Geophysical Research Abstracts
Vol. 17, EGU2015-5854-1, 2015
EGU General Assembly 2015

Earthquake focal mechanisms associated with dyke propagation and caldera collapse at the Bárðarbunga volcano, Iceland

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The dyke intrusion at the Bárðarbunga volcanic system which started on 16 August 2014, as well as the subsidence of its caldera were accompanied by an intense seismic swarm along the propagation path of the dyke and around the caldera ring fault. In this study we analyse focal mechanisms of both clusters, along the dyke and around the caldera rim, to reveal driving forces of the seismic and volcanic activity. Full moment tensors are determined for events larger than M_w 4.5 to obtain more complex mechanisms, especially for earthquakes associated with the caldera collapse.

Within the first two weeks between the onset of the seismic swarm and the opening of the first fissure eruption, an approximately 45 km long dyke migrated northeastwards from the caldera to the eruption site a few kilometers outside the glacier margin of the Vatnajökull ice cap. The dyke propagated with irregular velocities, alternating phases of arrest and spurts were accompanied by thousands of earthquakes of magnitudes up to M_w 4.5. The focal mechanisms range from strike-slip to normal faulting around the dyke, with a stable tension axis perpendicular to the dyke. Seismicity along the intrusion was driven by tensional stresses accumulated in the shallow crust and pressure induced by the magma intrusion itself. This assumption is supported by the significant drop of activity following the onset of the fissure eruption.

In contrast, the seismic activity around the caldera rim remains at high levels since the onset of the crisis while the underlying magma reservoir continues deflating. The caldera floor of Bárðarbunga has subsided by around 60 m since August. The strongest earthquakes on the ring fault reached up to M_w 5.7 and several dozens of events were larger than M_w 5. A moment tensor inversion of these events revealed consistent steep normal faulting with a significant compensated linear vector dipole component (CLVD). This mechanism can be explained by two different models: (1) A rupture propagating along at least 120° around the ring fault. While the movements on each element on the fault is purely double-couple, all movements sum up to a CLVD mechanism due to the curvature of the ring fault. (2) A joint mechanism of double-couple movements on the fault and a vertical single force linked to volume decrease in the magma reservoir and the resulting collapse of the caldera.

The results of this study help to understand the dynamic processes during the dyke propagation and the caldera collapse. Especially the observation of such a large number of $M_w > 5$ earthquakes related to a caldera collapse is globally rare and the complexity of the derived solutions calls for a deeper analysis of the involved mechanisms.