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Failure mechanisms during melt injection along dykes in Iceland

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We show moment tensor solutions from seismicity produced during two extremely well monitored dyke injections in the mid-crust of Iceland. They demonstrate failure by double couple mechanisms with little or no volumetric component. The inferred failure planes are consistently orientated parallel to the dyke, from which we infer that the seismicity is produced primarily by breaking chilled magma emplaced during an earlier injection episode.

The first dyke injection was at Upptyppingar in 2007 in the Northern Rift Zone of Iceland. Melt was injected in the mid-crust from 17.5 to 13.5 km depth over a 9 month period before freezing in situ. The dyke was inclined with a dip of approximately 50 degrees. The second dyke was injected sub-horizontally from Bárðarbunga at a depth of about 7 km over a two week period in late August 2014 until it erupted 45 km away in Holuhraun. The Holuhraun eruption precisely reoccupied old craters from a late eighteenth century (c. 1797) eruption. The petrology of the eighteenth century basalts suggests that the melt also came from Bárðarbunga. It is likely therefore that the 2014 dyke closely followed the earlier eighteenth century dyke path.

Both dyke injections were monitored by a dense seismic network of broad-band three-component seismic stations deployed and operated from 2006 to the present by the University of Cambridge in collaboration with the Institute of Earth Sciences, University of Iceland. These enable well constrained hypocentral locations and moment tensor solutions to be made. At its present peak the network consists of over 75 broadband seismometers. Fifteen additional seismometers were deployed in the days immediately following the onset of the dyke injection, including four seismometers on the Vatnajökull ice cap beneath which the dyke propagated and the remainder on Holuhraun surrounding the eventual eruption site: indeed two of the seismometers had to be rescued shortly before they were encroached by the advancing lava in the days following the onset of the eruption. The opportunity to deploy seismometers directly above the dyke and around the dyke tip mean that the earthquake locations are unusually well constrained.