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Exploring Geothermal Energy Potential in Ireland through 3-D Geophysical-Petrological Modelling of Surface Heat-Flow and Crustal and Upper-Mantle Structure

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Little is known of Ireland's deep, low-enthalpy geothermal resources and the potential for space heating and/or electricity generation based on geothermal energy to displace Ireland's significant reliance on carbon-based fuels. IRETHERM (www.iretherm.ie) is a four-and-a-half year, all-island, academic-government-industry collaborative project, initiated in 2011, with the overarching objective of developing a strategic and holistic understanding of Ireland's geothermal energy potential through integrated modelling of new and existing geophysical and geological data.

One of the challenges in searching for deep geothermal resources in the relatively unexplored setting of Ireland lies in identifying those areas most likely to support significantly elevated temperatures at depth. Available borehole data, although sparse and clustered around areas of mineral and hydrocarbon interest, suggest a marked regional increase in surface heat-flow across Ireland, from $\sim$40 mW/m2 in the south to >80 mW/m2 in the north. The origins of both the observed regional heat-flow trend and local temperature anomalies have not been investigated and are not currently understood. Although variations in the structure of the crust and lithosphere have been revealed by a number of active-source seismic and teleseismic experiments, their effects on surface heat-flow have not been modelled. Bulk 3-D variation in crustal heat-production across Ireland, which may contribute significantly to the observed regional and local temperature variations, has also not been determined.

We investigate the origins of Ireland's regional heat-flow trend and regional and local temperature variations using the software package LitMod. This software combines petrological and geophysical modelling of the lithosphere and sub-lithospheric upper mantle within an internally consistent thermodynamic-geophysical framework, where all relevant properties are functions of temperature, pressure and chemical composition. The major regional controls on surface heat-flow and crustal temperatures are (a) crustal thickness, (b) crustal heat-production and (c) lithospheric thickness. These unknown geological variables are modelled in LitMod3D against geophysical observations at surface – heat-flow, topography, gravity and geoid data – to identify a crustal and lithospheric-mantle model that satisfies and accounts for all the observations at surface (most importantly in our context, heat-flow). We present a range of 3-D crustal and lithospheric-mantle models that satisfy all observable constraints and account for the regional sources of heat in Ireland. These models provide the basis for isolating local temperature anomalies and for assessing the extent to which local lithological variation in heat-production and thermal conductivity affects the distribution of temperatures in our target depth range of 2000 - 6000 m. Significant, well defined temperature anomalies that emerge from this work will be targeted for further assessment during IRETHERM's planned field program of magnetotelluric and controlled source electromagnetic surveys.