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Investigating the response of seismic anisotropy in the crust to the 2014–15 Bárðarbunga-Holuhraun dyke intrusion and eruption

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Existing evidence points towards the evolution of magmatic intrusions being a complex function of both existing structures and the stress state within the crust. Consequently, developing means to make in-situ measurements and effective models of these two factors would provide crucial insight into the dynamics of volcanic systems, feeding forward to volcanic monitoring and crisis response agencies. Seismic anisotropy—the directional dependence of seismic wavespeeds—has been shown to be a direct proxy for the in-situ stress state of the crust, as well as the existing fabric, but its potential for further developing our general understanding of magmatic intrusions has yet to be realised. The wealth of geophysical data recorded during eruptions in the last decade presents a unique opportunity to explore these important natural phenomena in exceptional detail.

We first establish a general model for the bulk properties and structure of upper crust in the central highlands of Iceland by analysing shear-wave splitting (SWS), a common and near-unambiguous indicator of seismic anisotropy. Using this model as a starting point, we subsequently explore the evolution of seismic anisotropy before, during, and after the 2014–15 Bárðarbunga-Holuhraun dyke intrusion and eruption. Seismicity associated with this magmatic intrusion was used to capture the spatial evolution through time of this event in unprecedented detail. Persistent seismicity at “knot points” along the path of the dyke intrusion allow us to negate the effect of changes to source-receiver path on the measured variations in seismic anisotropic properties.

Our preliminary work suggests the far-field response of seismic anisotropy to the intrusion can be explained by existing models relating the stress field to the orientation of the fast direction. It is apparent, however, that this simple model fails to explain sufficiently our observations in the near field. Whether this is due to shortfalls in the stress modelling, the influence of the presence of melt along the raypath, or potentially a breakdown in the established relationship between stress and seismic anisotropy remains unclear.