The Geological Society

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The role of subsurface research labs in delivering net zero:

realising the potential of UKGEOS

3-4 February 2021

Virtual Event

Main Convenor:

Mike Stephenson (British Geological Survey)

Co-convenors:

Mike Spence (British Geological Survey)
Zoe Shipton (University of Strathclyde)
David Manning (University of Newcastle)
Linda Stalker (CSIRO, Australia)

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A range of energy resources, infrastructures and technologies are likely to be required as part of the transition to a low carbon energy system and net zero. Many of these resources are likely to have impacts on or implications for, the subsurface. Against this background, the purpose of the new £31 million UK Geo-energy Observatories (UKGEOS) is to facilitate research that improves understanding of subsurface energy developments, mass and energy transfer in coupled systems, and their impacts on the subsurface and surface and consequently their interactions with the wider energy system. The conference will bring together scientists from the UK and internationally, to talk about their experience with subsurface facilities, to examine the capacity of the UKGEOS facilities, to develop and stimulate research directions, to link these to decarbonisation policy and regulation, and to stimulate international collaboration in geo-energy.

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2021 YEAR OF SPACE

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CONFERENCE PROGRAMME

The role of subsurface research labs in delivering net zero: realising the potential of UKGEOS

Via Zoom GMT

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11.00	**The importance of test facilities in geoscience: Why subsurface CCS laboratories provide value and context to stakeholders** Linda Stalker & Susan Hovorka
11.30	**The Otway test facility** Matthias Raab and Peter Cook
12.00	**Regulatory and policy need** Alwyn Hart and Mark Ireland
12.30	Lunch Break
13.00	**UK Geoenergy Observatories (UKGEOS): Project Overview & Core Scanning Science** Mike Spence and Magret Damaschke
13.30	**Panel Discussion - Big challenges for geoenergy** Mike Stephenson & Speakers
14.30	**Day one closing remarks**

Thursday 4 February	
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11.30	**New geothermal observatories: Delft and Cornell** Phil Vardon & Patrick Fulton
12.00	**How Geological Survey Organisations (GSOs) can support the deployment of UTES across Europe** Gregor Götzl, Frank van Bergen, Joris Koornneef
12.30	Lunch

13.00	**Underground rock laboratories: their uses in delivering a deep geological disposal programme** Fiona McEvoy and Jonathan Turner
13.30	**Role of test sites in interfacing with the public** Jennifer Dickie
14.00	**Ways to bring test site community together** Chair Linda Stalker and session speakers
15.00	**Closing Comments** Mike Stephenson David Manning

Day 1

3 February 2021

Abstracts

THE IMPORTANCE OF TEST FACILITIES IN GEOSCIENCE: WHY SUBSURFACE CCS LABORATORIES PROVIDE VALUE AND CONTEXT TO STAKEHOLDERS

Linda Stalker (CSIRO, Western Australia), Susan Hovorka (The University of Texas at Austin)

Test sites, demonstration facilities, field laboratories: these terms tend to be synonymous with research activities, but they address a far broader range of stakeholder requirements. The ability to take a hypothesis, develop a model, build background laboratory-based concepts, and validate them in field trials provides critically important steps between concept and reality.

Field sites allow the gathering of data, the collection of information and the generation of more integrated and deeper knowledge of new geo-engineering processes than before. Geological observatories allow us to integrate that data, add the dimension of time series and demonstrate that methodologies and approaches to new activities, like geological carbon capture and storage, can be conducted in a low-risk, low-cost and above all, transparent manner.

Test facilities allow opportunity for up-scaling along the path from research to commercialisation. Testing new innovations and technologies, validating models and predictions of subsurface changes also enable regulators to develop informed frameworks and guidelines, providing certainty for new industries.

Test site allow safe probing of risk and problems, serve the role of “fire drills” to develop widespread experts in dealing with low likelihood but high consequence events. At test sites tests controlled releases or equipment or methods are pioneered. The consequences of success or failure are restricted, the lessons are shared, and new knowledge communicated to improve and validate innovative technologies. This presentation will share some of those aspects from some of the first field demonstrations in low risk environments, to testing deliberately more challenging geological environments

These sites also provide transparent methods of communication to industry, government and publics. Visualising new technologies like carbon capture and storage, energy storage, or geothermal energy developments is challenging to non-experts. The development of highly instrumented and investigated geological observatories and test facilities provide a valuable window into how the science of the subsurface can help with a low emissions future safely.

THE OTWAY TEST FACILITY

Matthias Raab (CO2CRC Limited), Peter Cook (University of Melbourne)

The Otway Test Facility was established by the CO2CRC (a cooperative research centre) in the early 2000s with the support of government, industry and academia from Australia and around the world. The site is unique in that it is located at a depleted natural gas field (Naylor), with a local supply of CO_2 rich gas in an adjacent field (Buttress). The CO2CRC has developed a series of research programs around this facility, becoming an observatory for geological carbon storage and the measurement, monitoring and verification of the site. It provides an excellent model of a geological observatory.

Stage 1: the characterisation of the Naylor field, design and deployment of a unique bottom-hole-assembly for in-reservoir monitoring, drilling of an injection well and design of a test that showed how CO_2 would interact with the co-existing natural gas in the field itself. The monitoring program covered atmospheric, soil gas, groundwater, in-reservoir sampling and geophysical monitoring. This monitoring continued over many years after 65,000 tonnes gas was injected in 2007-8.

Stage 2: a series of activities optimising the drilling of a well into a saline aquifer; a push-pull test to understand and quantify residual CO_2 saturation; a geophysical evaluation of how rapidly plume stabilisation occurs after injection ceases.

Stage 3: is underway, with a new series of tests looking at minimising invasive monitoring methods through geophysical activities and tomography.

Throughout, the site has been open to visitors to observe and contribute to the design and development of tests, testing and validating new monitoring tools and pushing advances in CCS research to support Australian and international commercial developments.

The work done has been widely communicated both in peer review publications and the book ‘Geologically Storing Carbon’ provides further insight into the establishment of the test facility and the regulation hurdles overcome to develop this site.

HOW CAN SUBSURFACE GEOENERGY SITES SUPPORT CURRENT AND FUTURE REGULATION AND POLICY?

Alwyn Hart (Environment Agency), Mark Ireland (Newcastle University)

The energy industry faces a challenge to decarbonise to support reaching net zero emissions by 2050. In nearly all scenarios these reductions are characterised by not only energy demand reductions, but also the decarbonisation of electricity, heating and cooling; all scenarios will likely include using the subsurface for energy extraction and storage, as well as sequestration of carbon dioxide. At present in the UK, the two main usages of the subsurface in our energy systems are for the extraction of fossil hydrocarbons and for management and maintenance of utility infrastructure and related underground assets. As we move to embrace those other subsurface energy opportunities such as wider use of geothermal we need to ensure that public concerns are addressed and regulatory or policy needs met.

Research led efforts and sites such as the development of the UKGEOS facilities at Glasgow and Cheshire, provide a unique opportunity to investigate the entire lifespan of subsurface projects. This extends from concept and planning through to decommissioning and includes investigating:

- Construction – surface to subsurface – research into land use change,
- Operation – perturbations of the subsurface – research into changing subsurface,
- Decommissioning – provision, effectiveness, cost and innovation,
- Legacy– construction with a sustainable end plan.

We should also recognise that utilising the subsurface in the future could be a multi-faceted domain compared with present usage, making use of the physical properties and the resources at a range of scales. Understanding the potential conflicts in use and how these can be minimised will be an important aspect of managing the subsurface to bring sustainable development while protecting form harm both people and the environment.

Engaging with regulatory bodies and Government in the early stages of research will help in the translation and adoption of research findings for end users.

UK GEOENERGY OBSERVATORIES (UKGEOS): PROJECT OVERVIEW & CORE SCANNING SCIENCE

Mike Spence (BGS) and Magret Damaschke (BGS)

In 2014 the UK Government Plan for Growth of Science and Innovation provided £31m to create world-class geoenergy research facilities to inform the responsible development of new energy technologies. The UK Geoenergy Observatories project is delivering borehole-based research facilties in Glasgow (for at scale minewater thermal energy storage research) and in Cheshire (for subsurface/ aquifer thermal energy storage research). These are complemented by a £1.4m core scanning facility based at BGS Keyworth that is undertaking imaging and physical/ chemical profiling of recovered rock core. A third field-based facility, the existing Cardiff Urban Geo- Observatory, is affiliated to UKGEOS and through the website and a shared informatics platform. Phase 1 of the Glasgow Observatory development was completed in 2020, with the completion of surface thermal infrastructure scheduled in 2021. Construction of the Cheshire facility is anticipated to begin in mid- 2021.

Here, we present preliminary results from the scanning of ca. 200 m of core recovered from site GGC01 of the Glasgow Observatory, acquired using computed tomography (CT), multi-sensor and X-ray fluorescence core scanning systems. The core scanner data is underpinning rock and reservoir characterisation studies that form the basis for understanding subsurface processes. We highlight the value of core scanning as a mechanism for correctly reconstructing the vertical position of core, for identifying specific intervals of interest, and for resolving new relationships between physical, structural and chemical properties. These measurements can be integrated with other datasets at different scale, thereby increasing analytical resolution and contributing to the development of integrated micro to macro geological models.

Day 2

4 February 2021

Abstracts

MINE WATER HEAT AND HEAT STORAGE: THE UK GEOENERGY OBSERVATORY IN GLASGOW, UK

Alison Monaghan (BGS)

Mine water geothermal heat production and storage can provide a decarbonised source of energy for space heating and cooling, however the large resource potential has yet to be exploited widely. Besides economic, regulatory and licensing barriers, geoscientific uncertainties such as detailed understanding of thermal and hydrogeological subsurface processes, resource sustainability and potential environmental impacts remain.

The UK Geoenergy Observatory in Glasgow is a research infrastructure for investigating shallow, low-temperature coal mine water heat energy resources available in abandoned and flooded mine workings at depths of around 50-90 m. It is an at-scale ‘underground laboratory’ of 12 boreholes, surface monitoring equipment and open data. The Glasgow Observatory is accepting requests for researchers and innovators to undertake their own experiments, test sensors and methods to increase the scientific evidence base and reduce uncertainty for this shallow geothermal technology.

NEW GEOTHERMAL OBSERVATORIES: DELFT AND CORNELL

Phil Vardon (TUD) & Patrick Fulton (CORNELL)

Two new geothermal observatories are under development: in Delft in the Netherlands and at Cornell in New York State, US, both on university campuses. In this talk we give an overview of the objectives, plans and current progress. We give insight into how to tackle societal questions of how to operate safe and efficient geothermal systems with scientific programmes.

The system at Delft will be an operating geothermal doublet, drilled to just over 2km deep, in a permeable sandstone layer. Initially, it is anticipated to be a 7 MWth project, increasing to up to 15 MWth with future decreases in return temperature and further expansion of the heating network. The research programme involved coring around 400m of the reservoir and select overburden, fibre optics in both wells shallow borehole arrays for seismic monitoring. The project is focused on developing monitoring techniques and knowledge for urban geothermal projects. The scientific programme is part of the Dutch contribution to the European Plate Observing System (EPOS) project.

Cornell is also pursuing development of low-temperature geothermal energy for direct use in district heating. This geothermal project — called Earth Source Heat (ESH) — constitutes one of the key components of Cornell's efforts to become carbon neutral by 2035. However, the geology at Cornell is quite different from Delft, consisting of low-porosity and permeability sedimentary rocks and metamorphic basement such that fracture flow and fluid–rock contact area may need to artificially enhanced. In an effort to de-risk a future geothermal doublet, the US Department of Energy has funded a dedicated 3km deep exploration hole that will be drilled, cored, and logged in late 2021. It will be also instrumented with a broadband seismometer and distributed temperature, strain, and acoustic sensing capabilities, and is designed to become a dedicated long-term observatory for advancing both low-carbon subsurface energy technologies and fundamental earth science.

HOW GEOLOGICAL SURVEY ORGANISATIONS (GSOS) CAN SUPPORT THE DEPLOYMENT OF UTES ACROSS EUROPE

Gregor Götzl (Geologische Bundesanstalt), Frank van Bergen (TNO), Joris Koornneef (TNL)

The 2050 challenges and way forwards for transforming the European H&C sector

Heating and cooling at moderate temperature levels below 150°C represents 25% of the end-energy consumption in the European Union. In contrast to electricity production, the H&C sector faces several major problems: 1) Low share of renewable energy supply (around 20%), 2) moderate energy efficiency (loss of primary energy), 3) strong dependency on energy imports, 4) emerging relevance of space cooling without proper technological solutions and 5) high level of emissions (GHG, dust, noise and waste heat) impacting the livability in the surrounding.

Current policies of the European Union, such as the Clean Energy Package or the EU Green Deal, aim at full decarbonisation of the H&C market and a circular economy until 2050. For 2030, the level of GHG emissions should be reduced by at least 50% compared to 1990, accompanied by a raise of energy efficiency by at least 32.5%. The Heat Road Map Europe 4 project (HRE4) concluded that these targets can be met without a) introducing new technologies for the H&C sector and b) without a significant expansion of bioenergy. Nevertheless, the H&C sector needs to be fundamentally transformed to achieve decarbonisation. This involves a massive expansion of efficient district heating & cooling from currently around 12% towards around 50% for urban and sub-urban areas as well as the introduction of heat pump based supply for individual buildings. In both technological sectors, geothermal energy may play a crucial role in the future.

New topologies needed for future heating and cooling networks

Future heating and cooling networks need to aim at the capitalization of on-site available heat sources and sinks as well as at a high share of energy efficiency. This basically implies empowering consumers to become prosumers (consume and produce heat or cold), which in turn transforms heating and cooling networks to market places for energy. Following the principle of exergy prioritization, high enthalpy heat sources, which need to be imported to a certain extent, will be limited to peak load and back-up supply.

The COST Action CA18219 Geothermal-DHC (www.geothermal-dhc.eu) currently investigates options for a better integration of geothermal energy into heating and cooling networks in order to demonstrate that geothermal energy has the potential to supply 25% to 50% of the European low temperature heating and cooling demand by 2050. In this context, future H&C networks will rely on two additional components: 1) underground thermal energy

storage (UTES) for enhancing the energy efficiency of fluctuating heat sources as well as 2) multi temperature, multi scale heat pumps acting as moderators inside multivalent, prosuming heating and cooling networks. In this sense, geothermal energy may contribute in terms of a heating source and as a storage in future H&C networks.

Underground thermal energy storage – status quo and future research

UTES technologies cover a large scale, starting at small scale single building and small H&C grids at storage volumes below 500 MWh_{th}/yr and reach up to medium and large scale district heating grids implying UTES sites of more than 50 GWh_{th}/yr. The technological range covers engineered pits (PTES) in soft rocks and caverns (CTES) in hard rocks as well as in abandoned mines, closed loop borehole heat exchangers (BTES) and aquifers (ATES). Currently, UTES technologies apply storage temperatures between less than 10°C and up to around 90°C. Most concepts focus on medium to long term (seasonal) energy storage. Although UTES concepts have been applied for more than 20 years across the globe, most concepts except BTES and low temperature, low scale ATES are still affected by moderate technological readiness levels (TRL) between 4 and 7. Future technological development challenges address, among others, enhancing the flexibility of large scale, high temperature storage (e.g. allowing for short term storage), enhanced storage efficiency (e.g. application of PCM or efficient storage operation) as well as the construction if UTES facilities in densely settled areas.

The support of Geological Survey Organizations (GSOs) for deploying UTES across Europe

The characterization of the subsurface for UTES significantly differs to already existing geothermal resource mapping and modelling approaches. Storability maps need to consider heat losses by advection and put a higher focus on the heat capacity of the subsurface rocks. In addition, the storage – groundwater interaction may play a more important role as for conventional geothermal energy use, which implies heat extraction only as well as stable pressure conditions in the reservoir. Moreover, subsurface spatial planning is of greater importance, especially when it comes to the re-use of abandoned hydrocarbon reservoirs (e.g. heat storage vs. CCS or green gas storage), which requires adapted governance and management approaches. The interlinkage between resource information systems on UTES and governance provides important future work areas for GSOs. The aimed Coordinated Support Action (CSA) towards a Geological Service for Europe, funded by the Horizon Europe programme, will offer an excellent opportunity to set important corner stones for future UTES assessment and management procedures.

UNDERGROUND ROCK LABORATORIES: THEIR USES IN DELIVERING A DEEP GEOLOGICAL DISPOSAL PROGRAMME

Fiona McEvoy (BGS) and Jonathan Turner (Radioactive Waste Management)

Underground rock laboratories (URL) have been used extensively by waste management organisations around the world to test the feasibility of deep geological disposal solutions for radioactive waste. The UK has no dedicated URL but has participated in international collaborative experiments in facilities in Sweden, Switzerland, France, Finland and other countries.

Since late 2018 RWM has been engaged in a live site selection process and the planning to characterise potential sites and adapt illustrative designs for specific geologies is advancing rapidly. URLs will continue to be important for development, de-risking and demonstration of the technology that will be employed in a geological disposal facility. URLs are an essential testing ground to embed a strong health-safety-environment culture in operational activities and they serve also to communicate the reality of underground operations to the broad range of stakeholders with whom RWM is engaged.

After a brief introduction to the UK's deep geological disposal programme, this talk will show the uses of URLs to international disposal programmes and present examples of experiments in which the UK has collaborated with overseas waste management organisations. As the national geoscience agency and custodian of the geoscience database, BGS are an essential source of geoscience excellence for RWM and a key message from this talk is the continued working together of RWM and the BGS on activities in URLs.

ROLE OF TEST SITES IN INTERFACING WITH THE PUBLIC

Jennifer Dickie, (University of Stirling)

The subsurface offers many opportunities to decarbonise our energy system, yet despite widespread societal support of a low carbon future, the technologies that will enable such a transition are often contested, with recent research identifying a complex mix of values and beliefs, social contexts, and types, scales and locations of technology amongst others as drivers that shape attitudes and perceptions. It is clear that the success of these emergent underground technologies relies heavily on public acceptance and support – as potential adopters, hosts, consumers and proponents of these technologies, therefore it is not surprising that establishing effective strategies for engaging citizens and communicating complex technical and scientific information are high on the geoscience community's agenda.

This talk explores the role of test sites such as UKGEOS in engaging citizens in geoenergy science by drawing on findings from participatory workshops that investigated public awareness, understanding of, and attitudes towards publicly funded geoenergy science in the UK. Members of the non-engaged public were recruited by inviting a variety of community groups to take part. Community groups included church groups, U3A, mother and baby and student groups. In total, 7 workshops were held in 3 different locations: Glasgow, Stirling and Lincolnshire with 41 participants taking part. The workshops explored 3 main topics: (i) public perceptions and attitudes towards underground energy technologies; (ii) engagement with publicly funded Geoenergy science; and (iii) the alignment of public attitudes and perceptions of Geoenergy options with the research agendas of the Earth science community. Despite a variety of concerns being raised about the use of the subsurface for energy related activities, there was recognition that a better scientific understanding of the risks and uncertainties associated with each technology is needed. Overall, participants were supportive of the UK Geoenergy Observatories in principle, however, the low level of awareness of the observatories, and the research being carried out, meant that participants were wary of providing their support. During the talk, we will explore some of the potential pathways to greater engagement and the effectiveness of using more informal social settings that promote participant-led rather that expert-led flows of communication and engagement.

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