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The importance of pre-existing structures and stresses to dike-induced earthquakes: The 2014–15 Bárðarbunga–Holuhraun rifting event, Iceland

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One of the most important tools available to observe dike intrusions is to detect and locate the seismicity they generate. However, the hypocentral and geodetic resolution achieved thus far has not been sufficient to deduce the exact relationship between the extent and opening of a dike and the earthquakes generated, limiting the insight that can be gained. During the 2014–15 Bárðarbunga-Holuhraun rifting event, Iceland, intense seismicity accompanied the intrusion of a ∼50 km lateral dike which culminated in a 6 month long eruption. Relocation of these dike-induced earthquakes using cross-correlated, sub-sample relative travel times recorded on a dense local seismic network has achieved unprecedented (∼100m) spatial resolution, allowing us to address this issue. The location data is combined with tightly constrained fault plane solutions derived from manual phase polarity picking to assess the geometry of the faulting.

Fault plane strikes vary along the dike path in correlation with a gradual change in the orientation of the rift fabric, with the slip-sense (right- or left-lateral) determined by the strike of the dike with respect to the fabric. This agrees with the independence of fault plane strikes from hypocentre lineations observed at smaller (∼1 km) scales, showing that pre-existing weaknesses control the orientation of faulting. We model the coulomb stress change induced on these faults by dike opening of a realistic geometry as constrained by geodetic studies of the distal ice-free dike segment, where InSAR observations may be made. This clearly demonstrates the influence of pre-existing stresses in the crust on the seismic productivity of the dike intrusion, alongside spatial variations in mechanical properties.

By comparing this exceptionally well resolved example of a seismic swarm caused by dike intrusion with others in Iceland and worldwide, we reflect on the general lessons which may be learned about the key factors controlling earthquake swarms associated with magmatic intrusion in the brittle crust.