UK GeoEnergy Observatories

NERC ideas workshop, 27th February 2019

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What are the UK Geoenergy Observatories?

£31 million BEIS-funded, UKRI-NERC research infrastructure across 2 sites to:

• Independently monitor underground energy technologies

• Gather scientific evidence on new and established energy and storage technology to increase efficiency and sustainability

• Gain a world-class understanding that could support management and regulation

• Develop innovative, exportable technology and expertise
Why do we need UK Geoenergy Observatories?

Low carbon transition

Making power cleaner

Dealing with intermittency

Storing energy better

Decarbonising heat

Achieving our commitments

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The underground is vital for the ‘low carbon transition’

Energy
- Geothermal hot dry rock
- Geothermal district heating
- Geothermal minewater heating
- Shale gas

Disposal
- Carbon capture & storage

Storage
- Compressed air energy storage
- Hydrogen storage

• How much potential is there?
• Can these technologies be done sustainably?
• Both of these are science questions…So we need the facilities to answer these questions

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Design of the facilities
UK Geoenergy Observatories Research Model

- BGS Keyworth Core scanning facility
- UK GeoEnergy Observatories web portal
- Glasgow Geothermal Energy Research Field Site
- Cheshire Energy Research Field Site
UK Geoenergy Observatory locations

Glasgow Geothermal Energy Research Field Site (GGERFS)

Cheshire Energy Research Field Site (CERFS)

Cuningar Loop, looking west (photo © Claire Ferguson/Clyde Gateway URG)
Glasgow Geoenergy Observatory

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Glasgow Geothermal Energy Research Field Site

- Provides research infrastructure to de-risk key geological questions that currently hamper the widespread development of low temperature geothermal energy (including heat storage).
- Improve understanding of the resource and factors critical to the successful long-term development of mine energy systems, e.g.
  - the longevity and sustainability of the resource and the hydrogeochemistry of mine waters through time
  - risks associated with drilling into the mine workings
  - the existence of subsurface-surface connections
  - the significance for environmental protection
What is mine water geothermal (and heat storage)?

**Heat pumps**

**Getting heat from the ground**

The interior of the Earth is hot, so the deeper you go, the warmer it gets. Water in flooded mine workings absorbs this heat – if we can extract it, we might be able to harness this energy to heat our homes.

1. Water is extracted from flooded mine workings underground and brought to the surface. This water is warm because it has been heated by geothermal energy.
2. The minewater is pumped into homes where its energy is extracted and used to power a heat pump (see right hand side of poster).
3. The used (and now cooler) minewater is pumped back underground – far enough away from the extraction point to ensure it doesn’t cool down the water we want to extract.
4. The returned water slowly filters back through the flooded mine system and warms back up. The research we will be carrying out will find out if extracting geothermal energy in this way is safe and efficient enough to be worthwhile.

**Using minewater to heat your home**

A device called a heat pump can turn warm groundwater into water that is hot enough to heat your radiators or fill a bath.

1. Warm groundwater (around 10-15°C) is pumped into a tank.
2. A liquid called a refrigerant is pumped through tubes in the water tank. Heat from the groundwater turns the liquid into a gas and the groundwater cools.
3. The cooled groundwater is pumped away and reinjected underground to be warmed up again.
4. The gas then passes through a compressor which heats it to around 50°C. Although the compressor uses some electricity, you get out about 4 times as much energy out of the heat pump as you put in.
5. The hot gas is pumped through a water tank. It heats up the water and the gas cools.
6. The cooled gas turns back into a liquid and returns to be heated up again.
7. The hot water is used to heat the house and then returned to the heat pump for reheating.
Generic questions: characterising & monitoring subsurface through change e.g.

- Characterising a complex, heterogeneous and evolving rock mass
- Transmissivity, temperatures in mining waste, voids, fractures....
- Biogeochemical response to artificial perturbations
- Mine water chemistry changes Geomicrobiological changes
- Surface-subsurface interactions and impacts
- Monitoring effects on brownfield sites

Risk & uncertainty-based questions e.g.

- Clogging of pipes and pumps
- Partitioning of flow
- Thermal breakthrough
- Pathways to surface
- Type of mine working
- Sustainability of flow
An example – mine geology/hydrogeology

Potential variability in mine workings. NOT the known geology/hydrogeology on site (e.g. there is not a known shaft between borehole locations)

Inject a heat or chemical tracer here

Does it get here? How long?
Introduction to the Glasgow Geothermal Research Field Site

Glasgow City Centre

Cunigar Loop
Target Geology

Heterogenous, faulted Coal Measures

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Typical post-industrial urban coalfield.
Decarbonising heat – local district heating/storage
Timeline, phased approach

**Phase 1**
- **2017-2020**
  - Environmental baseline characterisation & monitoring
    - Groundwater, surface water, soil/ground gas, soil chemistry
    - Ground movement, seismicity
  - Mine water characterisation and monitoring boreholes

**Phase 2**
- Geothermal infrastructure

**Research facility 2020-2035**
- Geothermal research phase

**Community engagement**
- Education, training activities
- Innovation and commercialisation

- **Ongoing monitoring**
  - subsurface/surface infrastructure and environment
  - 15 year lifespan
Mined geology
Borehole locations

- **199 m borehole**, cored, open hole wireline log suite, string of 5 seismometers
- **5 environmental baseline boreholes** 9 to 50 m
- **Mine water boreholes**: 3 to Glasgow Upper workings at c.50m, 3 to Glasgow Main at c. 85m
-3 boreholes to Glasgow Upper workings at c. 50m drilled depth
-3 boreholes to Glasgow Main working at c. 90 m drilled depth

Recorded extent of Glasgow Upper mine workings from BGS interpretation of mine plan records, XY location error of up to around 5 m.
Mine water characterisation borehole design

GGERFS01: Borehole GGA02 Mine water characterisation (Not to scale) BASE CASE SCHEMATIC

Start height: 11 m

Borehole target - Glasgow Main Coal mine working

Wide diameter (248mmID) for repurposing as geothermal abstraction/re-injection or research boreholes
Surface infrastructure/monitoring – Site 1

**Compound GGERFS01**

- Cabinets hosting ERT, DTS and soil gas connections, loggers, computers
- Weather station + anemometer
- Scanning lasers CO₂ and CH₄
- Power supply and ducting
- Soil/ground gas probe
- Active reflector for InSAR ground motion
- Fence
- Mine water borehole, Glasgow Upper (c. 45 m)
- Mine water borehole, Glasgow Main (c. 85 m)
- Environmental baseline borehole (c. 37 m near top bedrock)
- Access for aquifer properties testing, groundwater sampling, data logger downloads etc.
### Data acquisition summary

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<th>Environmental baseline monitoring</th>
<th>Pre-drill</th>
<th>During drilling</th>
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<th>Facility operation</th>
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2018-2020 Construction timeline

Nov 18-Feb 2019 (completed)
- Seismic monitoring borehole drilling (GGERFS10)
- Time-dependent core sampling
- Wireline logging
- Installation/connection of seismometers
- Core scanning, logging starts

Spring 2019 - early 2020
- Mine water and env. baseline drilling (GGERFS01-05)
- Inc. installation of ERT and DTS cables, groundwater data loggers
- Pump tests
- Installation of continuous soil gas monitors, InSAR reflectors
- Regular groundwater sampling starts

Informs Phase 2 geothermal infrastructure
Phase 2 geothermal infrastructure

- Depends on outcome of Phase 1 and another planning application (buried pipes and a small heat centre)

- Favoured scenario is to re-purpose between 2 and 4 mine water boreholes as reversible abstraction/reinjection boreholes in a closed system

- Investigating small continuous heat supply and much bigger capacity for research (c. 200 kW)

- Other boreholes will be available for monitoring/research
Cheshire Geoenergy Observatory

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Cheshire Energy Research Field Site

- Provides research infrastructure to reduce subsurface uncertainty and so encourage the widespread development of new low-carbon energy technologies including CO$_2$ storage, shallow geothermal and aquifer storage of heat and compressed air.

**Key Features:**

- **Innovation hub** for the testing of borehole fluids, sensors and new tools to aid geological characterisation (for example new geophysical logging technologies).

- **Online monitoring** of seismicity, ground resistivity, and groundwater parameters.

- **Research facility** to investigate the effect of subsurface heterogeneity on fluid flow pathways and the connectivity of sandstone aquifers at different scales.

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Target Geology

- A suite of up to 50 boreholes, ranging in depth from 25 metres to 1200 metres, will be drilled to deliver a multi-scale in-situ understanding of the subsurface.
- The boreholes have been divided into four arrays, each of which has a complementary research objective.

Initial Geology model, 2D seismic data courtesy of UKOGL
Location of Borehole Arrays
Array 1: Baseline monitoring and assessment of regional groundwater regime

- **Array Description:**
  - 16 BH at 8 sites, 100 & 50 m deep
  - 5 x 100 m boreholes cored to sample superficial & Permo-Trias geology
  - Automated & telemetered data logging in 6 boreholes

- **Data Available:**
  - 5 X 100m geophysical logs
  - Gamma-ray / caliper
  - Fluid samples / pump test locations
  - Telemetered Groundwater quality data
    - temperature, pH, conductivity, redox potential
  - Analytical Water geochemistry
Array 2: Seismic monitoring of very small earthquakes (ca. -0.8 to -1.0 Magnitude)

- **Array Description:**
  - 10 seismometers installed in boreholes
    - 3 x 300 m deep
    - 7 x 200 m deep (4 cored)
  - The total array will (in combination with the deep seismometer in Array 3) allow accurate recording of seismicity down to levels as low as ca. -0.8M. Each of these boreholes will be logged and cored.
Array 3: 1200m borehole for geological assessment and deep seismic monitoring

- **Geological prognosis:**
  - Spuds into Kemira graben in Sherwood Sandstone
  - Penetrates Dungeon Banks Fault Zone at ~360m
  - Base Coal Measures at ~950-1050 m
  - TD at 1200 m in lower Millstone Grit

- Consists of a single 1200m deep borehole which will be cored through the Permo-Triassic succession and Carboniferous Pennine Coal Measures Group through to the Carboniferous Millstone Grit Group.

- Borehole will be logged using a full suite of conventional geophysical logs including high resolution resistivity borehole imaging.

- Core will be scanned using state-of-the-art core scanners and then sedimentary logged.

- Following wireline fluid sampling a high-resolution seismometer will be installed before the borehole is cemented to surface.
Array 4: Multi-Scale Array

- Multi-scale array of boreholes drilled through the Permo-Triassic succession and into the underlying faulted contact with the Carboniferous succession.
Array 4: Science objectives

- **Multi-scale characterisation of geology & hydro (space & time):**
  - Cross-borehole and surface-borehole 2D and 3D geoelectrical imaging
  - Advanced hydraulic experimentation with 4D hydrogeophysical monitoring.
  - Role of faults as barriers/pathways
  - Time-lapse imaging of fluid processes in the near surface including natural and induced changes
  - This array will also allow highly detailed study of the complete Permo-Trias succession and hydrogeological properties of the in-situ fault materials.

![Diagram showing depth, possible damage zone, and casing design based on stratigraphy and fault geometry.](image)
Array 4: Dungeon Banks Fault zone

Given the vertical displacement of the Dungeon Banks fault (ca. 750m), the thickness of the fault zone is expected to be in order of hundreds of meters. The thickness of the damage zone might be up to 1000 m.

Timeline

- Design of Cheshire arrays was developed by BGS from 2014-2018 in consultation with the Science Advisory Group, landowners and statutory bodies
- Detailed planning application was submitted to local authority at end of 2018
- Decision expected in spring 2019
Core Scanning Facility

- Brand-new state-of-the-art core scanning lab at Keyworth
- New resource for **whole UK academic community**
- 4 High-res core scanners for non-destructive scanning of whole or slabbed core
  - Geophysics: Density, spectral gamma-ray, p-wave sonic, resistivity, Surface & whole core magnetometer
  - Geochemistry: NIR spectral mineralogy & XRF elemental concentrations
  - High-resolution optical, NIR & CT imaging
Core Scanning Facility
Data and sample access portal

(Illustrative initial designs, developed in discussion with different user groups)
Access to Core Material and Water Samples

- Rock and cuttings samples are scanned and archived at the NERC National Geological Repository (NGR) at BGS Keyworth
- BGS are hosting a workshop to manage access to core and water samples on 20th March 2019. This workshop will describe how to access:
  - Geological core, preserved geomicrobiology core, fluids from GCC01, cuttings from Cuningar Loop boreholes (an early sample call closed in Dec 18 for during-drilling samples)
  - All sample types that will be collected from the Cheshire facility which is scheduled to begin drilling during summer 2019 (subject to planning permission). It will describe in detail the types of samples that will be available
  - If you are interested in attending, please register via an email to: ukgeosenquiries@bgs.ac.uk

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Long-term Access to the Facilities

- The Glasgow and Cheshire facilities are intended to have 15+ year lifespan.
- They will be made available to researchers from industry and academia (UK and International).
- It is envisaged that a standard daily rate will be charged for access to the facilities, this to be confirmed when the outcome of the Cheshire facility planning decision is known.
- Researchers wishing to use the facilities can apply for funding through the relevant UKRI research council (likely NERC, EPSRC or cross-council for UKGEOS).
- Access decisions will be made by panels of academics following peer review; proposals will need to show evidence of consultation with BGS to confirm that they are possible from a technical perspective.
- All data generated by the project, or by researchers working on materials derived from the observatories, is public and will be made available via the UKGEOS website, in accordance with the NERC Data Management Policy.
Limitations

• Capital funding for facility construction is fixed/limited – the current scope cannot be expanded (would require further capital funding and new construction phase)

• There is limited access to the sites during the construction phase, for health and safety reasons

• Future research will have to abide by existing planning, licensing and permit conditions from the EA, SEPA, Coal Authority, landowner etc. Or researchers will have to obtain additional permits in conjunction with the facility operator (BGS)

• Research activities should not negatively impact the facility for future users (e.g. by clogging boreholes, changing subsurface flow and transport properties)