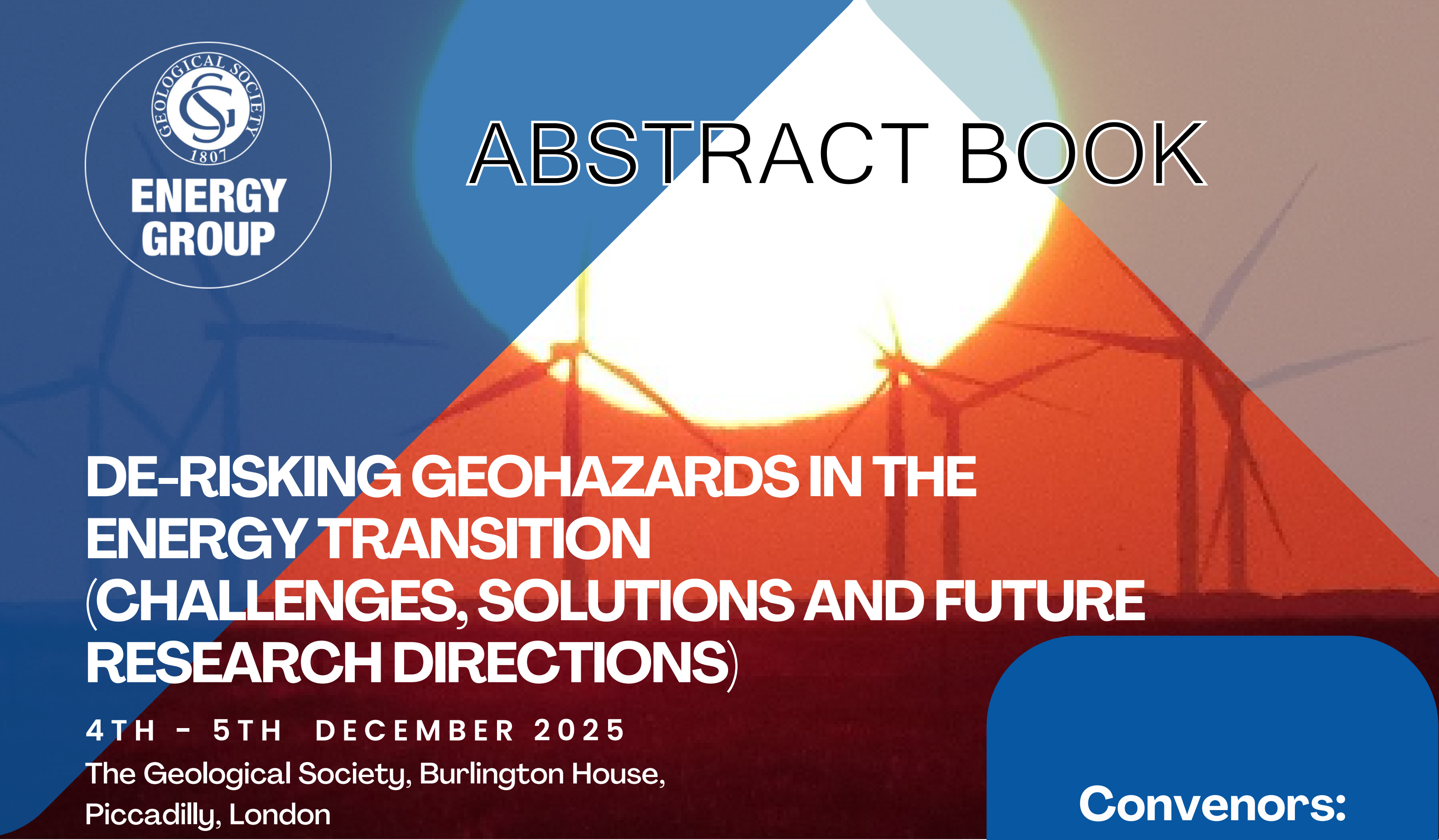

GEOLOGICAL SOCIETY 1807
ENERGY GROUP

ABSTRACT BOOK

DE-RISKING GEOHAZARDS IN THE ENERGY TRANSITION (CHALLENGES, SOLUTIONS AND FUTURE RESEARCH DIRECTIONS)

4TH - 5TH DECEMBER 2025

The Geological Society, Burlington House, Piccadilly, London

The energy transition aims to reduce greenhouse gas emissions from energy quickly and sustainably. Yet, geohazards pose major risks to areas, and projects, which are key for a sustainable energy transition. Sub- and near-surface fluid flow and unfavourable geotechnical conditions usually compound this risk, and require multi-disciplinary approaches for their complete de-risking.

This 2-day conference aims at presenting to a wide audience of geoscientists, engineers and energy investors, the best practices that successfully de-risked prospects at the forefront of the energy transition. The focus of the conference is on the solutions adopted in such prospects, not only on the geological issues (the geohazards per se), so that the conference becomes a forum for discussion on best practices, outcomes, and limitations of particular approaches to de-risking.

We welcome contributions focusing on geoenergy solutions in its broadest sense, including renewable energy, subsurface storage sites (CO^2, hydrogen, nuclear waste), geothermal heat, and those prospects where natural gas and hydrogen are being produced as a transitional fuels.

Main Themes

- **Techniques for the assessment of potential natural and environmental hazards** - a session focused on current and future approaches to assessing geohazards. Also important to the session are geomechanical containment and operation risks.
- **The economics of hazard-prone regions with geoenergy resources** - geopolitical and legislative approaches to geohazard management. A session focused on the economics of the energy transition and how it can be accelerated.
- **Case studies in tectonically active regions** – energy resources vs hazard vulnerability. Seismic and environmental risks in tectonically active regions.
- **Natural and induced seismic hazards** – a session focusing on geological vs locally induced risk. It focuses on the perception of geohazard by local populations and social licensing aspects of the energy transition.

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De-Risking Geohazards in the Energy Transition

4th – 5th December

Virtual and Burlington House, Piccadilly, London W1J 0BG

Programme

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10.45	**BREAK**
11.15	**When Heterogeneity Becomes a Hazard: The REV Approach** Annelotte Weert
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15.40	**The Effects of Fault Damage Zones on Geothermal Activity in Siliciclastic Reservoirs: A Modelling Study** Frans Abem
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09.45	**The Paso Anomaly: Shallow Gas Contained within Lower Pleistocene Glaciogenic Deposits in The Central North Sea** Jack McLoughlin
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11.45	**Insight into Soil Liquefaction Assessment Methods for Efficient Risk Management of Seismic Hazard** Indrasenan Thusyanthan
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13.40	**FUSE - A new infrastructure to help de-risk site selection for future Underground Hydrogen Storage and White Hydrogen exploration** Fausto Ferraccioli
14.10	**From Uncertainty to Confidence: Assessing Shallow Gas Risks in Offshore Renewable Energy** Michel Guillaume

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Layered Soils in the UK North Sea: Implications for Subsea Cable Burial and Risk Assessment Duncan Stevens
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Tracing active faults in the shallow subsurface of the Dutch North Sea – De-risking offshore wind energy Bart Meijninger, Johan ten Veen
A new geophysics facility to aid Underground Hydrogen Storage research Erika Barison
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The Energy Group of the Geological Society would like to thank the following for their support for this conference:

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ORAL ABSTRACTS
(In Programme Order)

Day One

Keynote – The Role of Rock Physics in the Energy Transition: Monitoring and Interpretation of Underground H2 And CO2 Storage Operations

I. Falcon-Suarez

The energy transition towards Net Zero requires an increasing use of renewables, together with a rapid development and safe implementation of geo-engineering technologies for seasonal underground (fuel-based hydrogen) energy storage (UHS) and carbon capture utilisation and storage (CCUS) to reduce CO2 emissions to atmosphere. A feasible industrial-scale approach is deploying underground reservoirs for UHS and CCUS, for which saline aquifers and depleted oil and gas reservoirs are the best candidates due to large storage capacity and high permeability (injectivity), with a proven sealing efficiency in the latter case.

Preserving the geomechanical integrity of the reservoir during and after human activities is crucial for safe and efficient UHS and CCUS. This concern requires field-scale predictions of the storing capability using geophysical (mainly seismic) remote sensing monitoring and laboratory data to define efficient operational roadmaps. However, the geophysical interpretation of the coexisting fluids and rocks interplay during UHS/CCUS is challenging. Fluids-distribution effects commonly mask alterations in reservoir rocks and stress resulting from gas/fluid-induced pressure-temperature and geochemical changes (i.e. coupled thermo-hydro-mechano-chemical processes).

In this contribution, I will deepen into the different combined approaches we use in the rock physics laboratory of the National Oceanography Centre, Southampton, to assess specific geological underground scenarios targeted for UHS/CCUS. I will analyse the lessons learned from the CCUS research to date, including the limitations of the geophysical tools commonly used in reservoir exploration (e.g., seismic, electrical resistivity) when applied to UHS/CCUS operations, and the importance of an up-to-date hydro-mechano-petrochemical characterization of the reservoir complex.

Assessing and Monitoring Surface Geohazards for Renewable Energy Projects in an Active Volcanic Region in British Columbia, Canada

Sergio Sepúlveda, Simon Fraser University; Glyn Williams-Jones (Simon Fraser University)

Surface geohazards such as mass movements can endanger the safe operation of energy projects. This is the case of the Mount Meager (Q̓welq̓welústen) Volcanic Complex, part of the Garibaldi Volcanic Belt in British Columbia. The area is prone to volcanic and non-volcanic landslides, including large rock avalanches, rock slides, debris flows and lahars; it was the site of Canada's largest historic landslide (~53 Mm3) in 2010. Active deglaciation, rapid tectonic uplift, and hydrothermal alteration of the volcanic rocks influence the susceptibility to mass movements. A run-of-the-river hydropower plant and geothermal energy prospect located in the volcano foothills are vulnerable to landslides, particularly long runout rock avalanches and debris flows that may reach critical infrastructure and local communities downstream of the volcanic edifice. Massif-scale landslide susceptibility mapping and local slope stability and runout models are being performed to better constrain the landslide hazards in the area. The hydropower plant is susceptible to direct impacts of flows originating from the northern side of the complex. In turn, while the geothermal prospect is located on the southern slopes with locally moderate to low landslide susceptibility, site access can be severed by flows from higher areas, impacting roads and bridges. A combined optical, meteorological, and seismo-acoustic field monitoring scheme, in conjunction with satellite remote sensing (radar and optical), is being gradually implemented to provide tools for operational detection of mass movements that will inform the implementation of early warning systems and mitigation measures.

Quantitative Seismic Risk Assessment for Construction Activities at Offshore Wind Farms

Vanessa Monteleone, DNV London; Kah Wai Hau (DNV London)

Installing offshore wind turbines in earthquake-prone regions brings a unique set of challenges, especially when soft or liquefiable soils increase the risk of foundation instability. Standards like ISO 19901 2 and ISO 19905-1 set strict reliability targets for manned structures under extreme seismic events, but these requirements are often unrealistic for short-term installation activities that involve frequent moves between sites.
To bridge this gap, a Quantitative Risk Assessment (QRA) approach that works within the framework of international standards while addressing the practical realities of offshore wind construction was developed. The method combines probabilistic seismic hazard analysis, soil–structure interaction modelling, and exposure-based risk calculations. It uses risk matrices to determine whether risks fall within acceptable limits and to guide mitigation measures. When full compliance with design-level criteria is not achievable, the process provides a structured way to demonstrate that risks have been reduced to a level that is As Low As Reasonably Practicable (ALARP).

This approach gives regulators and project stakeholders a clear, defensible basis for decision-making. By embedding QRA into planning and operational controls, it ensures that seismic risks are managed in line with ISO principles, without imposing impractical design requirements. The result is a framework that supports safe, efficient offshore wind installation in earthquake-prone regions while meeting the expectations of both regulators and the energy transition.

When Heterogeneity Becomes a Hazard: The REV Approach

Annelotte Weert, Delft University of Technology; Jesse Steinvoort (Delft University of Technology), Allard W. Martinius (Equinor ASA, Delft University of Technology), Sebastian Geiger (Delft University of Technology)

Sandstone reservoirs deposited in deltaic settings are among the most promising reservoirs worldwide. Yet, their heterogeneous nature can form economic and technical challenges for subsurface exploration, particularly in the context of the energy transition. Multi-scale heterogeneities, such as sand bodies, heterolithic intervals, and lateral discontinuities, occur across distinct scales and control key properties like porosity and permeability. As a result, heterogeneous properties influence subsurface flow behavior, storage capacity, and long-term performance, thereby introducing significant uncertainty in project planning and risk assessment.

One approach of managing these risks is the use of Representative Elementary Volumes (REVs). REVs provide a conceptual framework to determine the smallest volume over which heterogeneous reservoir properties can be treated as homogeneous. Defining the right size for REVs in heterogeneous reservoirs enables more robust upscaling of petrophysical parameters and flow characteristics. This approach improves the quantification of heterogeneity, constrains uncertainty, and supports more robust reservoir performance forecasts.

This contribution examines heterogeneity at two complementary scales. First, at the basin scale, demonstrating the impact of large-scale heterogeneity on subsurface energy projects. Secondly, at the well-bore scale, where examples for REVs from tidal sandstones illustrate how heterogeneity can be quantified and reduced to improve predictive models. Together, these insights underscore the role of REVs as a tool for managing geohazard-related uncertainty in heterogeneous reservoirs, and their potential to support safe, efficient, and sustainable energy transition projects.

Beyond the Basics: Optimising Marine Desktop Studies for Strategic Geohazard Assessment

Simona Caruso, University of Aberdeen (Main for this abstract) - other affiliation bp;

As offshore infrastructure, from traditional oil and gas to renewable energy, expands and grows more complex, the need for robust, early-stage desktop studies becomes critical. Marine geohazard research has accelerated over the past three decades, highlighting the foundational role of desktop studies in understanding ground conditions. While these studies are essential for providing a conceptual overview of site geology, geomorphology and potential geohazards, their full strategic value remains often underutilised. This work offers a solution to this gap.

This study introduces a systematic workflow that elevates the desktop study, turning it into a powerful, data-driven strategic tool. It integrates international industry guidelines (e.g. UK, USA, and Norway), best practices and research learnings with decision-support tools to create a framework that allows for efficient data integration and a systematic gap analysis. The approach also bridges the common divide between industry and academia, harmonising engineering geohazard classification with a deeper understanding of geological processes. Academic research, though often limited in extensive data access, benefits from extended study periods that enable deeper analysis. Industry, on the other hand, contributes practical experience, targeted datasets, and funding, offering valuable insights into specific geohazard scenarios.

The framework promotes a risk-based strategy and facilitates the creation of dynamic geohazard risk registers. By doing so, it not only informs project planning throughout the project lifecycle but also shows how even late-stage geoscience data can be leveraged more effectively ultimately avoiding costly rework and wasted time. This work advocates for improved collaboration and data sharing, enhancing geohazard identification and strengthening resilience in marine geoengineering projects.
This optimised approach helps to unlock critical subsurface insights and supports informed, risk-aware decision-making, establishing the desktop study as a strategic necessity for the energy transition.

Session Two: Economics of Hazard Prone Regions with Geoenergy Resources

KEYNOTE: The Cost of Risk in Hazard Prone Regions with Geoenergy Resources

Aggie Georgiopoulou, Ternan Energy;

Risk Assessments are common practice to assess seabed hazards and obstructions, whether natural or anthropogenic, to infrastructure developments offshore. Especially in the offshore environment where advanced technology is required to image and study the sites, good understanding is crucial for all stages of a development, from planning and designing to construction and finally operation. This understanding underpins nearly all the decisions made in the lifecycle of the project and in many ways controls costs.

It is often said that a project will have to pay for the project risk one way or another, but the big question, is at what cost? The cost can be part of the front end expenditure as part of detailed site investigations, and appropriate assessments that feed into careful designing. Otherwise a conservative design approach can be followed where the development might be overengineered to account and mitigate for potential risks that may not need mitigation. If none of the above is employed, problems may arise during construction and installation that can lead to failures and/or accidents with very high costs, both in engineering but also, crucially, in the safety of crew. Finally there is the cost during operation and maintenance where problems may be encountered due to an oversimplified design at the beginning.

One thing is certain, hazards and in general the ground conditions, no matter how challenging, will co-exist with any offshore development.

The Dynamics of Bias, Risk, and Uncertainty In Offshore Renewable Engineering Projects

Dan Morgan, Sulmara Subsea

Site investigations, both geophysical and geotechnical, form the cornerstone of offshore wind engineering projects. A typical geoscientific site investigation may cost less than 5% of the total $3bn - $4bn investment required to build a modern commercial-scale offshore windfarm, underestimating the importance of the data acquired or poor planning of the early investigation phases can see development costs spiral out of control during construction and commissioning. Although these costs seem small in the context of the overall cost of an offshore wind farm project, some of the key activities (design, installation and ongoing operation) are completely reliant on these geoscientific datasets. In real terms, some of the most expensive CAPEX costs borne by a developer are underpinned by geoscience data, which is often collected several years earlier. This means that the geoscience campaign is often conducted in vacuo, very often preceding the selection of the critical project components like foundations, cables or installation practices. Early design work on offshore windfarms is especially vulnerable to the perception of risk and a resulting need to cover all eventualities for a range of development scenarios that could evolve between site investigation and construction. This uncertainty can alter decision making on the types of survey needed and the data used in project development, ultimately causing further unknowns altering the perception of contractual risk. This talk seeks to highlight the shortcomings with the use, and overuse, of the word “risk” in offshore renewable site engineering contexts. The overall aim is to critically assess how the communication of different risks influence decision making from the earliest phases of project development and further seeks to suggest ways to improve the industry’s understanding of uncertainty and risk. This should support the multidisciplinary teams involved to better understand geoscience data, both in terms of its usefulness and its limitations.

KEYNOTE: Adaptation of Geohazards Assessment Process and Practice to Successfully Deliver Complex Offshore Projects through the Energy Transition

Gareth Wood

The requirement for robust geohazard assessment in support of offshore energy projects was recognised back in the late 1960's after several incidents during oil exploration drilling. Initially focussed on securing the safety of personal and assets during drilling operations, primarily through avoidance of shallow gas, the process of geohazard identification and risk assessment changed over time, as more complex and hazardous environments were developed. Systematic approaches to Integrated Geohazard Assessment were established in the period between 1994 and 2015 to adapt to these changing demands and challenges, providing a suite of tools ranging from a qualitative approach through to full Quantitative Risk Assessment, driven by geological complexity and manageability. Through the energy transition, and especially for the offshore wind sector, the primary drivers behind fundamental geohazard evaluation have had to adapt to the different engineering challenges faced by these vast projects. While in the oil and gas sector, many hazards can be avoided as the siting of infrastructure is, to some degree more flexible, this is less so in the case of offshore wind, where location of turbines is restricted by aspects such as wind yield, and consenting constraints. Here we showcase how the process of Geohazard Assessment within an energy developer has evolved to accommodate these shifts, from shelf to deep water and back again, and as areal extent of development sites has increased.

The Effects of Fault Damage Zones on Geothermal Activity in Siliciclastic Reservoirs: A Modelling Study

Frans Abem, TNO Geological Survey of the Netherlands; Allagianni, N., Peeters, S., Giliam, E.T., Wassing, B.B.T., Candela, T. (TNO)

We have studied the impact of considering permeability-reducing damage zones in thermo-hydro-mechanical (THM) simulations of geothermal cold water injection in siliciclastic reservoirs. The impact was assessed by analysing pressure- and temperature distributions from a FLAC3D-ToughREACT, and seismicity metrics obtained from a seismicity simulator that incorporates fault roughness. The model geometry and input parameters are based on a representative fault zone in the West Netherlands Basin, obtained via geological interpretation of seismic data and well logs. Two scenarios are presented: one without and one with damage zone. Our results show that the damage zone causes compartmentalization of pressure, and directs the cooling front away from the main fault. The damage zone shelters the main fault from stress changes, resulting in fewer seismic events and a lower maximum observed magnitude than without damage zone. We note that seismicity was analysed on the main fault only; seismicity on secondary faults in the damage zone have not been considered. The trends identified in this study suggest that damage zones should be considered in THM simulations.

The Role of Seismic Monitoring in Improving the Safety of Underground Energy Storage

Patricia Persaud (remote), University of Arizona; Joses Omojola (University of Arizona)

Underground caverns in salt formations were originally designed for storing natural gas and unrefined petroleum products but are now projected to play a key role in the large-scale storage of sustainable energy resources including hydrogen. The US Gulf Coast has several underground cavern facilities including the four US Strategic Petroleum Reserve sites that are used to increase energy supplies during emergency shortages. Salt caverns are subject to substantial modifications and are affected by loading and unloading. Unstable caverns pose a hazard to nearby communities and their collapse can lead to sinkhole formation and the release of gas with long-lasting environmental impacts. To better understand the factors influencing cavern stability, we characterize a salt dome in the US Gulf Coast that is actively used for natural gas storage. We installed an array of nodal seismometers to record seismicity over a 12-month period and developed a machine learning model for detecting microearthquakes in high industrial noise settings. 152 microearthquakes with magnitudes between -3 to 2 ML were detected within the salt. On the western side of the dome, microearthquake clusters allowed us to map a previously unidentified shear zone. A well integrity test failure in 2021 that occurred during our recording, and prior documented incidents show that caverns near shear zones experience frequent instability incidents, suggesting that shear zones directly impact cavern deformation. The effects on seven caverns were observed in time-lapse 3D sonar surveys showing changes in cavern shape. Our workflow provides a low-cost, improved methodology for mapping salt shear zones away from well control and can be applied at different stages of cavern field development ranging from site selection to facilities expansion and is useful for optimizing cavern placement for storing sustainable energy resources.

Session 3: Case studies in Techtonically Active Regions

KEYNOTE: Direct Monitoring of Subaqueous Mass Movement Geohazards: Implications for Offshore Energy Transition Infrastructure

Megan Baker, British Geological Survey; Peter Talling (Durham University), Ricardo Silva Jacinto (Institut Français de Recherche pour l'Exploitation de la Mer), Matthieu Cartigny (Durham University), Rebecca Englert (Monterey Bay Aquarium Research Institute), Sanem Acikalin (Newcastle University), Mike Clare (National Oceanography Centre), Pascal Kunath (GEOMAR Helmholtz Centre for Ocean Research), Andrew Finlayson (British Geological Survey)

Subaqueous mass movements, including underwater landslides and underwater avalanches of sediment called turbidity currents, pose a severe hazard to offshore infrastructure. For example, a powerful turbidity current travelled 5-8 m/s for 1,100 km down the submarine Congo Canyon-Channel, breaking multiple telecommunication cables and crippling the internet connections to west and south Africa. As the energy transition accelerates and offshore wind and subsurface storage projects expand, the vulnerability of associated offshore power cables, transport pipelines, and seabed monitoring stations to subaqueous mass movements is becoming a key geohazard consideration. Yet in many areas, the occurrence and behaviour of subaqueous mass movements remain largely unconstrained.

This talk will present how direct monitoring studies of subaqueous mass moments can improve our understanding, prediction, and mitigation of these events in order to protect critical seafloor infrastructure. Monitoring and assessment methods include repeat seafloor surveys, which can demonstrate the occurrence of subaqueous mass movements and how they impact the seabed. Acoustic Doppler current profilers placed in the water column can measure the flow dynamics (speed, height, duration), recurrence intervals, and triggers of turbidity currents, yet are vulnerable to being damaged by powerful events. This has prompted the use of passive ocean bottom seismometers and fibre optic cables, which can record subaqueous mass movement events from afar. Overall, direct monitoring of subaqueous mass movements can provide valuable insights to improve geohazard assessments for the seafloor infrastructure essential to the energy transition.

The Paso Anomaly: Shallow Gas Contained within Lower Pleistocene Glaciogenic Deposits in The Central North Sea

Jack McLoughlin, Sproule ERCE; Stuart G. Archer (Harbour Energy) , Alistair Swan (Harbour Energy) , Bartosz Kurjanski (University of Aberdeen) , Francis Buckley (Cuillin Geoscience) , Brice R. Rea (University of Aberdeen), Matteo Spagnolo (University of Turin), and Mark Burchell (University of Aberdeen)

The perception of shallow gas accumulations has changed from one of ‘drilling hazards’ to ‘potential resources’ over the last few years. The Paso Anomaly, identified on seismic at a depth of c. 550 m true vertical depth subsea (TVDss), is a high-amplitude soft reflector that exists in the overburden of the Catcher Field Area in the Central North Sea. This anomaly has previously been avoided during drilling as it could host gas. AVO analysis has been undertaken that suggests a class 3 response, inferring that the anomaly is likely to be indicative of a gas-filled sand. Seismic indicators of gas presence were analysed, and gas composition was analysed with reference to formation evaluation and gas ratio logs. This led to the interpretation that the Paso Anomaly represents biogenically altered thermogenic gas. It is further interpreted that the gas has migrated from depth due to faulting associated with Zechstein-aged salt diapirism and subsequently has been biogenically altered once trapped at shallow depths. By utilizing facies-based seismic characterization, this work interprets the depositional environment of the anomalously high reservoirs as glaciogenic. Regional mapping supports an approximate Lower Pleistocene age for the deposits, which consists of glaciogenic deposits. Construction of a regional palaeogeographical model demonstrates that these deposits are the depositional record of an ice stream on the eastern edge of the British and Irish Ice Sheet. This ice stream advanced in a northeasterly direction into the Central North Sea before retreating, which has implications for the direction of Early Pleistocene ice flow within this area. This work lays the foundations for the Paso shallow gas accumulation to be viewed as a possible energy resource rather than a shallow gas drilling hazard, with a region of a sandur plain interpreted to be a potentially developable resource.

Steps Toward Physics-Based Earthquake Forecasting: Simplifying Fault Slip and Building a Forecasting Framework

Jessica Hawthorne, University of Oxford;

As we further develop underground projects like carbon sequestration and hydrothermal energy extraction, we often need to forecast seismicity in "new," or changed, physical environments that have little past seismicity that we can reference. As a result, we need to build physics-based, not just empirical, earthquake forecasts, with time dependence. With this challenge in mind, I take a simplified—and therefore fast—approach to simulating earthquake ruptures and use this approach to build a toy seismicity forecast.

The approach to earthquake simulation is based on energy balance. Ruptures are assumed to propagate as long as they have enough energy. Here we do not recover the details of the rupture propagation. However, we can determine the size and stress release of the ruptures, as well as a range of other rupture properties. These properties are potentially observable in real scenarios and can help us assess earthquake likelihood.

To assess earthquake likelihood as a function of fault condition, I simulate 1-D ruptures in a range of stress fields, with different initial stress properties. Conducting numerous (>100,000) simulations allows us to build a map between (1) the conditions of the fault and (2) the frequency, magnitude, and stress drops of the simulated earthquakes. To make the map, or forecast, more accessible, I build a neural network between the initial conditions and the seismicity properties. I then test the forecasts with new scenarios, and I explore some of the challenges in physics-based forecasting.

De-risking Geological Disposal: Long-Term Natural Processes

Alex Hughes, NWS;

The UK's geological disposal programme, led by Nuclear Waste Services (NWS), must account for the influence of natural processes over timescales extending up to one million years. This presentation will outline how NWS is addressing this challenge through a comprehensive programme of work that supports the Initial Site Evaluation (ISE) and future safety case development. Drawing on recent studies, this work considers the potential impacts of climate change, sea-level variation, seismicity, and surface evolution on the long-term integrity of a geological disposal facility. These processes are evaluated in terms of their implications for site selection, as well as isolation and containment of the hazard. The presentation will highlight how this strategic approach to geohazard assessment supports regulatory expectations and provides a foundation for future site-specific investigations. Lessons learned will likely be applicable to other geoenergy projects requiring robust long-term risk management.

Insight into Soil Liquefaction Assessment Methods for Efficient Risk Management of Seismic Hazard

Indrasenan Thusyanthan, Venterra Group (GDG); Anastasios Batilas

As the energy transition accelerates, offshore wind developments are increasingly sited in seismically active regions, where soil liquefaction poses a significant geohazard to infrastructure resilience and investment security. This talk presents a comprehensive insight of three approaches for assessing soil liquefaction potential: Method A - a simplified empirical method, Method B - a numerical method using 1D nonlinear site-specific response analysis (SSRA), and Method C - a fully coupled 2D finite element analysis (FEA) using advanced soil constitutive model (PM4Sand).

Based on real assessment results, it will be demonstrated that while methods A and B are often used in projects, they tend to overestimate liquefiable zones, thus leading to overdesign and inflated costs. In contrast, advanced FE modelling (Method C) provides a more accurate representation of soil behaviour under seismic loading, reducing the estimated liquefiable thickness considerably. This advanced numerical modelling enables optimised foundation design, unlocking substantial cost savings and enhancing project feasibility.
For energy investors, these insights translate into reduced financial risk and improved confidence in asset performance. For engineers and geoscientists, the study underscores the value of integrating robust site-specific analyses into design workflows. Moreover, by aligning technical rigor with transparent risk communication, these best practices support social licensing and community trust -critical factors in the successful deployment of energy infrastructure.

This contribution demonstrates how targeted de-risking strategies not only mitigate geohazards but also advance the broader goals of the energy transition through safer, smarter, and more sustainable project delivery.

Session 4: Natural and Induced Seismic Hazards

KEYNOTE: Hazard and Risk Assessment for Induced Seismicity In the Groningen Gas Field

Frans Aben, TNO Geological Survey of the Netherlands; Aben, F.M., Osinga, S., Kraaijpoel, D., Pluymaekers, M., Vogelaar, B.

In this contribution we (TNO Geological Survey of the Netherlands) share our experience on developing, maintaining, and running the public Seismic Hazard and Risk Assessment for the Groningen reservoir, one of the most well-known and studied examples of induced seismicity. We show how scientific developments are weighted on their performance, and if deemed an improvement on existing models, included in the SHRA to produce better seismicity forecasts. Finally, we discuss how this knowledge is transferred to other Dutch subsurface activities in support of the energy transition.

FUSE - A new infrastructure to help de-risk site selection for future Underground Hydrogen Storage and White Hydrogen exploration

Fausto Ferraccioli

Underground Hydrogen Storage (UHS) and natural (‘white’) hydrogen systems are emerging as key components of Europe’s energy-transition strategy, offering large-scale, flexible and low-carbon solutions that can help mitigate the intermittency of renewable energy sources and strengthen energy security.

Achieving the ambitions of the EU Hydrogen Strategy and global Net Zero roadmaps requires robust geoscientific evidence and advanced technological capacity to identify, characterise and monitor suitable geological reservoirs for UHS. De-risking subsurface operations—technically, environmentally and geohazard-wise—demands new integrated research infrastructures.

FUSE, launched in April 2025, responds to this need. Developed through a strategic partnership between OGS, the University of Trieste, and the University of Udine, FUSE is building an open, distributed infrastructure that combines state-of-the-art geophysical instrumentation, laboratory facilities and multi-scale modelling environments. The infrastructure integrates borehole logging systems, seismic and geoelectric arrays, fibre-optic and orbital-vibrator monitoring solutions, and airborne/drone-based magnetic and gravity capabilities, alongside advanced petrophysical and fluid-dynamic laboratory platforms. Together, these components will enable enhanced imaging, experimentation and simulation of hydrogen–rock–fluid interactions in Italy and elsewhere.

We will present the scientific vision underpinning FUSE -also in relation to the recent North Adriatic Hydrogen Valley project- detailing how the new infrastructure enhances our capacity to map subsurface heterogeneity, assess structural and geohazard risks, and improve predictive modelling of hydrogen behaviour.

By strengthening national and transnational capability, FUSE will act as a catalyst for safer, more efficient UHS deployment and for advancing the frontier of white hydrogen exploration within the broader landscape of the energy transition.

From Uncertainty to Confidence: Assessing Shallow Gas Risks in Offshore Renewable Energy

Michel Guillaume, Venterra Group (GDG); Indrasenan Thusyanthan

Shallow gas in marine sediments is a widespread geohazard across coastal zones and continental shelves. Originating from the degradation of organic matter, it typically consists of methane, carbon dioxide, and hydrogen sulphide. Beyond flammability, toxicity, and overpressure risks, shallow gas can alter geotechnical behaviour (e.g., Bea et al., 1980), with major implications for foundation design and construction safety. Yet detection remains difficult: conventional geophysical, geotechnical, and sampling methods require high expertise, and risk is often either underestimated—leaving hazards unseen—or overestimated, driving excess cost.

In early offshore wind development, robust shallow gas assessment is critical to protect people, safeguard assets, and avoid costly redesigns. As projects expand into increasingly complex settings, a multidisciplinary approach to hazard evaluation is no longer optional but essential.

This talk provides a concise framework to quantify shallow gas risk and illustrates it through a case study. By integrating seabed mapping, geophysical interpretation, and geotechnical analysis, a more reliable and holistic understanding emerges (Michel et al., 2024). The benefits of breaking disciplinary barriers and adopting a shared framework are demonstrated—reducing uncertainty and supporting safer, more efficient decisions. Finally, innovative approaches and advanced analytical methods are highlighted. While requiring upfront investment, these tools can deliver long-term value by de-risking projects early and enabling confident progression from survey to design.

Risk Assessments of Upland Peat Sites Adjacent to Previous Landslides

Chris Engleman, Venterra Group; Paul Quigley (Venterra Group)

Peat landslides pose a significant risk to developments on peatlands across Ireland, and planning authorities have significantly increased the requirements for preplanning assessments. This presentation outlines a peat stability risk assessment (PSRA) undertaken to support compensatory measures associated with the lifetime extension of a wind farm in Ireland. In line with Article 6(4) of the EU Habitats Directive, the project was advanced under 'imperative reasons of overriding public interest' (IROPI), recognising the critical role of wind energy in climate change mitigation and energy security. As part of the IROPI compensatory package, lands in an afforested upland blanket bog were proposed for coniferous deforestation in order to restore an open blanket bog habitat for hen harriers.

The selected offsetting lands are located close to existing peat landslides, which mobilised a debris volume of approximately 125,000m3, causing significant pollution. The assessment combined aerial photo analysis, peat probing, shear vane testing, quantitative factor of safety analysis and qualitative risk assessment. A calibration exercise against the historic peat slides helped to confirm that the proposed works would not materially increase instability. Mitigation measures, including safety buffer zones, felled material restriction areas, and monitoring protocols, were specified to manage localised risks.

This case study demonstrates how an assessment combining remote and field components can ensure that geotechnical risks can be managed safely, enabling the delivery of renewable energy projects under IROPI while safeguarding sensitive peatland environments.

De-Risking Seal Failure Associated with Mississippian-Age Submarine Landslides above Devonian Chattanooga Shale, A CO_2 Storage Container In Tennessee, U.S.A.

C. Robertson Handford, Consulting Sedimentologist

One of the major technological risks associated with underground storage of injected CO_2 is leakage and seal failure above a shale gas reservoir. This presentation addresses a potential seal failure at the top of Devonian Chattanooga Shale due to previously unrecognized submarine landslides, which removed most or all of an overlying secondary seal in the Fort Payne Formation during Mississippian time.

The Fort Payne Formation (Viséan) is a carbonate (crinoidal-bryozoan) and calcareous-dolomitic shale succession of low-angle clinothems, which prograded basinward from south-central Kentucky into Tennessee. Clinothem foresets include sediment gravity-flow deposits representing slope channels, sediment waves, and MTDs. Thick bottomsets contain sediment waves and sheeted drifts deposited by bottom-currents. They extend into the subsurface where the Fort Payne produces oil and gas. Isopach maps unveiled anomalies interpreted as submarine landslides with headwall scarps, evacuation zones, and downflow accumulation zones of MTDs. The underlying Chattanooga Shale was the weak layer along which horizontal shearing took place. Evacuation zones are filled with siltstones and sandstones, which compromise the seal.

In the 2010s, DOE funded a field project to assess the injection and storage potential of CO_2 in the Chattanooga Shale in the study area discussed above. Although stratigraphic assessment of the shale was relatively comprehensive, it was minimal for the Fort Payne Formation. A regional cross section passed through a submarine landslide but did not include any wells which penetrated it. Thus, the slide complexes were overlooked. Fortuitously, the CO_2 injection test site was chosen outside the area affected by submarine landslides.

Poster Programmes

How Japan approaches Seismic resilience in the implementation of low carbon technologies, particularly in Nuclear and Geothermal

Dafydd Maidment, Cardiff University

Japan have been world leaders in seismic resilience for decades, and as they also develop strongly in their low carbon industries, the need for the two to merge is more pressing than ever. Japan is an extremely seismically active country, due to its location lying at the convergence of four major tectonic plates, along the pacific "ring of fire". This talk outlines how Japan has been a leader in developing technologies to derisk geohazards, particularly seismic related events, and their influence on low carbon energy production. Nuclear power remains central to Japan's decarbonisation strategy, yet safety concerns following the Fukushima disaster continue to shape design standards, policy frameworks, and public perception. Alongside Nuclear, geothermal energy provides a great option for low carbon energy production, due to its domestic abundance, but also faces engineering and regulatory constraints in seismic regions. By analysing Japan's institutional responses, technological adaptations, and lessons learned, today I shall highlight the ways in which seismic resilience is embedded in energy planning and how Japan's approach can influence global responses to derisking geohazards in low carbon energy production.

Layered Soils in the UK North Sea: Implications for Subsea Cable Burial and Risk Assessment

Duncan Stevens

Anchor–cable interactions currently account for between 70-80% of subsea cable failures, a figure expected to rise (ICPC) with the continued expansion of offshore wind. To mitigate this risk, it is essential that subsea cables are installed at appropriate depths. Current industry guidance – namely the Carbon Trust's 2015 "Cable Burial Risk Assessment" (CBRA) methodology - recommends burial depths up to 5 m below seafloor (mbsf), depending on ground conditions but assumes soil homogeneity within that range. This overlooks the geotechnical complexity of layered soil profiles, where vertical contrasts in soil type, and the strength and density profile, can significantly influence anchor penetration. We present the spatial distribution of soil layering combinations in the UK North Sea based on analysis of over 20,000 samples, compiled from open-source geotechnical datasets (e.g. BGS Offshore GeoIndex, Marine Data Exchange). We demonstrate that layered soil conditions within the upper 5 mbsf are widespread and we identify samples with layered soil combinations and geotechnical transitions that are likely to impact CBRA outputs. Case studies from this analysis have informed complementary physical and numerical anchor-penetration modelling (e.g., Sharif et al., 2023; Bird et al., 2023a, b) within the EPSRC-funded project "Offshore Cable Burial: How deep is deep enough?". These results highlight the need to refine CBRA methodologies to account for the variability of layered soils. The compiled core database and resulting maps provide a practical tool for early-stage planning, enabling improved prediction of Depth of Lowering (DoL) and reducing risk in future offshore cable developments.

BGS Marine Geoscience – Active mapping initiatives

Dayton Dove,

The Marine Geoscience group within the British Geological Survey (BGS) is currently engaged in a range of seabed and shallow subsurface mapping and analysis. Here we'll provide an overview of several activities, with the objective that these outputs will provide enabling geoscience resources for many users, including researchers, developers, and marine managers.

At a European scale, through the Geological Service for Europe programme (GSEU), BGS scientists are leading the development of **Geo-assessment tools** that describe and classify geo-engineering implications for offshore wind farms (OWF) (and associated infrastructure), as a function of the seabed and shallow sub-surface geology. Within the UK Continental Shelf (UKCS), BGS have recently completed a predictive mapping of **Seabed Sediment (SBS) distribution**, based on the largest compilation of sediment samples in UK, and using new machine learning methods. These products will be released open-access in Sep 2025. Further map products being developed at a national-scale (and open-access) include a compilation of previous **250k Quaternary** map sheets combined into a single digital product (i.e. helpful to inform preliminary assessments of Quaternary deposits - release Autumn 2025), as well as a recently begun effort to map the **Seabed Geomorphology of the UKCS** , based on semi-automated methods**.** At a regional scale, we are preparing an updated assessment (Open Report) of the shallow **sub-surface geology of the Southern North Sea,** integrating results from numerous OWF developments as well as recent research advances. Finally, further fine-scale **Seabed Geology** maps will be released this FY, from the Bristol Chanel, Sound of Jura, and Offshore Orkney (https://www.bgs.ac.uk/datasets/bgs-seabed-geology/). These maps, underpinned by high-resolution bathymetry data and further supporting sample and geophysical data, provide a comprehensive characterisation of the often-complex geological record preserved at/ near seabed.

Tracing active faults in the shallow subsurface of the Dutch North Sea – De-risking offshore wind energy

Bart Meijninger, Johan ten Veen

The subsurface of the Netherlands is dissected by a network of NW–SE trending faults, identified through onshore and offshore seismic studies. These deep-seated faults have been reactivated multiple times since the late Paleozoic under extension, compression, and strike-slip regimes, and have predominantly acted as normal faults since the Neogene.

Onshore, a few faults reach the surface, influencing river courses and groundwater levels. Offshore, however, their Neogene kinematics, continuity, and impact on the seabed remain poorly understood. This knowledge gap is critical as offshore wind farms are planned as part of the energy transition. Faults near the seafloor may pose risks to infrastructure stability or act as fluid migration pathways.

Between 2022 and 2025, TNO-GDN analyzed publicly available 2D and 3D seismic datasets to assess the geometry and continuity of deep-seated faults toward the seabed. More than 120 fault segments were mapped to within 200 m of the seafloor, and 30 segments extend even shallower into middle–late Quaternary strata. Several intersect planned wind farm areas, with tips reaching foundation depths. We present two examples where such faults may pose potential geohazards for offshore infrastructure. These findings underscore the need for integrating fault mapping into geotechnical risk assessments to ensure safe and sustainable offshore energy development.

A new geophysics facility to aid Underground Hydrogen Storage research

Erika Barison

A new geophysics facility to aid underground Hydrogen Storage research

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Abstract

A new geophysical facility funded by the Regione Autonoma Friuli Venezia Giulia is being developed within two complementary projects: FUSE (2025–2027) and IHOST (2026–2029) that aim to accelerate Underground Hydrogen Storage (UHS) research in Italy.

Our approach combines infrastructure development and experimental and field work design and advanced modeling to reduce risk levels in site selection and aid safety and efficiency in UHS. Specifically, FUSE focuses on building an open infrastructure equipped with cutting-edge geophysical instrumentation and software to identify, monitor, and model potential UHS sites and natural/geological hydrogen systems.

Here we will focus on describing each suite of geophysical instrumentation that we are acquiring, including borehole seismic systems, seismic nodes and geophysical logs, electrical resistivity equipment, drone based aeromagnetic sensors and design work to augment our remote sensing airborne platform with enhanced aeromagnetic and airborne gravity data acquisition capabilities.

IHOST will leverage on this new infrastructure to help develop innovative methodologies and imaging techniques, while also training Early Career Researchers to strengthen national expertise levels in UHS and white (geological) hydrogen, which will assist in launching next generation research projects and industry applications in these fields.

Collectively the main advancements are expected to arise through:

1) technical innovation enabled via the integration of new geophysical tools and data acquisition, and processing workflows
2) improved predictive models of hydrogen behavior in the subsurface from combined geophysical and fluido-dynamic modelling
3) new training opportunities
4) and the development of sustainable national and transnational access opportunities for the new infrastructure.

Tracing active erosion in the Gulf of Squillace: Multidisciplinary analysis and implications for offshore Geohazards

Nora Markezic

The Ionian Calabrian Margin (ICM) located in the central Mediterranean Sea hosts a complex forearc basin incised by submarine canyons and characterised by active tectonics and rapid margin uplift.

Through the integration of multibeam and autonomous underwater vehicles (AUV)-based bathymetry datasets, high-resolution seismic profiles, remotely operated vehicle (ROV) imagery and slope stability modelling, this work provides new insights into the main factors driving submarine canyon development in an area of significant geohazard potential.

Bathymetric and seismic data revealed that canyon evolution is strongly controlled by the spatial distribution of structural highs, shallow gas accumulation and migration and the proximity to ephemeral terrestrial rivers. AUV and ROV-based datasets provide the opportunity to identify centimetre- to metre-scale fracture networks acting as precursors to wall failure, evolving into spalling surfaces that promote further retrogressive failures. In addition, biological activity exerts an unexpected yet significant control on wall stability as benthic organisms colonize freshly exposed surfaces, producing intense bioturbation and localized weakening leading to new unstable sectors. To further quantify slope stability mechanisms, three-dimensional slope stability models were developed by coupling geotechnical analysis with seabed mapping. These models demonstrate that pre-conditioning factors such as sediment density and slope gradient alone are insufficient to trigger instabilities under static conditions. However, earthquake-related loading produces factors of safety (FoS) values that fall below unity.

In conclusion, this study provides a comprehensive, multi-scale analysis of the processes governing submarine canyon initiation and evolution along the Ionian Calabrian Margin. The integration of multiple datasets allowed to identify processes that act on different timescales and lead to instabilities.

Geological Society
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