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

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Why are we interested in the subsurface temperature in Britain and Ireland?

**The Irish Times**

Geothermal energy could be new heat source for Ireland, reports show

Heat from beneath Earth's surface could be used in buildings, while decarbonising heat sector

**Daily Echo**

Southampton celebrates 25 years of geothermal District Energy Scheme
How can we map the geothermal gradient?

Directly
• Boreholes

Indirectly
• Seismic imaging
• Geophysical-Petrological inversion
• Magnetotellurics

Mather et al. 2018
Lithospheric vs Crustal model for Geothermal

• Surface heat flow arising from 2 main sources
  - Crust
  - Mantle

• Earth’s temperature rises from the surface to the core.

• Can have geothermal heat almost anywhere in the world

• Low enthalpy geothermal most efficient in heating systems

Figure credit: Alamy

Mallow warm spring. From Goodman et al. (2004).
DIG - De-risking Ireland’s Geothermal Potential

Primary Objective - De-risk borehole drilling costs to promote geothermal energy.

- Creation of a reliable geothermal resource map of Ireland
- Determine the regional geothermal gradient in Ireland
- Investigate the thermo-chemical crustal structure and secondary fracture porosity within the Upper Devonian Munster Basin
- Identify and assess the available low-enthalpy geothermal resources at reservoir scale in the Munster Basin
Regional Seismic Tomography

Rayleigh Dispersion Curves

Bonadio et al., GJI 2021

Love Dispersion Curves

This study

Based on Bonadio et al., GJI 2021
Phase Velocity

Shear Velocity

RAYLEIGH & LOVE PHASE VELOCITY MAPS

Rayleigh

Love

SHEAR VELOCITY MAPS

Bonadio et al. 2021

Δcl/c = [3.66, 4.23 km/s]

ΔV_s / V_s (%) - [3.38, 4.70 km/s]

ΔV_s / V_s (%) - [4.34, 4.52 km/s]
Geophysical-Petrological Inversion

- Use a joint geophysical-petrological inversion (Fullea et al. 2021).

- Input:
  - Phase velocity
  - Surface Heat Flow
  - Elevation

- Inversion Output:
  - Temperature
  - Composition
  - Density
  - Shear velocity
Geophysical-Petrological Inversion

Average for all of Ireland

- Temperature (°C)
- Density (kg/m^3)
- Vs (km/s)
- Al₂O₃ (wt%)
Results

• Massive, new Rayleigh and Love surface wave datasets.
• New insights into the lithospheric structure (Bonadio et al. GJI 2021).
• Isotropic average shear-wave velocities related to temperature and composition
• Isotropic average shear-wave velocities, related to temperature and composition
• Multi-Parameter models of Ireland from the petrological inversion
• Inversion framework that can also incorporate MT, ambient noise data and other datasets.

Goals

• 3D petrological-geophysical, self-consistent model across Ireland
• Geothermal gradient map
• Identify areas of high heat flow for further geothermal exploration
• Fine-scale MT and seismic surveys in areas of particular interest (Mallow warm springs)

Mallow warm spring (19.5 °C ± 2.5 °C)
From: Goodman et al., 2004
Conclusions

• Low enthalpy geothermal systems can be used at most locations around the world

• Mapping the geothermal gradient requires a lithospheric model, not just a crustal model

• Geophysical-Petrological inversion: combines seismic and other data and outputs temperature, composition, density, seismic velocities

• DIG project: creating a temperature and geothermal resource map of Ireland
Conclusions

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• Geophysical-Petrological inversion combines seismic and other data and outputs temperature, composition, density, seismic velocities.

• DIG project: creating a temperature and geothermal resource map of entire Ireland.

For the latest updates on the DIG project visit: www.dig-geothermal.ie

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