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Thursday 1st December 2022

Croke Park, Jones' Rd, Drumcondra, Dublin 3

ORAL PRESENTATION ABSTRACTS

HOST INSTITUTION

University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

PARTNER INSTITUTIONS

Trinity College Dublin · DIAS · Ollscoil na Gaillimhe University of Galway · UCC · Maynooth University · Teagasc · DCU · Geological Survey Ireland

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iCRAG – Making a Difference

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Since its establishment in 2014, iCRAG, the SFI Research Centre in Applied Geosciences, has developed into a world-leading geoscience research centre focused on driving research and discovery and delivering societal and economic benefit. iCRAG's 150+ highly diverse group of researchers spread across the country are dedicated to creating solutions for a sustainable society, frequently in close collaboration with industry, government, and other partners.

iCRAG research is organised around three challenge area; Earth System Change, Earth Resources, and Earth Science in Society, which are underpinned by enabling methodologies in geomodelling, geochemistry, geophysics, geosensing, and geodata. The research programme currently includes more than 75 projects, including 35 recently announced PhD projects, plus an additional 22 supplementary awards. More than 25% of these projects include industry funding and over €7 million has been garnered from non-exchequer-non-commercial sources in the past two years.

iCRAG research projects and the Centre's extensive Education and Public Engagement activities are designed to make a positive contribution to environmental, economic, and societal well-being. The presentations today will illustrate iCRAG's commitment to excellent science and partnership to address many of the critical local and global challenges we are facing in Ireland and worldwide.

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KEYNOTE ADDRESS

Biodiversity in a warming world

Prof. Yvonne Buckley[1]

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Globally, we are faced with a climate crisis that requires urgent transition to a low-carbon economy. Simultaneously, the biodiversity crisis demands equally urgent action to prevent further species loss and promote restoration and rehabilitation of ecosystems. Climate change is currently causing extinction of populations and species and redistribution of biodiversity, and its effects will accelerate. Through Earth System processes, climate and biodiversity are inextricably linked, with ecosystems as key regulators of climate; this presents significant opportunities for both climate change mitigation and adaptation through nature-based solutions.

Climate action itself must prevent further pressures on biodiversity and options for synergistic gains for both climate and biodiversity change mitigation and adaptation need to be explored and implemented. However, acknowledgement of these intertwined crises is only a first step; implementation of synergistic solutions requires careful planning. I demonstrate how synergy between climate and biodiversity action can be gained through explicit consideration of the effects of climate change mitigation strategies, such as energy infrastructure development and land-use change, on biodiversity. I identify several potential "win-win" strategies for both climate mitigation and biodiversity conservation. For Ireland, these include increasing offshore wind capacity, rehabilitating natural areas surrounding onshore wind turbines, and limiting the development of solar photovoltaics to the built environment. Ultimately, climate mitigation should be implemented in a "Right Action, Right Place" framework to maximise positive biodiversity benefits.

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ECONOMY SESSION

Panel discussion: **Addressing the Energy Crisis through sustainable solutions**

Panel chair and moderator:

Margie McCarthy, Director of Research and Policy Insights, SEAI Sustainable Energy Authority of Ireland

Panelists:

Dr John Fitzgerald, Professor of Economics at Trinity College Dublin, a Research Affiliate at the Economic and Social Research Institute ESRI, and a Member of the Royal Irish Academy.

Dr Sarah Blake, Senior Geologist and Head of the Geothermal Programme at the Geological Survey Ireland

Martina Hennessy, Principal Officer in the Department of the Environment, Climate and Communications (DECC), head of the policy division for Offshore Renewable Energy

Sean Finlay, Director of Geoscience Ireland

Ireland is facing major challenges in providing secure, affordable supplies of energy. Geosciences play an essential role in locating and producing sustainable and reliable sources of energy. The panel will frame the energy crisis in an Irish context, discuss its impact on the Irish economy, and how interdisciplinary research can help us meet the demands of the energy security challenge. Panelists representing government, research and industry will focus on the contribution of geoscience research in areas such as geothermal and wind energy, energy and geological storage, raw materials for the energy transition, and will consider research priorities for future development.

Geoscience, renewable energy and subsurface storage

English, K.L.[1], Walsh, J[1]. Manzocchi, T.[1], Coughlan, M.[1], McDermott, F.[1], Childs, C. [1], Roy, S.[1], Henry, T.[2], Bean C.[3], Kiyan, D.[3]

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Geosciences have an important role to play in the future challenges of energy security and decarbonisation. Ireland has set a target of 80% annual renewable generation by 2030, and 7GW of offshore wind by 2030. In the renewable electricity sector including wind, iCRAG is actively de-risking offshore wind energy projects through seabed geohazard and environmental assessments, as well as acoustic technology development for geotechnical engineering applications. Ongoing work on medium term (20-80 years) climate-related changes in wind capacity is assisting in planning for future installations and wind energy production.

The heat sector currently emits 38% of the CO_2 emission in Ireland (SEAI, 2022), and the deployment of shallow and deep geothermal can help tackle emissions and support district heating systems. iCRAG researchers across different institutions are involved in projects investigating the geothermal potential at different scales, from basin level to urban environments and demonstration projects for decarbonisation of heating with the inclusion of geothermal energy.

iCRAG are also developing a number of initiatives to characterise the subsurface for energy storage and injection, to buffer the intermittent energy supply using geobattery concepts, and to decarbonise CO_2 emissions from point source emitters through carbon capture and storage (CCS). These projects are mainly performed by post-doctoral researchers and faculty, and several new iCRAG PhD projects are starting in energy transition research.

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(Re)sourcing the Clean Energy Transition

Melo A.[1], Chew D.[2], Zhou L.[1], Torremans K.,[1] Bean C.[3], Murray Hitzman[1]

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The world is facing an energy transition process that revolutionises how energy is generated. The International Energy Agency (IEA) predicts that by 2040, there will be a three-fold increase to 300 GW of solar and 160 GW of wind energy capacity being added each year worldwide in a best-case (i.e. sustainable development) scenario. Additionally there is an increased push for decarbonisation as a result of the global disruption to energy supply seen in 2022, and a substantial predicted expansion in the electric vehicle market. This represents a significant challenge as clean energy technologies require significant use of raw materials - to reach a scenario that meets the Paris Agreement goals, total demand will rise significantly over the next two decades by over 40% for copper and rare earth elements, 60-70% for nickel and cobalt, and almost 90% for lithium[1].

In addition to the challenge of securing a sustainable supply of raw materials itself, other challenges include i) improving how these metals are extracted to make them more ethical and sustainable, ii) addressing resource dependency and security of supply, and iii) improving end-of-life recycling rates which are currently < 1% for lithium and the rare earth elements (REE).
iCRAG is developing improved genetic models of deposits and mineral districts for exploration targeting of minerals. These approaches include using detailed petrophysics and geology constraints to guide 3D inversions of subsurface geophysical data, and developing geochemical vector tools to enable more efficient exploration for mineral deposits, and ensuring a sustainable supply of primary metals. iCRAG is also researching recovering metals from secondary sources such as mine and e-wastes to re-source metals through circular innovation.

References

[1] *The Role of Critical Minerals in Clean Energy Transitions*, International Energy Agency, March 2022. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

Building a Sustainable Future through Infrastructure and Materials Research

Unitt, R.P.[1], Meere P.A.[1], Goodhue R.[2], McCabe B.[3], Donohue S.[4]

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Every successful economy requires sound transport infrastructure and a thriving building sector. Today, these areas face the modern challenges of sustainability, unpredictable climate and access to suitable raw materials.

iCRAG understands these challenges and has researchers in many disciplines investigating innovative solutions to these issues. Their work focuses from the microscopic properties of minerals to major infrastructure and large civil engineering projects. In more detail, a number of projects are examining the reactivity and behaviour of deleterious minerals, such as mica and pyrite, in building materials. Other work is studying the role of stone aggregates in generating sustainable friction in our national roads. Civil engineering projects are examining how new techniques can mitigate the extraction of peat during road construction while another uses state-of-the-art technology to monitor the stability of rail cuttings.

Together, this research allows infrastructure and building authorities to regulate and mitigate for issues that arise in their industries associated with the challenges of sustainability, climate change and raw materials.

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ENVIRONMENT SESSION

Innovative techniques to unveil Arctic climate tipping points

Dr Audrey Morley[1]

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Arctic climate change has global implications because some of the most sensitive climate tipping points amplifying global climate change such as deep-water formation, sea ice extent, and permafrost melting are intrinsic to the Arctic region. Unfortunately, our understanding of climate tipping points and their impact on future Arctic and global climate remains limited due to the shortness of our observational records (at best 150 years) and the absence of high-impact climate events therein to serve as a potential analogue for future change. It is therefore essential to develop and apply indirect measures of climate (i.e., proxies) to assess past Arctic climate variability, stability, and its sensitivity to climate forcing. However, most climate proxies are unable to quantify sea surface temperatures or the carbonate system in Arctic or Subarctic Oceans because biological and physiochemical processes besides temperature influence their geochemical composition in cold seawater. SiTrAc addresses this critical gap by pioneering a new holistic multidisciplinary approach to palaeoceanographic proxy development that considers foraminifera as a living organism and not just as a proxy carrier. Using innovative biogeochemical techniques and micro-structural analyses of polar foraminifera Neogloboquadrina pachyderma (NP), which is the dominant and often only species present in surface waters below 4C, SiTrAc will track essential climate variables via the living proxy into the archive (i.e., marine sediments). Further, SiTrAc's unique research strategy will quantify biological and physiochemical processes, that influence how geochemical tracers are recorded, at the time of proxy development and thereby fundamentally advance our understanding of proxies and Arctic climate. SiTrAc provides the critical basis for testing future hypotheses, inside and outside of the Arctic, related to mechanisms controlling climate tipping points globally in the past, present, and future.

Living with elevated CO_2: *What does it mean for surface runoff and flood risk?*

Sate Ahmad*[ab], Laurence Gill [b], Jennifer McElwain [a]

**presenter*

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The global average carbon dioxide (CO_2) level is currently 415 ppm, which is around 50% higher than preindustrial times. While the effect of increased CO_2 on global temperatures is well understood and is being continuously updated, its impact on plant functions such as transpiration (T), and overall evapotranspiration (ET), is still lacking. To optimise water use efficiency (WUE) plants have been shown to respond to elevated CO_2 levels by decreasing stomatal conductance and thus transpiration. This optimisation means that less water is lost for the same amount of carbon assimilated. But what implications does decreasing transpiration have for the global hydrological cycle, namely for surface runoff and associated catchment flood risks?

The 20th century underwent an increased continental runoff, despite higher human water use. Studies have attributed such an increase to a number of different changes such as deforestation rates, climate change and variably, land use land cover change, increasing hazy atmosphere (solar-dimming) as well as on the direct effect of elevated CO_2 on plant transpiration. The results of Gedney et al (2006), who found evidence to support the direct effect of CO_2 on stomatal closure, paved the way for "fascinating avenues of investigation" and scientific discourse on the role of CO_2 on transpiration suppression and modulation of catchment water regimes. While several authors have acknowledged the importance of their results, others have raised concerns regarding the use of incomplete data sets and methods (Peel & Mahon, 2006) and have found other factors (climate and land use change) to be much more important to global runoff trends than the direct effect of rising CO_2). A more recent study by Yang et al. (2019), attributed CO_2 to increased global runoff generation, yet at the local scale they found changes in precipitation to be the dominant influence on historical runoff.

Further mechanistic understanding is thus important, not only at the global scale, but also at the regional, local, catchment and plant level. To this end, our research project (under iCRAG) investigates the response of surface runoff under to elevated CO_2 concentration, with the help of (1) controlled column experiments (microcosm, plant level) (2) field site monitoring (mesocosm - ecosystem scale) and (3) hydrological modelling of catchments (landscape scale). For the column studies, along with previously determined transpiration rates from stomatal conductance, a water balance approach will be employed to determine overall evapotranspiration (ET) and compared between treatments (ambient CO_2 vs elevated CO_2). Values of ET will be then be used as inputs for Hydrus 1D simulations to determine runoff generation. For the mesoscale experiments, field sites in sealed basins with willow stands, instrumented to determine actual ET, will be utilized. These ET values will be combined with direct leaf level transpiration measurements and relationships between plant transpiration and other factors such as stand density will be developed for further use in existing catchment scale models. The newer model can then be used to simulate the likely impact of increased CO_2 in the future on runoff and associated flood risks in Irish catchments.

Keywords: evapotranspiration; ecohydrology; catchment hydrology;

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Can passive seismic be used to locate flowing water in karst environments?

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Karst underground systems transport water primarily through cracks or conduits. Locating the flowing conduits and pathways in karst is important in terms of water resource management, groundwater flooding, geotechnical and engineering projects. Understanding flow pathways is particularly important for road and railway construction, so as not to adversely affect hydrological networks, in particular those associated with Turloughs.

The aim of this study was to develop methods for directly detecting energetic ground water flow in sub-surface conduits through passive seismic applications, by detecting the small ground vibrations (seismic microtremor) that flowing water in the sub-surface may generate. This is in contrast to the current 'traditional' approach of attempting to actively image the conduits using geophysical and other methods, in order to determine the geometry of flow paths. Imagery of conduits in karst is a very difficult problem and determining if they contain flowing structures is also a very significant challenge using traditional methods, which is the motivation for developing a new approach to the problem.

We undertook experiments at two sites on karst; Pollnagran Cave in Frenchpark, Co. Roscommon as an example of a gently-sloping shallow conduit and Polltoophill-Polldeelin Cave in Gort, Co. Galway, as an example of a relatively deep and complex-structured conduit. We observed that subterranean flow-related micro-tremor in karst appears as persistent frequency bands on the spectrograms that varies with time and seismic station location with respect to the conduit. Application of an Amplitude Location Method (ALM) to the linear profiles clearly delineated the conduit as the source of the micro-tremor, in both Frenchpark and Gort. To date we have not seen this method reported in international scientific literature.

Monitoring surface movement in peatlands using satellite data

Dr Eoghan Holohan

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Peatlands are highly sensitive ecosystems subject to a range of Irish and European Union (EU) environmental legislation and they are a major long-term reservoir of carbon. Protection and restoration of peatland are thus central to achieving numerous environmental and climate policy goals, although a challenge is to monitor their progress and effectiveness at large scales (regional or national). This presentation will show how satellite-derived Synthetic Aperture Radar (SAR) missions potentially hold the key to tackling this challenge. SAR penetrates clouds, thus overcoming a major limitation of the optical/multispectral imaging approaches more commonly used for peatland mapping. The EU's Sentinel-1 satellite mission provides SAR data at a temporal resolution of 6-12 days and a spatial resolution of c.15 m. Focusing on two temperate raised peatlands, Clara Bog in Ireland and Cors Fochno in Wales, it will be demonstrated that Interferometry of Synthetic Aperture Radar (InSAR) enables the mapping of surface motion at these peatlands to mm-scale accuracy. These ground motions are mapped over a timeframe of several years (2015-2021) and are shown to be tied to (i) both long-term and annual changes in groundwater levels and to (ii) variations in peat thickness. Satellite-based InSAR thus has the potential for more spatially complete long-term monitoring of peatland eco-hydrology and for upscaling point-like in-situ data to peatland-wide or regional scales.

Water and wastewater treatment by using gas hydrates

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Industrial water treatment involves separating water from a mixture of water and pollutants. This is done to reduce the volume of pollutants that must be transported to a disposal site. Concentrating polluted waste from the raw polluted water is an industrial necessity in many industries. Currently, existing water-treatment methods are insufficient where a mix of solid particulates and biological materials, chemicals, and dissolved ionic solids are present in water, especially in high concentrations. Membranes often pass chemicals along with water and become ineffective at high salinities where both power demands become unsupportable and scale clogs membranes. Multiple-effect distillation methods also are ineffective at high salinities and in water-carrying chemicals. Pond water stored at sites is often biocidal and dangerous. Unprocessed waste of industrial water is a major problem for many industries.

A chemical-engineering method for treating complexly polluted, high-salinity industrial water has achieved laboratory proofs of concept, with scale-up in mind. Gas hydrate is a solid crystalline compound that is formed from water and hydrate-forming gases. Gas hydrate can be fabricated because it is an easily managed crystalline-chemical system, and we also use magnetic fields and biological agents to support this process. Nucleation and growth take place at manageable energy demand at salinities up to supersaturation separating all materials, such as acids and base chemicals, from hydrate since water molecules are employed to form water cavities for incorporating guest gas molecules under elevated pressure and low-temperature conditions. Thereafter, the formed hydrate can be separated and dissociated to release the fresh water. Overall, gas hydrates can be a potential method for industrial wastewater treatment.

Harnessing geomicrobiology for geotechnical and carbon dioxide removal solutions

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Foundation- and ground-improvement methods in geotechnical engineering have traditionally relied on Portland cement, a ubiquitous but carbon-intensive anthropogenic material (almost one tonne of CO_2 is emitted per tonne of Portland cement produced). We are developing alternative microbial- and enzyme-driven bio-cementation methods that will reduce Portland cement use in these applications, with the potential to be carbon-negative. These methods involve rapid in-situ precipitation of calcium carbonate under water-saturated conditions to form calcium carbonate mineral bridges between the grains of unconsolidated soils, sands and gravels. The approach will use modified microbially-induced carbonate precipitation (MICP) and enzyme-induced carbonate precipitation (EICP) methods that were developed originally in the U.S. for silica-sand systems. The methods are being optimised at laboratory scale for application in unconsolidated carbonate-bearing soils and glacial/fluvioglacial deposits that are common in Ireland. Bio-augmentation methods involve inoculation of soils with urease producing bacteria such as Sporosarcina pasteurii and/or bio-stimulation of indigenous ureolitic bacteria to produce carbonate ions from the hydrolysis of urea, which in the presence of free calcium ions precipitate calcium carbonate on timescales of hours to days.

In a separate but related project we are investigating field-scale chemical weathering of natural and anthropogenic silicates and hydroxides for CO_2 removal from the atmosphere. Mineral weathering consumes carbonic acid that arises in soil solutions from the dissolution of biogenic soil-gas CO_2 by infiltrating rainfall. The current focus of our research is on the use of recycled alkaline waste materials such as crushed returned concrete as a reactive soil amendment which can raise soil pH and simultaneously convert soil-water dissolved CO_2 to stable bicarbonate ions. Once exported to the oceans via streams, rivers and groundwater, bicarbonate ions have a residence time of c. 80,000 years, effectively 'permanent' in the context of the current climate crisis.

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SOCIETY SESSION

Making a difference through engagement

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Making a difference through engagement iCRAG has developed a comprehensive education and public engagement strategy to engage non-scientists with our research on the Earth's system, the sustainable development of natural resources and our relationship with our planet. Our aim is to make a difference through the creation of scientifically informed publics. In this talk, we will give an overview of our strategy for making a difference through engagement. We work with a number of different audiences including teachers, students and artists. Together with the target audience, we co-create the best method of engaging the audience with the geoscience that is important to them in a way that is meaningful, appropriate and impactful.

How dirty are urban soils?

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Soils are essential natural resources for food production, flood mitigation and carbon storage, especially in the current climate crisis. Soils in urban areas offer important amenity value to society via public parks and sportsgrounds, but are frequently contaminated, especially by metals. This is a major environmental concern, especially where urban recreational amenities are located on former industrial sites and/or where these soils have accumulated metals from anthropogenic sources, including the historic use of leaded petrol, coal combustion and other industrial activities over long periods of time. The status of these urban soils is thus a topic of public concern but is understudied. To address this issue, we surveyed soils from ten urban recreational sites in Cork city to assess the degree of metal contamination. The results show that lead concentrations exceed Irish national background levels (according to the National Soil Database) in all soil samples from all sites; at certain sites, lead concentrations are ten times above background levels. Manganese, iron and zinc also exceed background levels at all ten sites, by up to five times above background levels. Overall, metal concentrations are highest in the sites closest to the city centre, reflecting diverse sources that potentially include traffic and current and historical domestic coal burning and industry. Informing society on the direct impact that city centre pollution is having on urban soil metal contamination will not only increase awareness but also potentially lead to a change in behaviour to help mitigate urban pollution. Government regulation of urban soil contamination, which includes contamination thresholds, are urgently needed. This research helps to inform the Geological Survey of Ireland (GSI) on the metal contamination of urban parks in Cork city.

Global actions on inclusion and diversity in the geosciences

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Over recent years the way people interact and engage with each other has changed drastically, with new collaborations and more global networks evolving from the move to virtual platforms. This has led to new ideas and projects forming through collaborators around the world, working across disciplines to solve crucial societal challenges.

Within geoscience, many of these projects have focused on the green transition, the supply of critical resources and what this means for different communities. The ReSToRE (Researching Social Theories, Resources, and Environment) International Summer School, organized through iCRAG, is an example of how social scientists and geoscientists can work together to address these challenges. During the 2022 event, key topics like demand and supply for resources, stakeholder engagement and the just transition were discussed, highlighting the need for responsible practices. ReSToRE shows the benefit of multidisciplinary work between geoscientists, social scientists and other experts to foster novel ideas to overcome global challenges.

While programs like ReSToRE show the need, and success, of cross-disciplinary research, they have also shown the need for diversity within these discussions. Within geoscience, diversity (e.g., gender, ethnic background, geography, sector) has traditionally been low. Several initiatives have been formed to address equity, diversity, and inclusion (EDI) challenges within geoscience, such as the EDI in Geoscience (EDIG) project. The EDIG project aims to provide a platform for all in the community to come together to listen, learn and act, to help remove barriers to geoscience.

This talk will share insights learned from the ReSToRE Summer School and the EDIG project, to increase awareness of the benefits of cross-disciplinary work to solve crucial challenges, and foster discussions around these key themes.

Science communication in the framework of the UN Decade of Ocean Science for Sustainable Development

Prof. Peter Croot[1]

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The Oceans are often out of sight and out of mind for many people, with very few people having ventured beyond coastal zones, yet the ocean is a key component of the climate regulatory system on the planet and as such provides essential climate and ecosystem services. Observations of the ocean are critical in providing data for assessing ecosystem and planetary health, yet collecting data in the ocean is challenging due to the harsh marine environment and the logistics involved. Communicating the results of research and the risk implications, under climate change, to those involved in marine governance, policymakers and the general public is key to raising awareness of critical issues in the marine environment, such as ocean warming, deoxygenation and acidification. In this context, the UN Decade of Ocean Science (2021-2030) presents an opportunity and framework for co-design and co-delivery of solution-orientated research that is needed for a healthy ocean. In this short presentation I will discuss current activities in Ireland and elsewhere that are contributing to the UN Decade of Ocean Science and UN SDG 14 Life below water.

Panel Discussion: **Opportunities to Collectively Make a Difference**

Panel chair and moderator:

Dr Jean O'Dwyer, Deputy Director of iCRAG, lead of the iCRAG-GSI Environmental Geoscience PhD Programme, and Deputy Head of Environmental Science in the School of Biological, Earth and Environmental Sciences at UCC.

Panelists:

Mary Frances Rochford, Programme Manager in the Office of Environmental Sustainability and a member of the EPA Senior Management Team

Dr Dierdre Lewis PhD PGeo EurGeol, Technical Director in Environmental and Social Impact with SLR Consulting

Dr Marie Cowan, Science Director with the British Geological Survey and Director at its Belfast Office, the Geological Survey or Northern Ireland

Koen Verbruggen, Director of Geological Survey Ireland

As a multi-institutional, multi-disciplinary, collaborative applied geoscience research centre, iCRAG works to strengthen the cohesion that already exists in Irish geoscience and to bring academic, semi-state and industry bodies together in one forum.

We are continually looking for novel ways to grow and expand our contribution towards a sustainable future. This panel session will explore how we and our partners can enhance collaboration and expand our stakeholder partnerships to increase our collective contribution to confronting multiple crises and challenges.

Our panellists will outline future national and global priorities for geoscience and how research can deliver impact across the economy, environment and society.

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