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The contribution of heat production studies to geothermal exploration in Ireland

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The upper crust under Ireland includes several thick Carboniferous sedimentary sequences where measured geothermal gradients are, for the most part, moderate ($<25^{\circ}$C/km), though viable sources of geothermal energy may exist beneath them.

Exploration for deep-drilled geothermal energy can benefit from knowing the variation in heat production rates (HPR) in 3D. Generally extrapolation in depth is challenging. However, Ireland is fortunate in this regard since the surface geology provides a series of quasi-3D sections as a result of several episodes of exhumation by folding and faulting during the Caledonian and Variscan orogenies and subsequent erosion. Effectively, measurements of HPR at outcrop are a valid proxy for rocks at depth. By extrapolating the HPR of the major stratigraphic units combined with a consideration of structural geology, borehole data and geophysical data, a 3D model of the Irish upper crust is in progress.

The first step towards achieving this has been to calculate heat production rates of rocks exposed at the surface and obtained from drilling, including buried granitoids. Published whole-rock geochemical data have been combined with new analyses, using XRF and field-based gamma-ray spectrometry, to establish radiogenic element compositions of a wide range of crustal rocks from across Ireland. Concentrations of uranium, thorium and potassium, along with rock density measurements, have been used to determine the heat production rate using the calculation: HPR = $10^{-5}\rho$ (9.52 C_U + 2.56 C_{Th} + 3.48 C_K) (Rybach, 1988).

In this way, over 3,000 data have been used to produce a map of bedrock radiogenic heat production. The data show that heat production generally corresponds to variation in lithology. Of the large volume lithologies, basalts yield the lowest HPR with a mean of 0.5 μW/m^3 and, as might be expected, granitoid rocks are generally hotter than other major lithologies. For example, unit G4 of the Cenozoic Mourne Granite records the highest mean HPR of granitoids of 7.64 μW/m^3. Other high heat production rates are found in the Costello Murvey Granite in the west and the Carnsore Granite in south-east Ireland. By contrast, the high-volume, late Caledonian Leinster Granite has a much lower HPR, ranging from 1.19 to 4.69 μW/m^3. The variation in heat production of granitoid rocks is shown to be attributable to petrogenetic parameters although a correlation with crystallisation age is also apparent.

The highest mean heat production rate in Ireland of 24 μW/m^3 is recorded in the Clare Shale Formation in the west of Ireland. This comprises high-uranium, phosphatic shales of Upper Carboniferous age which are likely laterally extensive, though only up to 180m thick.