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Imaging the temperature beneath Ireland and Britain using massive, broadband surface-wave datasets and petrological inversion

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Deep geothermal resources in low- to medium-temperature settings remain poorly understood and untapped in Ireland and much of Europe. Our new project DIG (De-risking Ireland's Geothermal Potential) integrates multi-disciplinary, multi-scale datasets in order to investigate Ireland's low-enthalpy geothermal energy potential. Seismic measurements constrain the distributions of seismic velocities and, through them, the composition and temperature within the lithosphere and underlying mantle. Recent deployments of broadband seismic stations and the surface-wave measurements using the new data yield an unprecedentedly dense data sampling of the crust and upper mantle beneath Ireland and neighbouring Britain. These data form a foundation for the region-scale, multi-parameter modelling of the thermal state of the lithosphere.

We use the recently assembled dataset of over 11,000 Rayleigh-wave, phase-velocity curves, measured for pairs of stations across Ireland and Britain (Bonadio et al. 2021) and complement it with new interstation measurements of Love-wave phase velocities. The measurements were performed using two methods with complementary period ranges, the teleseismic cross-correlation method and waveform inversion. Spanning a very broad period range (from as short as 4 s to as long as 500 s), the phase velocities provide resolution from the upper-middle crust to the asthenosphere. The joint analysis of Rayleigh and Love measurements constrains the isotropic-average shear-wave velocity, relatable to temperature and composition. The optimal-resolution, phase-velocity maps of Bonadio et al. (2021) for Rayleigh waves and the new maps for Love waves computed in this study provide essential constraints on the thermal structure of the region's lithosphere. We demonstrate this by inverting the data using an integrated geophysical-petrological thermodynamically self-consistent approach (Fullea et al., 2021). The multi-parameter models produced by the integrated inversions fit the surface-wave and surface-elevation data and reveal the temperatures and geothermal gradients within the crust.

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