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Slowly migrating tectonic microearthquake swarms in the Icelandic Rift Zone: driven by pore-pressure or aseismic slip transients?

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Intense swarms of microearthquakes have been detected in the rift zone of Central Iceland since the 1970s, but the cause of their clear swarm-like nature remains enigmatic. We use the QuakeMigrate earthquake detection and location software[1] to produce a highly complete catalogue of microseismicity from 2007-2020, using data from a dense local seismic network. Automatic hypocentre locations have been refined using waveform cross-correlation and double-difference relocation, and tightly constrained focal mechanisms have been obtained by manual analysis of a subset of events.

The resulting high-resolution earthquake catalogue reveals a network of conjugate strike-slip faults, oriented to accommodate plate-boundary extension. Sharply defined fault planes imaged by the microearthquake hypocentres range from 1-10 km in length, and are found between 1 and 8 km b.s.l., with their orientations closely matching the fault plane geometry inferred from the fault plane solutions. Seismicity within individual swarms displays a systematic migration of hypocentres at velocities of ~ 1 km/day. In the majority of swarms we also observe clusters of identical repeating events, providing evidence for re-loading of brittle asperities.

For a selection of swarms our high resolution seismic observations are complemented by GPS and InSAR measurements, allowing us to place constraints on the amount of fault slip. Comparing this, and the area of the fault plane activated in the swarm, to the seismic moment release reveals a significant contribution of aseismic slip, or very low effective stress drop. Analysis of swarms within this fault network triggered by the 2014 Bárðarbunga-Holuhraun dike intrusion provides further constraint on the amplitude of the stress cycle.

We combine our observations with comparisons to numerical & laboratory modelling studies, observed swarm scaling properties and knowledge of the geological and permeability structure of the Icelandic crust to determine the nature of the transient forcing driving these exceptionally well-recorded tectonic earthquake swarms.

1: https://github.com/QuakeMigrate/QuakeMigrate Tom Winder, Conor Bacon, Jonathan D. Smith, Thomas S. Hudson, Julian Drew, & Robert S. White. (2021, January 15). QuakeMigrate v1.0.0 (Version v1.0.0). Zenodo. http://doi.org/10.5281/zenodo.4442749