dipping plane. We interpret these as due to melt injection into chilled lavas of the dyke. Swarms of such events typically occurred over a period of a few hours.

Abundant shallow seismicity in the top 7 km of the crust occurs where the crust is sufficiently cold to fail by brittle fracture under extension. It exhibits normal tectonic faulting caused by extension in the rift. T-axes of the fault plane solutions from the shallow seismicity align closely with the spreading direction of 106º. There is a distinct gap in the depth of seismicity between this upper brittle failure and the deep crustal events. Micro-seismicity in the lower crust which is normally ductile is attributed to locally high strain rates caused by melt injection.

Detailed micro-earthquake locations together with fault plane solutions constrained by both polarities and amplitudes show that the fracture is dominantly by double-couple mechanisms and is remarkably consistent between events. The melt injection occurred in dense swarms, and we were able to track the melt from individual injection events as it moved upwards and laterally through the dyke.

The deep seismicity in the Upptyppingar region coincides in time with similarly deep seismicity in the adjacent Askja rift system, for which a similar origin of melt injection into the normally ductile lower crust has been postulated (Soosalu *et al.*, 2009). It is possible that the enhanced seismic and melt movement activity in the two regions is related.

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