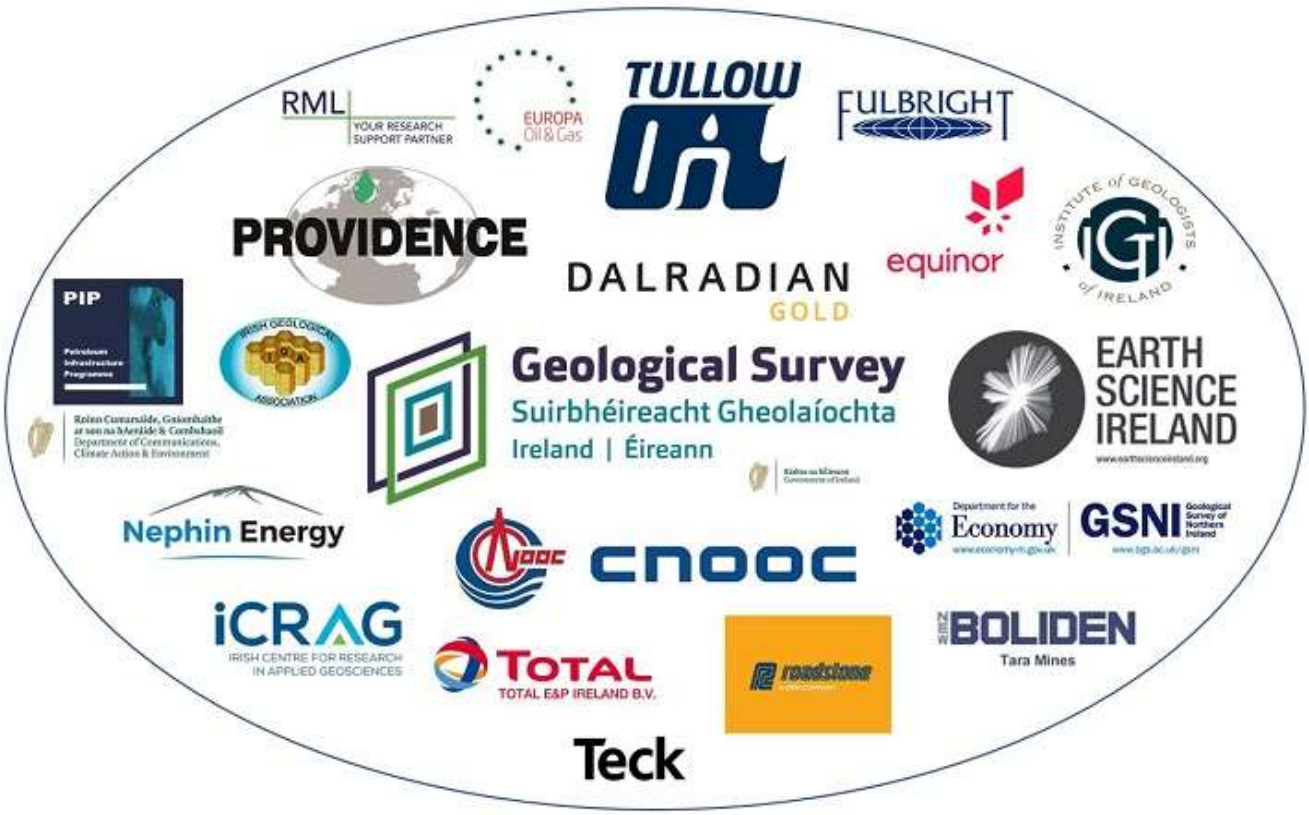
#IGRM2019

62nd Irish Geological Research Meeting

UNIVERSITY COLLEGE DUBLIN

01.03.2019 – 03.03.2019

Programme and Abstracts



62nd Irish Geological Research Meeting

Friday 1st March - Sunday 3rd March 2019

The IGRM 2019 Organising Committee would like to extend a warm welcome to everyone attending the 62nd Irish Geological Research Meeting in UCD. It is very pleasing to see the meeting so well supported with 275 registrants at the time we went to press. There will be 44 talks and 51 posters in the sessions on Saturday and Sunday.

The invited guest speakers this year are Professor Paul Wignall (University of Leeds) and Professor Rachel Wood (University of Edinburgh) whose talks are kindly supported by Geological Survey Ireland and Tullow Oil respectively. Professor Wignall's talk is entitled "Mass extinctions and supercontinents" and takes place 6:00 pm on Friday following the ice breaker. Professor Wood's talk on "What controlled carbonate mineralogy through geological time?" is at 6:15pm on Saturday.

In addition to these traditional events, this year's IGRM will feature two special sessions. On Friday 1st March at 2:00pm Professor Hugh Jenkyns (University of Oxford) will give a lecture entitled "Oceanic Anoxic Events 40 years on: the search for feedbacks" supported by Trinity College Dublin. This will be followed at 3:30 pm by a workshop on "Application of multiple sulfur isotopes in geochemistry" presented by Professor James Farquhar (University of Maryland) and supported by the Fulbright Commission in Ireland and iCRAG.

We hope that as always the IGRM will be an opportunity for researchers, both new and seasoned, to present their work, exchange ideas and renew friendships through both the academic and social events that we have arranged. As always, the success of the Irish Geological Research Meeting rests in large part on the generous contributions of its sponsors. Sponsorship allows us to continue the tradition of not charging a registration fee, encouraging as large an attendance as possible, particularly by students. We are hugely grateful to the following organisations for their support:

Geological Survey Ireland (GSI)

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Providence Resources
Tullow Oil
Earth Science Ireland (ESI)

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Roadstone
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Europa Oil and Gas
Fulbright Commission in Ireland
Irish Geological Association (IGA)
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Programme

Friday 1st March

14:00 – 15:00 **Oceanic Anoxic Events 40 years on: the search for feedbacks**
Professor Hugh Jenkyns (University of Oxford)
supported by Trinity College Dublin (TCD)

15:30 – 17:00 **Application of multiple sulfur isotopes in geochemistry**
Professor James Farquhar (University of Maryland)
supported by the Fulbright Commission in Ireland & iCRAG

17:00 – 18:00 **Icebreaker Reception**
supported by the CNOOC Ireland

18:00 **Mass extinctions and supercontinents**
Professor Paul Wignall (University of Leeds)
supported by Geological Survey Ireland (GSI)

Saturday 2nd March

Session 1: *Chaired by: Daniel Giles and Pablo Rodriguez Salgado*

08:50 **Welcome and Introduction**
Patrick Orr

09:00 **Project SEA-SEIS: Structure, Evolution and Seismicity of the Irish offshore and the wider North Atlantic**
Sergei Lebedev, C. Bean, M. Judge, R. Bonadio, L. Bérdi, J. de Laat, C. Gómez Garcia, B. Chagas de Melo, L. Collins, S. McCarthy, D. Farrell, D. Stalling, A. Schwenk and the SEA-SEIS Team

09:15 **Analysis of equilibrium conditions for particle-laden flows: implications for sediment transport and geomorphology on Earth, Mars and Titan**
Lawrence Amy and R. Dorrell

09:30 **Testing the ability of forward stratigraphic modelling to replicate tectono-sedimentary interactions in rift basins ***
Eoin O'Donnell, P.D.W. Haughton, L. Amy and C. Childs

09:45 **CAIs give the Solar System's age of 4567 Myr, but are they from the Solar System?**
Ian Sanders

10:00 **Microstructural and physiochemical processes influencing fracture sealing in geothermal systems ***
Aisling Scully, D.D. McNamara, S. Piazolo and I. Chambefort

10:15 **Comparing the relationship between sand fraction and connectivity using different conventional facies modelling methods ***
Deirdre Walsh and T. Manzocchi

10:30-11:00 Break - Refreshments

supported by Providence Resources

Session 2: *Chaired by: Laura Bérdi and Brydon Lowney*

11:00 **Monitoring supratidal boulder deposits on Ireland's west coast using structure-from-motion photogrammetry and quantitative differencing**
Rónadh Cox, T. Nagle-McNaughton and P. Cox

11:15 **Modelling of the 1755 Lisbon Tsunami ***
Daniel Giles and F. Dias

11:30 **Modelling fluid flows around a boulder: consequences for initiation of motion**
James Herterich

11:45 **Field measurements of extreme coastal waves on intertidal platforms using pressure sensors - Issues and Advances**
Pal Schmitt, R. Cox, F. Dias, L. O'Boyle and T. Whittaker

12:00 **UAV photogrammetry and 3D scan data for topographic mapping and monitoring of coastal areas**
Kieran Craven, J.Barry, R. O'Toole and S. Cullen

12:15 **Remote Sensing for Mapping Groundwater Floods in the Republic of Ireland**
Joan Campanyà, T. McCormack, O. Naughton and R. Bradford

12:30-13:30 Lunch

Session 3: *Chaired by: Eimear Deady and Thomas Farrell*

13:30 **Initial results from the first detailed study of the Charlie-Gibbs Fracture zone**
Maria Judge, A. Georgiopoulou, B. Murton, S. Hollis, I.Yeo, J. Menuge, P. Collins, K. Robert, A. Scully, A. Dutrieux, P. Nomikou, O. McManus, E. Klein, A. Lohrberg and S. Krastel

13:45 **Simulating Storm Surges on the Irish West Coast: A Numerical Modelling Approach**
Nicole Beisiegel, R. Cox and F. Dias

14:00 **Acoustic evidence of shallow gas and fluid seepage in the north Irish Sea**
Mark Coughlan, S. Roy and C. O'Sullivan

14:15 **Mapping, Modelling and Monitoring Key Processes and Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro)**
Aaron Lim, L. O'Reilly, K. Harris, J. Appah, J. Titschack, O.J. O'Conner, L. Conti, and A. Wheeler

14:30 **A New Approach to Compute Seismic Wave Velocities by Means of Non-Equilibrium Molecular Dynamics Simulations (NEMD)**
Dolores Melgar Freire, M. Lauricella, G.S. O'Brien and N.J. English

14:45 **Recent Advances in Diffraction Imaging: Enhancing existing methods vs. a machine learning approach ***
Brydon Lowney, I. Lokmer, G.S. O'Brien, C.J. Bean and M. Igoe

15:00-15:30 Break - Refreshments

supported by Providence Resources

Session 4: *Chaired by: Bébhinn Anders and Jess Franklin*

15:30 **Late Triassic to early Jurassic stratigraphy & palaeoenvironments from Co. Antrim**
Ian Boomer, A. Azmi, R. Raine, P. Copestake, J. Fenton, K.Page

15:45 **Alternative resources of the rare earth elements***
Eimear Deady, K. Goodenough, A. Lacinska and R.A. Shaw

16:00 **Climate dynamics and the stable isotope hydrology of Irish River water during 2018**
Anne Carey, T. Henry, D. Smith, P. Croot and W.B. Lyons

16:15 **The Geochemistry of Rivers in Ireland: a Snapshot**
W. Berry Lyons, P. Croot, A.E. Carey, T. Henry, S.A. Welch, C.B. Gardner and R. Flynn

16:30 **Tellus More**
Jim Hodgson and Tellus Team: R. Scanlon, M. Ture, M. Glennon, E. Scanlon, K. Knights, J. Mather, V. Gallagher, M. Szpak, E. Palenius, M. Muller and B. Crowley

16:45 **Geoscience and Public Policy: What role should geoscientists play?**
Maeve Boland

17:00 **Celebrating two decades of Earth Science Ireland**
Kirstin Lemon and F. McAuliffe

17:15-18:15 Conference Reception

supported by Earth Science Ireland (ESI)

18:15 **What controlled carbonate mineralogy through geological time?**
Professor Rachel Wood (University of Edinburgh)
supported by Tullow Oil

Conference Dinner in the Generator Hostel

Buses leave at 7.30

Sunday 3rd March

09:00-09:30 Poster Session with light breakfast

supported by Providence Resources

Session 5: *Chaired by: Aodhán Ó'Gogáin and Tiffany Slater*

09:30 **The origin and nature of a pervasive vein system within The Burren, Clare**
John Walsh, J.P. Moore, C. Bunce, S.P. Hollis, J. Kelly and J.F. Menuge

09:45 **The Geology of Skellig Michael – Finally Revealed**
Patrick Meere, K. Higgs, M. O'Sullivan, A. Lim, R. Hennessy and S. Johnson

10:00 **Viséan limestone, karst and the Galway Outer Bypass ***
Megan Dolan, B. McCabe, J. Murray, T. Henry and M. Fleming

10:15 **The character of thin-bedded deposits associated with submarine channels: examples from the Ross Sandstone Formation, Co Clare**
Emma Morris, P.D.W. Haughton, J. Lopez-Cabrera, P.M. Shannon and C.S. Pierce

10:30 **Rule-based models of deep-water lobes. What can we learn from them? ***
Javier López-Cabrera, T. Manzocchi and P.D.W. Haughton

10:45 **En-masse freezing of hybrid sediment gravity flows with implications for deep-marine carbon burial ***
Arif Hussain, P. Haughton, E. Morris, P.M. Shannon and C. Pierce

11.00-11:30 Break - Refreshments

supported by Providence Resources

Session 6: *Chaired by: Megan Dolan and Aisling Scully*

11:30 **The Aïstopods (Tetrapodamopha) from the Jarrow Assemblage, Kilkenny, Ireland ***
Aodhán Ó'Gogáin and P.N. Wyse Jackson

11:45 **Experimental taphonomy of melanosomes: impact on trace element chemistry ***
Valentina Rossi, M. McNamara and S. Webb

12:00 **Response of melanosome chemistry to diagenesis explored through experimental maturation**
Chris Rogers, M.E. McNamara and S.M. Webb

12:15 **Dynamic Sand Supply to a Carboniferous Delta; Mixing and Matching with Multiple Provenance Proxies ***
Bébhinn Anders, S. Tyrrell , J. Murray, J.R. Graham, C. Mark and D. Chew

12:30 **Innovations in Raman Spectroscopy Analysis: Testing correlations between Raman spectra and radioactive decay ***
Odhrán McCarthy, A. Resentini, B. Fairey, P. Meere, S. Ando and M. Tunwal

12:45 **Provenance of the Tullig Cyclothem sandstones from the Clare Basin: A multi-proxy approach ***
Martin, Nauton-Fourteu, S. Tyrrell, A.C. Morton, C. Mark and G. J. O'Sullivan

13:00-14:00 Lunch

Session 7: *Chaired by: Javier López-Cabrera and Valentina Rossi*

14:00 **Investigating the biochemical fidelity of fossil feathers using sulfur X-ray absorption near-edge spectroscopy (XANES) ***
Tiffany Slater, M. McNamara, N. Edwards and S. Webb

14:15 **A study of the evolution of colour patterns in fossil insects using geometric morphometrics**
James Jepson, M. McNamara, C. Shih, D. Ren and N. MacLeod

14:30 **Magnetic-Field Effects on Methane-Hydrate Kinetics and Potential Geophysical Implications: Insights from Non-Equilibrium Molecular Dynamics**
Niall English and C.C.R. Allen

14:45 **Probabilistic Surface Heat Flow Estimates Assimilating Palaeoclimate History: New Implications for the Thermochemical Structure of Ireland's Crust ***
B. Mather, Thomas Farrell, and J. Fullea

15:00 **The three-dimensional geometry of relay zones within segmented normal faults**
Vincent Roche, G. Camanni, C. Childs, T. Manzocchi, J. Walsh, J. Conneally, M. Mudasar Saqab and E. Delogkos

15:15 **A quantitative model for the internal structure of normal faults**
Tom Manzocchi, C. Childs, V. Roche, G. Camanni, E. Delogkos, A. Soden, I. Telles, A. Heath and M. Carneiro

15:30 **Conjugate relay zones and transfer of displacement between faults of opposed dip**
Conrad Childs, R. Worthington, J. Walsh, V. Roche and C. O'Sullivan

15:45-16:00 Wrap up and Award of Prizes

supported by Irish Geological Association (IGA)

Poster Presentations

Undergraduate Posters:

1 **Using Airborne LiDAR to identify and map glacial geomorphology and landforms in Co. Roscommon ***

Weston Harding and E. Daly

2 **Magnetic Fabrics and Remnant Magnetism of the Fair Head Sill, Co. Antrim: Testing Emplacement Linked to the Great Gaw Fault ***

Elspeth Jamieson, C. Stevenson, M. Cooper and R. Raine

3 **A mineralogical and geofluids study of gold bearing quartz veins from the north-west of Ireland ***

Shane McQuillan, D.D. McNamara and J. Hunt

4 **Airborne Electromagnetic Datasets from the Tellus Programme: Quantitative Analysis of the Role of the Flight Altitude Parameter on the Resulting Subsurface Inversion Models ***

Méabh Ní Mhuilleoir, D. Kiyan, V. Rath, M.D. Ture and J.A. Hodgson

5 **Ground Penetrating Radar investigation of Rathcroghan, Co. Roscommon ***

Jeromine Schmitt , M. Folan, S. Rooney and E. Daly

Poster Presentations:

6 **Characterizing the TELLUS Airborne EM anomaly over the Longford down inlier, Ireland through hyperspectral core scanning**

Connor Allen, B. McConnell and R. Rogers

7 **Integrating Gravity and Surface Elevation With Magnetic Data: Mapping the Curie Temperature Beneath the British Isles and Surrounding Areas**

Eldar Baykiev, M. Guerri and J. Fullea

8 **The link between stress, pore pressure, and subduction dynamics: Implications for offshore geohazards and resource development ***

Effat Behboudi, D.D McNamara, J. Murray, L. Wallace, D. Saffer, P. Barnes, I. Pecher, H. Lee, G. Kim, W. Hung-Yu, K. Petronotis, L. LeVay, Expedition 372 Scientists, Expedition 375 Scientists

9 **Geological evolution and complex magmatic history of the Hatton Basin, northeast Atlantic Ocean ***

Laura Berdi, M. Prada, B. O'Reilly, P. Shannon and P. Haughton

10 **Heavy metal analysis of peat using ETV-ICP-OES: A highly efficient technique for direct solid sampling ***

Lucy Blennerhasset and E.L. Tomlinson

11 **SWEMDI_1.0: Space Weather Electromagnetic Database for Ireland**

Joan Campanya, P.T. Gallagher, C.Hogg, S.P. Blake, D. Kiyan, R. Scanlon, D. Jackson, M. Gibbs, D. Reay, J. Fullea and V. Rath

12 **SKS Seismic Anisotropy Observations in Mid-Plate South America : Investigating Mantle Flow and Effects of Cratonic Keels ***

Bruna Chagas De Melo and M. Assumpcao

13 **The Formation, Evolution and Characterisation of a Tunnel Valley System in the Southern Irish Sea: an Investigation of Wicklow Trough**

Mark Coughlan, Z. Tóth, A.J. Wheeler, S. Wenau, S. McCarron, M. Long and V. Spiess

14 **Sediment Connectivity in Modern Deepwater Turbidite Systems: Examples and Implications**

John Counts, L. Amy, P. Haughton and A. Georgiopoulou

15 **Exploring the characteristics of the Tuaheni Landslide Complex, Hikurangi Margin, offshore New Zealand ***

Ben Couvin, A. Georgiopoulou, J. Mountjoy, G. Crutchley and IODP expeditions 372 and 375 participants

16 **Radon Potential as a diagnostic tool for indoor radon hazard mapping**

Quentin Crowley, J. Elío, M. Hughes, M. Dardac, L. Vucinic, R. O'Toole, P. McGuire and S. Wolfe

17 **Eastern North Atlantic Mid-to-Late Holocene transition: Palaeoceanographic evidence and implications for atmospheric modes ***

Michelle Curran, Y. Rosenthal, J. Wright and A. Morley

18 **Investigating acoustic noise propagation across various continental margin settings ***

Eoghan Daly, S.Crawford and M. White

19 **Correlated petrographic and isotopic studies (S, Pb) of high-grade Zn-Pb mineralization in the Island Pod orebody, Lisheen deposit, Ireland ***

Aileen Doran, S.P. Hollis, J.F. Menuge, J. Güven, A.J. Boyce, S. J. Piercey and O. Turner

20 **Using in-situ mineral geochemistry to safeguard the integrity of building structures: An Irish example**

Tadhg Dornan and R. Goodhue

21 **Tara Deep Preliminary Observations: Setting, Mineralogy and S Isotopes ***

Drew Drummond, A. J. Boyce, L. Yesares, R. Blakeman and J. Ashton

22 **PS-InSAR analysis of Sentinel-1 data for detecting ground motion in temperate oceanic climate zones: a case study in the Republic of Ireland**
Simone Fiaschi, E.P. Holohan, M. Sheehy and M. Floris

23 **Seismic reflection imaging of the crust using ambient noise autocorrelations ***
Clara Gomez, S. Lebedev, T. Meier and L. Wiesenberg

24 **Enhancing the Operational Capacity of the Irish National Seismic Network**
James Grannell, M. Moellhoff, D. Craig and C.J. Bean

25 **Three-dimensional electrical conductivity characterisation of Furnas and Fogo Volcanoes, São Miguel Island (Azores archipelago, Portugal), by magnetotelluric data**
Colin Hogg, D. Kiyan, V. Rath, A. Junge, R. Carmo, F. Vivieros, R. Marques and the Fogo team

26 **Chemical anomalies in stream sediments associated with lithium pegmatites in Leinster, SE Ireland ***
David Kaeter and J.F. Menuge

27 **3-D Magnetotelluric Imaging of the Lithosphere beneath Ireland**
Duygu Kiyan, J. Campanyà, C. Hogg, J. Fullea, S.P. Blake, V. Rath, R. Bonadio, P.T. Gallagher, A.G. Jones and R. Scanlon

28 **Petrophysical Characterization of Highly Polarizable Rocks from the Moffat Shale Group (Ireland)**
L. Römhild, M. Sonntag, Duygu Kiyan, V. Rath, R. Rogers and J. Börner

29 **Study of the Palaeoenvironments and Geological Setting of the Kilbride Peninsula, County Mayo**
Cameron Lane and G. Nichols

30 **The role of the continental shelf on ocean induced seismic surface waves generated offshore Ireland**
Florian Le Pape, D. Craig and C. Bean

31 **Relating Catchment Lithology to Minor and Trace Elements in Irish Rivers**
C.B. Gardner, S.A. Welch, P. Croot, T. Henry, R. Flynn, A.E. Carey, and W.Berry Lyons

32 **Submerged Landscapes of Ireland**
Eoin MacCraith, D. Tappin and M. Judge

33 **Spatio-temporal analysis of long term/short term shoreline change rates using remote sensing approaches**
Sojan Matthew, C. Gallagher, X. Pellicer and X. Monteys

34 **GEO-URBAN - Identification and assessment of deep GEOthermal heat resources in challenging URBAN environments**
James McAteer, S. Blake, J. Clarke and The Geo-Urban Consortium

35 **The Iapetus suture zone in Ireland**
Brian McConnell, N. Riggs and T. Fritschle

36 **Thermodynamically constrained joint inversion of seismic refraction, surface elevation and gravity data for crustal composition and structure: application to the Porcupine Basin**
Dimitri Molodtsov and J. Fullea

37 **Deciphering the mineral-scale record of planetary scale processes ***
Maeve Murphy Quinlan, T. Müller, A. Walker, C. Davies, J. Mound and J. Harvey

38 **The Next Generation of Irish Geoscientists: Exploring Attitude And Understanding Towards Geoscience At Junior Secondary Level In Ireland ***
Emer Neenan

39 **Geophysical remote sensing of subsurface properties for sustainable agricultural management ***
David O'Leary, B. Thebaudeau, O. Fenton, P. Mellender, S. Green, C. Brown, P. Touhy, S. O'Connor and E. Daly

40 **Temporal variability of cold-water coral habitats from the Porcupine Bank Canyon NE Atlantic, using ROV-vibrocoring, CT-scanning and PSA: preliminary results ***
Luke O'Reilly, A. Lim, A, O.J. O'Connor, J. Titschack, K. Harris, J. Appah and A. Wheeler.

41 **Biogeochemical modelling of soil organic carbon - insights into the processing procedures of selected atmospheric input data: Part I – an example from E-OBS climate datasets**
Alina Premov, J. Zimmermann and M. Saunders

42 **Biogeochemical modelling of soil organic carbon - insights into the processing procedures of selected atmospheric input data: Part II – atmospheric nitrogen deposition from EMEP datasets**
Alina Premov, J. Zimmermann and M. Saunders

43 **Preliminary LA-ICP-MS AFT & AHe Results Offshore West of Ireland**
Remi Rateau, C. Ansberque, C. Mark and D. Chew

44 **Surface Deformation from Stalled Magma ***
Eoin Reddin, S.K. Ebmeier, D.J. Morgan and E. Rivalta

45 **A Quaternary Geological Map at 1:10,000 scale for the Keady Region, Northern Ireland**
Sam Roberson and L. Hughes

46 **Palaeoenvironmental reconstruction from the mineralogy of the Pliocene Camp dels Ninots maar lake sediments (Catalan Volcanic Zone, NE Iberia) ***

Pablo Rodriguez Salgado, J. Ibáñez, P. Anadón, B. Gómez de Soler, G. Campeny, J.Agustí and O. Oms

47 **Structural style and timing of the inversion structures in the Celtic Sea basins (offshore Ireland): Insights from the Mizen Basin ***

Pablo Rodriguez Salgado, C. Childs, P.M. Shannon and J.J. Walsh

48 **A New Raman Microscopy Facility at the School of Biological, Earth and Environmental Sciences, UCC**

Richard Unitt, M. Tunwal, O. McCarthy and P. Meere

49 **Improving the Groundwater Geochemistry Toolkit for Mineral Exploration ***

Sean Wheeler, T. Henry and J. Murray

50 **Northern Ireland one 14 new Regional Geological Visualisation Models**

Katie Whitbread, C. Ritchie, M. Cooper, R. Raine and D. Reay

51 **In-situ S isotope analysis reveals genetic links between Irish-type deposits and related geochemical halos**

Lola Yesares, D. Drummond, J. Menuge, A. Boyce, R. Blakeman and J. Ashton

Invited Lectures

Oceanic Anoxic Events 40 years on: the search for feedbacks

Professor Hugh Jenkyns

Department of Earth Sciences,University of Oxford, South Parks Road,Oxford OX1 3AN, UK

Application of multiple sulfur isotopes in geochemistry

Professor James Farquhar

University of Maryland, Department of Geology, 8000 Regents Dr., College Park, Maryland 20742, USA

The analysis of all four sulfur isotopes has the potential to provide information about reaction pathways that differentiate equilibrium from kinetic effects as well as provide information that can be used as tracers of geochemical processes. This talk will review the basic principles that control the nature of sulfur isotope variability in terrestrial environments extending from the modern atmosphere to the ancient atmosphere, sediments in deep geological time, and recycling of material from ancient sediments to solid-Earth reservoirs.

Mass extinctions and supercontinents

Professor Paul Wignall

School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK

The history of life has been punctuated by five devastating mass extinctions. Two of them occurred within 50 million years of each other, at the end of the Permian (251 millions years ago) and the end of the Triassic (201 million years ago). There were also several other crises both before and after these events making it one of the worst periods to be alive. Every extinction coincides with the eruption of a giant volcanic province and the interval also coincides with the accretion and zenith of the Pangean supercontinent. I will argue that all these factors – mass extinction, volcanism and supercontinent – are closely linked. Pangea began breaking up in the Mid Jurassic and since that time life on Earth has endured no more crises (with the exception of a giant meteorite impact at the end of the Cretaceous) even though there have been many more intervals of giant volcanism. The talk will look at the role of volcanism in driving major environmental changes and why these effects may be getting less intense.

What controlled carbonate mineralogy through geological time?

Professor Rachel Wood

School of GeoSciences,Grant Institute,University of Edinburgh,KingsBuildings,James Hutton Road,Edinburgh EH9 3FE, UK

Inorganic carbonate mineralogy has changed through the Phanerozoic and probably before. It has been proposed that conditions have oscillated between those that have facilitated the preferential formation of aragonite + high Mg calcite (HMC) mineralogies, termed 'aragonite' seas, and those which favored low Mg calcite (LMC) mineralogies, termed 'calcite' seas. This oscillation is thought to be caused by a secular variation in Mg/Ca ratio of seawater, changes in carbon dioxide partial pressure (pCO_2), and also changes in dissolved SO_4, which decreases the Mg/Ca ratio at which calcite is destabilized and aragonite becomes the dominant $CaCO_3$ polymorph. In this talk I wish to explore the relationship between extrinsically-driven changes in seawater chemistry and biological response, and also the nature of potential feedbacks. Many animal (metazoan) skeletons are composed of calcium carbonate [$CaCO_3$], forming as aragonite, LMC or HMC. By contrast, dolomite [$CaMg(CO_3)_2$] has a highly ordered crystal lattice with slow kinetic growth rates, does not readily form in modern oceans despite supersaturation, and has never been documented as a biomineral. This is of note because early metazoan skeletal clades commonly co-opted carbonate minerals in concert with ambient ocean chemistry. In addition, mimetic preservation by dolomite (i.e., retention of original crystallographic orientation) of originally aragonite and/or HMC grains as well as dolomite cements provides evidence that early marine dolomite precipitation dominated Cryogenian to early Ediacaran oceans (ca. 740 to ca. 630 Million years ago). This is inferred to be due to widespread low-oxygen oceans or stratified oceans and high-Mg/Ca seawater. The presence of high iron (ferroan) concentrations in early dolomite cements and ferroan dolomite concretions in shales further indicates that these oceans were anoxic and ferruginous. These so-called "aragonite-dolomite seas" are thought to have been largely replaced by "aragonite seas" during the Ediacaran. Ratios in Mg/Ca are presumed to have been driven by enhanced rates of mid-ocean ridge expansion which promotes the preferential removal of Mg from seawater via hydrothermal reactions. Plate tectonic activity as a driver for Mg/Ca ratios does not satisfy, however, data that show that seawater composition has changed during the past 40 Million years even though seafloor spreading rates have been nearly constant. Mineral proxies of inferred major changes in Mg/Ca ratios may also record Mg removal from seawater by basinalto global-scale processes, such as dolomitization of large, expansive platforms during periods of high sea level. A quantitative compilation of carbonate skeletal mineralogy through the Phanerozoic shows a progressive replacement of low-Mg calcite (LMC) by aragonite. This general trend overrides the subsidiary trend of Greenhouse intervals favoring biogenic 'calcite' seas, and Icehouse intervals facilitating 'aragonite' seas. The replacement of low-Mg calcite by aragonite was, however, achieved episodically at mass extinction intervals. In particular, the end-Permian extinction both preferentially removed species bearing 'unfavorable' LMC, and allowed the selective radiation of biota with 'favorable' aragonite. This demonstrates the importance of 'incumbency' in the evolution of skeletal mineralogy.

Abstracts for Oral Presentations

Abstracts are listed in alphabetical order by first author

Analysis of equilibrium conditions for particle-laden flows: implications for sediment transport and geomorphology on Earth, Mars and Titan

L. Amy[1] (lawrence.amy@ucd.ie) and R. Dorrell[2]

[1] *UCD School of Earth Sciences, University College Dublin, Belfield, Dublin 4.*
[2] *School of Earth and Environment, University of Leeds, LS2 9JT, United Kingdom.*

Sediment erosion, transport and deposition by rivers and turbidity currents are key processes responsible for shaping large areas of the natural landscape and seascape. Similar resurfacing of planetary surfaces by liquids associated with a volatile cycle is also inferred for other planetary bodies in the solar system, including Mars and Titan. This talk will consider the sediment transport dynamics of suspended-load dominated flows, and in particular a new model for equilibrium flow conditions, where sediment erosion equals deposition. Understanding this condition is key to predicting some of the most fundamental aspects of sediment laden flows, their effects on the land/seascape and resulting stratigraphic architecture, for example: whether flow will be erosional or depositional, how much sediment they can transport (i.e., their capacity and sediment flux) and what slope gradient they will attempt to achieve (i.e., equilibrium graded slope). Results pertinent to several areas of research will be presented: what are critical slopes of sediment bypass by turbidity currents? How important is particle size distribution in sediment transport? Are graded slopes on Mars and Titan, and by implication the current/past geomorphology of these planetary bodies, similar to those on Earth?

Dynamic Sand Supply to a Carboniferous Delta; Mixing and Matching with Multiple Provenance Proxies

B. Anders[1] (b.anders1@nuigalway.ie), S. Tyrrell [1,2], J. Murray[2], J.R. Graham[3], C. Mark[4], D. Chew[4]

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This study investigates source to sink processes in a complex ancient deltaic system utilising a multi-proxy provenance approach. During transport and deposition, sediment is modified by processes such as mixing, which influences sand composition and thus provenance signal. The Mullaghmore Sandstone Formation (MSF), a mid Viséan fluvial/deltaic sequence in the Northwest Carboniferous Basin (NWCB) of Ireland is an excellent target for this study as it comprises various repeated facies packages with variable energy and input from multiple distinct sources. Optical microscopy, zircon and apatite U-Pb geochronology, trace elements in apatite and Pb-in-K-feldspar analysis have been used to investigate potential variations in supply to the NWCB.

Four sections through the MSF have been logged and sampled at high resolution. Three main grain populations have been identified: 1) Archean-Paleoproterozoic sources (Lewisian or Nagsuggtoqidian); 2) Laurentian affinity sources; and 3) Caledonian-aged detritus. Pb-in-K-feldspar data seem to better reveal changing sources, while zircon data show little variation throughout the sedimentary sequence. Apatite geochronological data differs from that of zircon, as it yields a large proportion of Caledonian-aged grains – which trace element analyses reveal to be of metamorphic origin. These were likely derived from the Dalradian Supergroup or equivalents and reset during the Caledonian Orogeny. Overall, the analytical results indicate that sediment derives from the northwest. Provenance data are more unimodal in channelised sandstone facies, compared to a broader “mixed” signal in shoreface facies sandstones, likely reflecting point sourcing and shelf mixing respectively.

Simulating Storm Surges on the Irish West Coast: A Numerical Modelling Approach

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Storm surges are extremely dangerous events facing society at the current time and with its exposed location facing the Atlantic Ocean, the Irish West Coast is particularly vulerable to storm surges and is often battered by violent storms during the winter months. Computer simulations are a crutial part in the study of these severe storm events: Flood forecasts are needed by warning managers and insurance companies alike to issue warnings and estimate damage respectively, and hindcasts (simulations after the events) contribute to ultimately improve our understanding of the physical mechanisms that cause these large storms and their impacts.

Although simulations of storm surges have been produced for decades and current simulation tools are able to give good estimates for high water levels during storms, these predicitons are often based on simplified assumptions and only give reasonable results at broad geographic scale. They fail to take into account all the complexities that are present on finer scales such as topographic features. The latter, however, can have a large impact on the wave behaviour and the resulting predicted run-up.

This is why we use a Discontinuous Galerkin model that is capable of simulating physical non-linearities with the additional advantage of being computationally efficienct through the use of adaptve mesh refinement. This dynamically non-uniform mesh follows dominant physical features on fine scales and reduces the overall computational complexity of the simulation. The presentation will conclude with preliminary simulation results for a winter storm on the Irish West Coast.

Geoscience and Public Policy: What role should geoscientists play?

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There are ethical and pragmatic reasons for geoscientists to engage with public policymaking. The ethical obligations stem from our duty to inform the public and to support responsible stewardship based on our understanding and interpretation of the Earth.

More pragmatically, geoscientists frequently encounter the two broad categories of “policy for geoscience” and “geoscience for policy” in their professional lives. Policy for geoscience refers to decisions that affect the geoscientific enterprise. Government and EU policies, for example, strongly influence what research is done in universities. Policies and regulations govern exploration for, and development of, most earth resources. Geoscience for policy is the provision of geoscience information to help inform policy decisions.

It is important to distinguish between two different roles that geoscientists can play: providing the factual basis for policymaking that involves the Earth system and advocating for a policy option that reflects preferred values.

Outside of government agencies, there appear to be few well-established channels of communication between the Irish geoscience community and policymakers. Should we develop these communication structures and – most importantly – what messages do we, as a geoscience community, wish to deliver to policymakers?

Late Triassic to Early Jurassic stratigraphy & palaeoenvironments from Co. Antrim

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The 'Latest' Triassic to Early Jurassic interval is marked by global sea-level rise and distinct faunal turnover and extinction world-wide. Across NW Europe this interval is usually represented by a transgressive pattern of sedimentation, Rhaetian marginal-marine sediments being replaced by marine sedimentation in the Hettangian. The transgressive nature of this boundary makes correlation difficult and it is only in the last decade that a GSSP has been established at Kuhjoch, in the Austrian Alps.

Sediments of this age are known to occur subsurface across the northern and eastern parts of Northern Ireland, but such records are rare at outcrop. The recovery of recent borehole material has permitted a detailed study of this important interval in earth history. Cuttings samples from the Ballinlea-1 borehole on the North Antrim coast (at 630 m, the longest Jurassic sequence known onshore in Ireland) and completely cored records from Carnduff-1 and 2 in East Antrim (156 m) have been the focus of multiproxy studies in a bid to understand the precise age and completeness of these sections, as well as the local environment of deposition and to correlate these new sections with contemporaneous records in the UK and further afield.

The Carnduff cores have received most attention, with ammonites, foraminifera, ostracods and palynomorphs giving a robust chronology, as well as providing palaeoenvironmental data. The microfossil and palynological evidence supports a marginal-marine setting for the sediments of the Penarth Group, while the Waterloo Mudstone Formation records shallow-marine, shelf conditions that are generally well-oxygenated, but with occasional intervals of dysaerobia, though never becoming anoxic.

The Carnduff cores have also provided an important sedimentological record with what appears to be continuous succession through the boundary interval. Distinct carbon isotope excursions (CIEs) in both the organic and inorganic fractions at the boundary of the Cotham and Langport members (Lilstock Formation, Penarth Group, 'latest' Triassic) suggests the possibility of global correlation, in this largely unfossiliferous part of the section, with similar CIEs reported elsewhere at this time. The overlying Waterloo Mudstone Formation is essentially marine, though ammonites and microfossils are not recorded until about 6 m into that unit.

Remote Sensing for Mapping Groundwater Floods in the Republic of Ireland

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Groundwater flooding represents a significant hazard in many rural communities in Ireland. The unprecedented flood events in recent years have reinforced the need to improve our ability to quantify the location and likelihood of flood occurrence. Geological Survey Ireland, in collaboration with Trinity College Dublin and Carlow Institute of Technology, has established a collaborative project to investigate groundwater flooding specifically related to seasonal lakes known as turloughs. There are over 400 recorded turloughs across Ireland, the majority of which located on limestone lowlands. Turloughs can completely dry during summer months but extend to hundreds of hectares during the

winter flood season. The practical limitations of establishing and maintaining a network of over 400 turloughs supported the use of remote sensing and GIS techniques to delineate flood extents using passive satellite imagery such as the ESA Sentinel programme. Measurements at 50 sites for over 18 months were used to calibrate and validate results from satellite data. With limited recorded groundwater flood data, the use of remote sensing data provides historical archives of images to look at past flood conditions to optimise the detection of groundwater and delineate maximum groundwater flood maps. This project will provide essential technical knowledge to key stakeholders to develop scientifically-informed decisions with regard to groundwater flood mitigation and prevention.

Climate dynamics and the stable isotope hydrology of Irish River water during 2018

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Climate variations in Winter and Spring 2018 provided opportunity for a field experiment on Irish river isotope hydrology. After the cold and wet winter of 2017–18, Ireland experienced a drought in Summer 2018. Stable isotope analyses of stream samples collected in March–August 2018 showed evaporative signals in repeated sampling along the mainstem of the River Shannon and other rivers. Met Éireann data showed total rainfall at its Athenry synoptic station for January 2018 was 173.2 mm; mean monthly January rainfall was 116.7 mm. Record wet weather continued through April 2018. In May the weather became warm, sunny, and dry. June rainfalls were below long-term averages. Monthly mean temperature for January 2018 was 5.3 °C, lower than the 30-year average of 5.5 °C. By June mean temperature was 15.9 °C, greater than the 30-year average of 13.7 °C.

We constructed a regional meteoric water line (RMWL) from 558 published δD and δ^{18}O analyses of Ireland rainfall collected from 1960 to 2016 and analyzed by the GNIP program. Our samples from 7 locations along the main stem of the Shannon and 3 of its tributaries in March 2018 clustered together and plotted above the Global Meteoric Water Line (GMWL) and calculated RMWL. Samples from those River Shannon locations plus others from the Shannon in June and August 2018 plotted below the GMWL and the RMWL, indicating an evaporative signal. We speculate on the role of climate and the relationship of the loughs along the rivers in controlling isotopic signals observed.

Conjugate relay zones and transfer of displacement between faults of opposed dip

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The transfer of displacement between faults that dip in the same direction is well understood and relay ramps between adjacent fault segments have been frequently described. Perhaps counterintuitively, displacement can also be transferred between faults that dip in opposite directions but the structure at the boundaries between opposed dipping faults is not well understood. We constrain the mechanism by which displacement is transferred between opposed-dipping faults by examining the geometries of faulted horizons and fault throw distributions at these 'conjugate relay zones'.

Structure contour maps of horizons offset by overlapping opposed-dipping faults from different extensional settings display a consistent pattern. Above the line of intersection between the conjugate faults the deformed horizon is flat between converging faults and displacement transfer is reflected in changes in footwall elevation. Below the line of fault intersection the mutual footwall is flat and elevation changes occur in the hanging walls of the divergent faults. These elevation changes can be explained as a simple superposition of the deformation fields of two faults that have retarded lateral propagation due to the presence of the other synchronous fault, irrespective of whether the two faults actually intersect. The observed patterns of horizon elevation strongly resemble those seen at boundaries between adjacent basin-scale half-graben of opposed polarity.

Acoustic evidence of shallow gas and fluid seepage in the north Irish Sea

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Shallow (typically within the upper 30 m) accumulations of gas in marine sediments can be identified by distinctive seismic features recorded on sub-surface acoustic profiles, including; (1) enhanced reflectors, (2) turbidity zones, and (3) acoustic blankings (extending in both vertical and lateral directions). Identifying and characterising such accumulations is important for assessing marine geohazards, for developing offshore infrastructure as well as locating deeper hydrocarbon reservoirs. In addition, methane is one of the most important greenhouse gases in the atmosphere with an estimated 20% of the total contribution of atmospheric methane coming from the world's shallow shelf areas. In the Irish Sea, such accumulations are often associated with seabed morphological expressions, in the form of pockmarks and mud diapirs, suggesting previous or active seepage to the seafloor.

The origin of shallow gas in the Irish Sea is widely debated with arguments for a biogenic and thermogenic source. Other geochemical studies have proven inconclusive. Here we present an integrated marine acoustic study of seafloor morphology, stratigraphy of marine sediments, and deeper bedrock and tectonics to investigate the controls on shallow gas distribution in the north Irish Sea. Ee analyse deeper (up to 3 km) 2D multichannel seismic reflection data to identify possible source rocks and potential migration pathways between these sources and the near-seafloor shallow gas accumulation and seafloor seepage locations.

Monitoring supratidal boulder deposits on Ireland's west coast using structure-from-motion photogrammetry and quantitative differencing

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Supratidal boulder deposits along Ireland's Atlantic coast—both isolated clasts and organised boulder ridges—include megagravel weighing tens to hundreds of tonnes. Despite their importance as archives of extreme wave events, little is known about their sedimentology or geomorphology: how often new boulders are created and added, whether boulder ridges are actively migrating, or whether they are currently aggrading or eroding. To address this, we are implementing drone-based structure-from-motion (SfM) monitoring. We have generated benchmark models, at cm-scale

resolution, covering ~17 linear km of deposits; and are using the open-source software *CloudCompare* www.danielgm.net/cc/ to quantitatively compare time series of these models.

Initial tests from Valentia Island and Inis Mór show the power of the *CloudCompare* differencing approach. SfM models of deposits on Valentia Island (data from July and November 2017), served as a control for *CloudCompare*'s change-detection algorithms. *CloudCompare* correctly reported zero change between the two image sets, down to the ~3cm/pixel resolution of the models. On Inis Mór however,*CloudCompare* identified substantial boulder movement at one site (near Bun Gabhla) between 2015 and 2017, despite the lack of large storms during that time interval. Although there was essentially zero net volume change, *CloudCompare* detected displacement of ~200 boulders within the Bun Gabhla deposit, ranging in size from a few 10s of kg to 28 tonnes. Individual clasts moved distances ranging from a few 10s of cm to more than 15 m. We corroborated the *CloudCompare* results by manually comparing the SfM models, drone images, and field photographs.

UAV photogrammetry and 3D scan data for topographic mapping and monitoring of coastal areas

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Coastal areas experience change via marine processes and other natural and anthropogenic causes. These changes to coastal geomorphology must be assessed on a range of temporal and spatial scales to understand the evolution of these environments, particularly in the context of projected climate change yielding increased sea-levels and storm frequency. Commercial survey grade unmanned aerial vehicle (UAV) and 3D scan equipment, data processing and analysis tools are available to coastal managers, engineers and researchers.
This study, undertaken as part of the CHERISH project, analyses the use of photogrammetry via UAVs and 3D scan data from scanning total stations in Irish coastal locations to produce orthoimage mosaics and digital surface models. These products extend and complement acoustic bathymetric data from the Irish national seabed mapping programme (INFOMAR) in mapping coastal regions. Preliminary results indicate that combining relevant techniques to produce seamless onshore-offshore maps can provide high-resolution information about emergent and submergent coastal geomorphology on a range of scales for use in coastal mapping, monitoring and management.

Alternative resources of the rare earth elements

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Rare earth elements (REE) are essential raw materials for much modern technology. Current production of REE is dominated by hard-rock mining, particularly in China. In order to expand the resource base of the REE, it is important to determine what and where alternative sources exist. This presentation overviews two deposit types, a REE placer and red mud, the waste of alumina production from bauxite ore.

REE placers are well known, however, these are typically derived from eroded granitic rocks and are commonly radioactive. Other types of REE placers, such as those derived from volcanic activity, are rare. The Aksu Diamas heavy mineral placer in Turkey was assessed for REE extraction as a by-product of magnetite production, but its genesis has not previously been well understood. Fingerprinting of mineral phases identified the source of the placer as the nearby Gölcük alkaline

volcanic complex with a history of eruption throughout the Plio-Quaternary. This type of deposit may represent a potential resource of REE in other alkaline volcanic settings.

REE also occur in karst-bauxites, forming authigenic REE-bearing minerals, as accumulations of detrital phases and through adsorption of ions onto clays and other mineral surfaces. REEs are concentrated into red mud, the waste product of alumina production from bauxite. Red muds contain ~900 ppm REE compared with <100 –500 ppm REE in bauxite. Annual European extraction of bauxite is ~3.5 million tonnes, resulting in ~1.4 million tonnes of red mud waste, understanding the REE resource potential of red muds is integral to the assessment of future REE resources.

Viséan limestone, karst and the Galway Outer Bypass

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The discovery of a previously unknown *c.*100 m deep sediment-filled karst feature in the area between Lough Corrib and Galway city (during preliminary site investigation for the N6 Galway City outer bypass road) has prompted a research project focused on improving the understanding of both the local and regional geology and geomorphology. A detailed geological investigation of the unconsolidated infill sediment and local limestone bedrock in the vicinity of the large-scale karst depression provides insight into the timing and style of its formation. Fluvial and lacustrine palaeoenvironments are interpreted from the sediment also within which three phases of glaciation are potentially represented, the oldest possibly dating to the Late Pleistocene or older. Major joint sets developed in the limestone govern the local hydrogeology and appear to have controlled the east-west formation propagation of the deep enclosed depression. An integrated investigation of the bedrock, including logging, mapping, petrography, palaeontology and geochemistry, facilitates reconstruction of the geological history locally, and highlights relationships between lithology and karstification. The latest published regional bedrock map has been integrated with local and regional karst records to demonstrate a correlation between particular types of karst features and specific carbonate lithologies which could be useful for detecting additional buried karst features elsewhere in future geotechnical projects across the region.

Magnetic-Field Effects on Methane-Hydrate Kinetics and Potential Geophysical Implications: Insights from Non-Equilibrium Molecular Dynamics

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We have conducted non-equilibrium molecular-dynamics (NEMD) simulation to show that externally-applied magnetic fields, including their reversals in direction, have important effects on gas-release dynamics from methane hydrates. In particular, we apply fluctuation-dissipation analysis in the guise of Onsager's hypothesis to study hydrate kinetics at lower applied-field intensities, including temporary hydrate destabilistaion in the wake of field-polarity switch; we scale down to the lowest practicable field intensities, of the order of 1 T. We conjecture, that these NEMD-based findings, particularly those involving polarity switch, may have ramifications for superchron-related Earth's magnetic-field polarity swaps affecting methane release into the geosphere, although a good deal of further work would be needed to provide a more definitive causal link.

Modelling of the 1755 Lisbon Tsunami

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Tsunamis are rare events which have the potential to cause massive loss of life and destruction. From an Irish perspective, the last known tsunami to affect our shores was the Lisbon 1755 event. This earthquake and subsequent tsunami was felt across the Atlantic basin and resulted in a huge number of fatalities. With the ever growing population and increased economic importance of coastal areas, the threat of a similar sized event is now being recognised.

Owing to their rarity, accurate modelling and simulation of tsunamis play a vital role in identifying vulnerable sites, producing hazard assessments and developing early warning systems. A study focusing on the threat to Irish coastlines has been carried out by utilising our recently developed VOLNA-OP2 software. VOLNA-OP2 is capable of simulating the complete life cycle of a tsunami: generation, propagation and inundation. Within this framework, a brief overview of tsunami modelling will be introduced and some findings from this study will be given.

Modelling fluid flows around a boulder: consequences for initiation of motion

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Boulder quarrying by large waves along steep, high-energy coastlines contributes to erosion both by causing inland migration of cliff faces and by vertical lowering of coastal platform surfaces. It also leads to the formation of coastal boulder deposits above and inland of the high water mark. We consider the fluid-structure interaction that results in transport of these large boulders.

Fluid flow around on object such as a boulder generates hydrodynamic forces, drag and lift, and their associated moments, on the object's surface. Typically, these are described by experimentally derived drag and lift coefficients, and an average velocity. However, these coefficients and velocities are often not representative of real physical systems. We build on existing models of fluid-structure interaction for initiation of boulder motion, and consider non-uniform flows, including wakes, around the boulder.

The local flow depends on the obstacle shape, slowing down in confining corners and speeding up in expanding corners. As such, the hydrodynamic forces can differ significantly on each face depending on the boulder geometry (eg, aspect ratio). We discuss the implications in the modelling of coastal boulder extraction and transport. We show how boulders in different geometries can be transported against gravity, and analyse the influence of a wake region behind a boulder. The models are applicable to initiation of motion. We compare results to the existing literature.

Tellus More

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Tellus is the Geological Survey Ireland's geochemistry and airborne geophysical national survey. The data are useful in helping to understand and map Ireland's rocks, soils and waters. In 2019 we plan to complete airborne surveys over counties Limerick, Tipperary and west Cork which commenced in autumn 2018. Further airborne survey work for summer 2019 is planned over counties Wicklow, Wexford, Carlow and Kilkenny. All data will be seamlessly merged with previous datasets providing continuous coverage over large parts of the country. In-fill geochemistry soil and drainage sampling across the midlands during 2019 will bring geochemistry sample collection to approximately 50% of the country. All data are made freely available and the latest data release event is planned for the Autumn.

As the survey progresses and new data are released the Tellus Programme will continue to develop new products based on the geochemical and geophysical datasets. Towards the end of 2018 a new research project 'Terra Soil', in conjunction with Teagasc was launched. This project will provide additional analysis and modelling on the collected Tellus soil samples to maximise agronomic applications including indicators for soil fertility and soil management, and the advance of a spectral library to develop a chemometric model for soil particle size and texture class. Further projects in collaboration with the EPA on soil chemistry in respect of Soil Recovery Facilities and modelling radon risk are both on-going. However, we are always keen to hear about new proposals for research or products that use the Tellus data.

En-masse freezing of hybrid sediment gravity flows with implications for deep-marine carbon burial

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Hybrid event beds (HEBs) are the deposits of an enigmatic yet common class of sediment gravity flow involving turbidity currents that partly transform to debris flows as they run out. The deposits thus typically comprise a basal clay-poor turbidite sandstone and an upper clay-rich debrite. The linked debrites can contain significant volumes of fractionated clay and organic carbon (hereafter OC) and the processes leading to their formation may offer an efficient mechanism for transport and rapid burial of OC in submarine fans. However, the extent of OC segregation between the co-genetic turbidite and debritic parts of the bed and understanding the impact of depositional processes on OC burial have yet to be addressed. The vertical distribution of OC in representative HEBs from Pennsylvanian Ross Sandstone Formation, western Ireland is investigated. A total of 55 core plug samples comprising clean and muddy sandstones and mudstones were collected and used for thin sections and rock powder preparation. Textural quantification was carried out using thin sections whereas LECO carbon, Rock-eval and stable carbon isotope techniques were used to determine OC content, type and source(s). Muddy sandstones have on average 4 times higher OC than co-genetic turbidites with 77% of the OC sourced from tropical terrestrial plants. The mudstones have the same average OC content but with slightly lower terrestrial OC reflecting fractionation and/or preferential oxidation. This suggests that rapid freezing of turbulence damped sediment gravity flows can bury large quantities of OC within submarine lobes, with important implications for atmospheric carbon sequestration over geological timescales.

A study of the evolution of colour patterns in fossil insects using geometric morphometrics

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Wing colour patterns are the basis for diverse insect communication strategies and thus are critical to understanding aspects of the roles of innovation, homology, and convergence in driving insect evolution. Fossil insects often exhibit wing colour patterns, but with the exception of a single study on eyespot patterning in Kalligrammatidae (Neuroptera) there has been no systematic investigation of their evolution in fossil insects. We investigated colour patterns in Middle Jurassic neuropterans from the Daohugou Lagerstätte (Jurassic, China) using novel geometric morphometric methods. Digital wing images from 300 specimens were attributed to 11 descriptive morphogroups (e.g. vertical stripes, apex pattern, eyespots, spots). Eigenimage analysis tested whether these qualitative visual morphogroups represent mutually exclusive geometric pattern categories. Our results show that some pattern morphogroups are geometrically more diverse than others. Mapping the pattern morphogroups onto a phylogeny of Neuroptera reveals how the geometric diversity relates to the evolutionary history of these insects. Our results confirm that quantitative, image-based analytical methods can be applied successfully to non-traditional morphometric data and can facilitate studies of evolutionary diversity through time.

Initial results from the first detailed study of the Charlie-Gibbs Fracture zone

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The oceanic crust forms about 60% of Earth's solid surface and is largely generated by volcanic activity at mid-ocean ridges. Segmentation of the mid-ocean ridges results in strike-slip motion that is accommodated at seismically active conservative plate boundaries called transform faults. These fundamental structures dissect the Earth's crust, segment the mid-ocean ridge system and form bathymetric scars. Little is known about how transform faults form, accommodate plate motion, affect the nature of the oceanic crust and interact with seawater. Once considered simple strike-slip faults, we now recognise transform faults as key components in the evolution of the oceanic lithosphere and in shaping the Earth's surface.

Here, we report initial results from a study of the largest, yet relatively unknown, transform fault zones in the North Atlantic, the Charlie Gibbs Fracture Zone and the discovery of hyper-extensional spreading. In contrast to crust generated by normal seafloor spreading, the floor of the transform zone is devoid of volcanic material. Instead, it is formed by tectonic uplift, serpentinisation and

exhumation of mantle rocks that were intruded by isolated plutons of magma while simultaneously being deformed and metamorphosed by high-strain ductile shear. Relocation of extensional rifting within the transform fault zone accompanies extreme changes in elevation forming a line of massifs that extend across the North Atlantic. We propose that this processes of crustal formation, has significant effect on the chemical and thermal exchange between the ocean and crust and the strength of the oceanic lithosphere.

Project SEA-SEIS: Structure, Evolution and Seismicity of the Irish offshore and the wider North Atlantic

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Most of Ireland's territory, including its largest sedimentary basins, hydrocarbon resources and, probably, natural hazards (offshore landslides) are in its vast offshore. Sparse data sampling has, so far, hindered our understanding of the deep mechanisms of the lithospheric hyperextension that formed the basins, mechanisms of the Paleogene uplift and volcanism in and around Ireland (probably related to the enigmatic Iceland Hotspot activity), regional-scale structure and evolution of the area's crust and lithosphere, and its current deformation and seismicity. In this project, we have deployed 18 new, broadband, ocean-bottom seismometers across Ireland's offshore, with a few instruments also in the UK and Iceland waters. The unique new data will enable seismic tomography at various scales, with state-of-the-art waveform and array methods. An offshore earthquake catalogue will be obtained, and the lithosphere-scale thermal evolution of the basins will be modelled.

SEA-SEIS kicked off in 2018 with a 3-week expedition on RV Celtic Explorer, which, apart from the pioneering OBS deployment, presented a unique opportunity for broad public engagement. Outreach with schools, in particular, can have a profound, lasting impact. It shows the students how science works, encourages them to study science, and broadens their career perspectives – to quote from the teachers' feedback survey of the SEA-SEIS outreach. The SEA-SEIS outreach programme comprised live, ship-to-class video link-ups and successive, national school competitions, seismometer-naming and seismology song-and-rap ones for secondary schools and a drawing one for primary schools. We shall present some of the remarkable entries.

Website: www.sea-seis.ie

Celebrating two decades of Earth Science Ireland

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In late 1999, it was looking bleak for Earth science education in Ireland; the geology department at Queen's University Belfast had just announced its imminent closure, and teaching of geology in schools was at an all-time low. Determined to address this issue, a group of passionate geologists from across the country created a network dedicated to raising awareness of Earth science across the island of Ireland and Earth Science Ireland was born.

Earth Science Ireland quickly evolved and went from strength to strength. It has supported Earth science education and learning at all ages, promoted the conservation of critical Earth science sites, engaged the public on topical issues and demonstrated the environmental and economic benefits of Earth science.

The flagship output of Earth Science Ireland is its excellent magazine, of which there have been 34 issues in total. At its peak the magazine was distributed to approximately 6000 people twice a year including to 1200 individual members across the island of Ireland and worldwide, and also to libraries, museums, science centres, and all post-primary schools.

Nearly two decades on and thanks to the foundation that Earth Science Ireland has laid, there has been a huge increase in the number of organisations with Earth science public engagement as part of their core work. For this reason, the current edition of the magazine will be the last hard copy, with the proceeding edition in March 2019 being the final digital copy.

Earth Science Ireland has achieved such a huge amount thanks to the support and sponsorship from a vast number of organisations, societies and individuals including most recently the Geological Survey of Northern Ireland, Geological Survey Ireland and iCRAG. Without this support and that from its 1200 members, the vast journey that Earth Science Ireland has travelled would never have been possible.

Mapping, Modelling and Monitoring Key Processes and Controls on Cold-water Coral Habitats in Submarine Canyons (MMMonKey_Pro)

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Submarine canyons are vast, steep-sided geomorphological features that cut through continental slopes globally. Channelling flow from the shelf to the deep sea, organic matter and sediment flux at these sites are common allowing to host and sustain a range of benthic habitats. The Porcupine Bank Canyon, NE Atlantic, is a tectonically-initiated canyon, cut-off from direct terrigenous input. Ranging from -600 m to -3000 m water depth, the canyon hosts a range of cold water coral habitat types (reefs and mounds, coral gardens, isolated colonies and coral carbonate talus slopes). This study utilises a novel, integrated approach to understand habitat drivers and development in space and time. Spatial analyses of regional- (hull-mounted multibeam echosounders), local- (ROV-mounted multibeam echosounders) and fine-scale (3D photogrammetry and video) data show that these habitats types are distinctly different in the modern environment. Preliminary results of sediment

core CT-scans offer a unique perspective on how these habitats vary through time. This summer, 8 deep water landers equipped with sediment traps and current meters will be deployed via ROV for a period of 3 months within each of these habitat types and on their boundaries to understand the processes driving variability between habitat type and provide a temporal context for the sediment cores and mapping data. This presentation shows the work completed to date on this project.

Rule-based models of deep-water lobes. What can we learn from them?

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Unlike traditional geomodelling techniques, such as conventional object-based modelling, surface rule-based methods are capable of reproducing very complex geometries with geological realism. This realism will be dependent on rules which are based on simple geological concepts, such as the law of superposition, as well as more complex ones such as hierarchical constrains. These rules are applied to each depositional event while the models are built, which at the same time will lead them to define the evolution of the next depositional events. A new code based on several geological rules has been generated, with the aim to characterize deep-water lobes geometrical frameworks.

A four-fold hierarchy is often seen in deep-water lobes, and the code can reproduce it by the addition of inter-element shales, which will behave as barriers to flow. Erosion rules are also introduced and can connect different hierarchical elements by removing their associated inter-element shales. Furthermore, compensationally stacked and aggradational depositional self-controlled sequences can also be generated, providing a wide range of feasible geometries and complexity levels. Since they are capable of generating complex structures with geological realism in a manner impossible in more conventional approaches, rule-based models are a powerful reservoir modelling tool.

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Recent Advances in Diffraction Imaging: Enhancing existing methods vs. a machine learning approach

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The seismic wavefield is a complex series of interactions between the source wavefield and the subsurface. These interactions can take several forms including reflections, diffractions, refractions, with various types of noise also influencing the wavefield and degrading the quality of recorded data. Conventional seismic images focus on enhancing reflections at the expense of other components of the wavefield. Whilst reflections are useful in imaging continuous stratigraphy, they can fail to image sharp corners, such as those found in fault-zones and pinchouts. Diffractions, however, form when the wavefield encounters objects which are small in comparison to the wavelength. By imaging the

diffractions, these objects, which are geologically significant, can be directly imaged. To image diffractions, they must be separated from the wavefield; however, this proves a difficult task due to the overlap with reflections and the low amplitudes of the diffractions.

Several methods exist to separate diffractions from reflections. Here, we focus on two methods, one which involves enhancing an existing technique and a novel method which uses machine learning. Plane-wave destruction is a common diffraction imaging technique which estimates the local slope of reflection energy and removes any energy which conforms to this slope, leaving behind diffractions and noise. Here, we enhance this method using F-K filtering to remove remnant reflection energy and noise. Multi-domain diffraction identification is a novel method which uses a convolutional neural network to classify the wavefield and separate it into three component wavefields: diffractions, reflections, and noise. Once separated, these wavefields can be processed separately.

The Geochemistry of Rivers in Ireland: a Snapshot

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We analyzed the geochemistry of 23 of Ireland's largest rivers and some low order monolithologic streams during the wet 2018 winter and the prolonged dry period following. This was done to compare compositions, estimate geochemical fluxes and elemental yields from the catchments, investigate differences resulting from landcover and bedrock geology, and compare individual river compositions in wet and dry seasons. We focus on 9 rivers where published particulate matter fluxes exist. Rain-corrected riverine compositions were dominated by calcium and bicarbonate in all rivers. Rivers originating in the Midlands have higher magnesium and sulfate values. Whether this is due to natural or anthropogenic input is unknown. Weathering of carbonate minerals is a major process in all catchments; silicate weathering yields are as much as three orders of magnitude lower than calcium weathering yields. Compared to monolithologic low order stream chemistry, larger rivers represent a mix of inputs of different land covers and lithologies, even though most are dominated by carbonate dissolution. Loughs along rivers have some control on overall geochemistry of the large river systems, especially River Shannon. We speculate that longer residence time of waters in loughs homogenizes riverine geochemistry. We have compared our rain-corrected total chemical denudation fluxes to particulate matter flux data demonstrating that chemical denudation is the primary mode of mass loss. This work presents an overall view of the geochemistry of rivers throughout Ireland and shows the importance of geochemical characteristics of the bedrock and the landcover on the riverine geochemistry.

A quantitative model for the internal structure of normal faults

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Over recent years we have undertaken a focused study systematically measuring geometrical properties of normal faults offsetting clastic sequences formed in diverse geological setting and covering a wide scale-range varying from a few millimetres to a few hundreds of meters of maximum throw. The research was driven initially by the realisation that although we had long recognised that normal faults are segmented zones comprising multiple interacting slip surfaces rather than single surfaces accommodating all of the displacement, we had few quantitative constrains on the segmentation. A complete characterisation of a segmented fault generally cannot be obtained in the subsurface, and therefore in the absence of a description of likely segmentation, we were unable to assess probabilistically the importance of fault segmentation when addressing practical questions, such as the likelihood that a 20 m thick sandstone aquifer is entirely offset by a fault with a total throw of 50m over a horizontal distance of 1 km. In this presentation we will describe one of the results of the research, which is a quantitative model for fault segmentation in a map-view sample of a fault zone, constrained to parameters derived from real faults. The model has been expressed both as an equation able to answer questions like the one stated above, and as a stochastic tool embedded in geomodelling software and able to create equiprobable models of segmented faults based on a low-resolution input fault.

Probabilistic Surface Heat Flow Estimates Assimilating Palaeoclimate History: New Implications for the Thermochemical Structure of Ireland's Crust

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Regions where surface temperature has increased since past glaciation events, such as Ireland, underestimate the heat output of the Earth unless paleoclimate corrections are applied. We apply probabilistic techniques to quantify the uncertainty of 22 palaeoclimate-corrected heat flow estimates in Ireland, which assimilate multiple surface temperature histories associated with 130 ka of glacial oscillation in the British Isles. Heat flow values increase by ~15 mW/m^2 after a palaeoclimate correction and provide new insights into the thermochemical structure of the lithosphere. The heat flow regime is broadly delineated by the Iapetus Suture Zone that separates Laurentian to the north and Avalonian terranes to the south (mean surface heat flow of 73 ± 14 and 65 ± 14 mW/m^2, respectively). The degree to which heat-producing elements are partitioned into the uppermost crust is described by the differentiation index of a heat flow province. From Bayesian inversion, we determine that radiogenic elements are substantially more differentiated in the uppermost crust of Laurentia (DI = 2.8 ± 1.4) than Avalonia (DI = 1.5 ± 1.3), despite a moderately enriched lower crust (0.8 ± 0.3 μW/m^3). This is facilitated by a thin yet highly radiogenic layer in the uppermost crust of Laurentia (3.9 ± 1.8 μW/m^3). Extrapolating these results across the British Isles and Newfoundland suggests that heat-producing elements have been more successfully reworked into the upper crust to the north of the Iapetus Suture Zone during continental accretion between Laurentia and Avalonia.

Innovations in Raman Spectroscopy Analysis: Testing correlations between Raman spectra and radioactive decay

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Single grain age dating techniques are powerful tools in provenance; however they are limited to destructive, time-consuming methods. Raman spectroscopy analysis is a proven method for mineral identification and polymorph characterisation; but it is also a proxy for α –decay radiation damage. New advances in Raman technology produce unprecedented levels of data with a wide range of applicability. Raman spectra are 2D representations of the molecular structure of a mineral at a point with up to a micron resolution. Molecular concentration, crystallization and structural variations of sub-phases within minerals like zircon are reflected in Raman spectra by their peak intensity, width and frequency. In this study, novel Raman spectral analysis is developed to characterise zircon phases. Two age dated zircon separates which have been cathodeluminsence (CL) imaged are re-analysed with two approaches aimed toward characterising zircon populations; detailed 1 – 4 micron resolution Raman spectra maps and a simpler point map taking <30 spectra to characterise zircon phase profiles. Datum are processed using an "R" based algorithm, developed to isolate the peak intensity, frequency and width of the B1g and A1g internal modes and 355 cm^{-1} external Raman active bands of Zircon. Characterised phases are compared with CL imaging and U/Pb isotope age dating results. Novel Raman spectroscopy analysis presents a non-destructive, simple and rapid age profiling tool with a wide range of scientific applications.

The Geology of Skellig Michael – Finally Revealed

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Preliminary results of a recent geological study of the World Heritage site of Skellig Michael represent the first description of the Skellig rocks since they were first reported by the Geological Survey in 1861. The island is composed of a ~400m thick succession of Upper Devonian fluvial sedimentary and volcaniclastic rocks representing the most westerly exposure of Old Red Sandstone succession in the Munster Basin. The island is structurally divided by the NW-SE trending Blue Cove Fault, a westerly dipping late Variscan normal fault. East of this fault the succession is sandstone-dominated and is lithostratigraphically correlated with the onshore St. Finan's Sandstone Formation. It contains a previously unknown ~60m thick volcanic sequence of pyroclastic lithic and welded tuffs. Newly acquired U-Pb magmatic zircon dates from this unit have yielded an isotopic age of 374.6±7Ma (Upper Devonian, Frasnian). The younger succession west of the fault is dominated by laminated siltstones and is correlated with the onshore Caha Mountain Formation. The structural geology of the island is typical of Variscan deformation in SW Ireland involving the initial development of a LPS cleavage followed by folding and subsequent reactivation of early strike parallel normal faults as reverse faults following fold lock up. Overall, the structure of Skellig Michael is dominated by an open syncline that plunges (c.15°) to the northwest. INFORMAR bathymetric data show the Skellig islands are sited on the north western corner of a shallow (<75m depth) submarine bedrock platform that extends offshore southwest of the Iveragh coast.

A New Approach to Compute Seismic Wave Velocities by Means of Non-Equilibrium Molecular Dynamics Simulations (NEMD)

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The characterization of the nanoscale properties of geophysically relevant materials is important for determining the elastic properties that govern phonon and sound propagation. These phenomena are notably significant in the context of oil exploration and seismic prospecting. Herein, we present a new method in which NEMD were used to track the propagation of an artificial perturbation. To the best of our knowledge, this is the first time where seismic velocities were directly calculated at the atomistic scale. The propagation is followed using different descriptors. In addition to the comparison between the different metrics used to track the perturbation, a wide range of perturbation amplitudes were tested, as well as the behaviour of the seismic velocities under stress and in the presence of crystallographic defects. The seismic velocities do not depend on the way the perturbation was created, tracked, or on its amplitude, confirming the robustness of this new methodology. This approach was tested on different geophysically relevant materials, such us SiO_2 materials and hydrates systems, showing an excellent agreement with the experimental observations.

This new computational approach allows the full control of the features of the geological sample in terms of composition, porosity, lattice heterogeneities, stress, temperature, and other petrophysical characteristics, as well as the particularities of the seismic wave itself, such as its magnitude and direction. This new approach opens a new avenue for research, where relationships between the seismic waves velocities and different characteristics of the sample can be established in a more systematic and simpler way.

The character of thin-bedded deposits associated with submarine channels: examples from the Ross Sandstone Formation, Co Clare

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Submarine channels are the primary conduit for transporting terrigenous sediment from the continent to the deep ocean; they extend from the continental shelf, along the slope and out onto the basin floor. They vary by depth of erosional confinement, width and sedimentary fill as they pass down the slope, they are also typically flanked by levees. Levees are wedge-shaped, constructional features that thin away from the channel and can form extensive deposits that reach 10's-100's metres thick and many kilometres wide. Previous outcrop-based studies have documented extensive levee deposits adjacent to channels on submarine slopes, however, detailed observations of levees on the base-of-slope to basin floor in sand-rich systems are less common due to limited outcrop exposure.

Recent outcrop and core-based studies from the Ross Sandstone Formation of the Clare Basin have demonstrated the presence of significant thin-bedded and fine-grained successions adjacent to channels on the base-of-slope to basin floor. Observations and interpretations of these features have shown that they have a complex depositional history that is governed by the distance from the parent channel. They display a predictable upwards facies transition from relatively thick-bedded sandstones to finer grained facies that is exclusively composed of well-structured thin to very thin

beds of current-rippled sandstone isolated in siltstone. Where they can be mapped laterally, they are characterised by a wedge-geometry that records a thinning and fining lateral facies transition over a distance of up to 10km. These observations and relationships suggest at least some of the Ross channels had low-relief levees.

Provenance of the Tullig Cyclothem sandstones from the Clare Basin: A multi-proxy approach

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This study investigates the provenance of deltaic sandstones from the mid-Carboniferous Clare Basin, western Ireland. Previous studies, based on palaeocurrent data, interpret contradictory basin infill histories with competing models suggesting sediment input from either the northwest or the southwest. Previous zircon U-Pb geochronology (Pointon et al. 2012) were performed on one sample from the Tullig Cyclothem. Results suggest sources from both north (Laurentian) and south (Avalonian) of the basin.

Detailed logging and sampling of Tullig cyclothem sandstones was performed at three locations. Petrographic analyses indicate these are mineralogically and texturally mature quartz-arenites. Heavy mineral assemblages show high ZTR indices, suggesting a potentially polycyclic sand. Zircon U-Pb geochronology results from six samples present near-identical age distributions, with a dominant zircon population of peri-Gondwanan age (~600Ma), a wide range of zircon interpreted as coming from Laurentia (900-2500Ma) and a population associated with Caledonian granites (~430Ma). Apatite U-Pb geochronology from the same samples also show little variations with stratigraphy, but have a main population of Caledonian age (~400Ma) and a population of peri-Gondwanan age (~600Ma).

This multi-proxy approach suggests a partially polycyclic origin for sandstones from the Tullig Cyclothem. A comparison of the U-Pb zircon and apatite data with published regional datasets suggests these sandstones could have been derived from Devonian Old Red Sandstones to the south, with an additional input of fresh peri-Gondwanan-aged material potentially from the southwest. This sediment dispersal model is in agreement with some, but not all, of the published palaeodrainage models for the Clare Basin.

Testing the ability of forward stratigraphic modelling to replicate tectono-sedimentary interactions in rift basins

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Tectonics plays a key role in controlling regional and local surface gradients, drainage patterns, sediment entry points, depocentre locations and across-rift asymmetry. Modern rift basins, ancient examples and both physical and numerical models have all contributed to understanding the

interplay between tectonics, climate and sedimentation. Forward stratigraphic modelling is also increasingly used to assess the depositional response to variable subsidence, sediment supply and base level and can potentially help predict lithology where this is poorly constrained in the subsurface. However, it is important to verify that forward models can replicate the behaviour of natural systems. One way to do this is to test the extent to which numerical simulations can reproduce the stratigraphy generated in scaled physical experiments where all the inputs are known.

A set of numerical simulations were run duplicating the experimental models of Kim et al. (2010) and Straub et al. (2014). The models showed that local fault related uplift and subsidence could steer channels and divert them via a relay into a subsiding hanging wall depocentre. A cyclicity consisting of cross system channel steering around the fault tip alternating with periods of footwall trenching is reported. This cyclicity is dependent on the cross system to downstream tilting and the sediment source discharge. Trenching across the uplifted footwall delivers coarse sediment transversely, creating a fan. When the channel is steered around the uplifting footwall, an axial delta forms close to the fault tip with finer, prodelta sediment deposited in the deepest part of the depocentre. Comparison of the models indicates that the forward stratigraphic models capture many of the key aspects of the physical models.

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The Aïstopods (Tetrapodamopha) from the Jarrow Assemblage, Kilkenny, Ireland.

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Aïstopods are an extinct clade of limbless tetrapodomorphs with elongated snake-like bodies. Traditionally they have been placed on the amniote stem or as a sister clad to modern caecilians. However, these relationships are likely a product of convergent characters in each group because of miniaturisation and limb loss. A recent description of basal aïstopods has identified a host of primitive characters, placing aïstopods on the tetrapod stem and making them an important clade for understanding the origin of crown tetrapods.

Aïstopods were first described from two species, *Ophiderpeton brownriggi* and "*Dolichosoma*" *emersoni* from the Jarrow coal seam (Langsettian, Pennsylvanian) of Kilkenny. Although aïstopods are found in older Mississippian deposits, the Jarrow assemblage represents the first appearance of an assemblage with more than one species of aïstopod. Despite the importance of the Jarrow aïstopods, little work has been done since their initial description. This is likely due to the poor nature of specimens from Jarrow, with detailed anatomical features difficult to discern due to a coating of matrix and a partial coalification of the bones. Here we use non-destructive micro-computed tomography (µCT) and the rendering software Spiers to produce 3D models of the aïstopods.

Better imaging of the skull of *O. brownriggi* reveals a host of tetrapodomorph characters supporting the placement of aïstopods on the tetrapod stem. *D. emersoni* is officially described and is here transferred to the genus *Phlegethontia*. A third species of aïstopods is described making the Jarrow

The three-dimensional geometry of relay zones within segmented normal faults

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Normal faults often comprise arrays of fault segments. Current models for the geometry and formation of relay zones between adjacent fault segments have been informed mainly by 2D analysis of relay zones from either maps or cross-sections and, to a less extent, by the analysis of relay zones from seismic reflection data. Using high quality 3D seismic reflection datasets from a selection of sedimentary basins, including the Porcupine Basin, we investigate fundamental characteristics of segmentation based on the analysis of an extensive collection of normal faults and relay zones. Our analysis shows that relay zones most often develop by bifurcation from a single fault surface but can also arise from the formation of segments which are disconnected in 3D from their inception. Relay zones generally occur between fault segments that step in the dip or strike direction, and intermediate oblique relay zones are less frequent. This is attributed to the strong influence of mechanical stratigraphy and potentially also to a tendency for faults to locally propagate laterally and vertically rather than obliquely. Cross-sectional stepping of relay zones typically forms compressional rather than extensional relay zones. Comparing datasets from different geological settings suggests that the mechanical heterogeneity of the faulted sequence and the influence of pre-existing basement structure are the underlying controls on relay zone geometrical characteristics, and different combinations of these two controls can account for the variation in fault zone structure observed between datasets.

Response of melanosome chemistry to diagenesis explored through experimental maturation

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Melanosomes encapsulate the pigment melanin, are commonly found in vertebrate tissues and persist in the fossil record. The concentration of metal ions bound to melanin is known to vary between different tissues and taxa. Melanosomes from the eyes of fossil vertebrates are known to be enriched in Cu; it is unclear, however, whether this signal is biological or taphonomic. To explore the effects of diagenesis on melanin trace element chemistry, melanin extracts from the eye of the European sea bass (*Dicentrachus labrax*) were experimentally matured in distilled water or solutions of Cu, Zn and mixtures of Cu and Zn at 200°C for 1 hr. The trace element chemistry of matured and untreated melanin extracts was investigated and compared to that of fossil melanosomes using Synchrotron Rapid Scanning-X-Ray Fluorescence (SRS-XRF) and X-Ray Absorption Near Edge Structure (XANES) spectroscopy. Our data reveal that the Zn:Cu ratio is much lower in fossil eye melanosomes with respect to those in extant taxa and that experimental maturation of melanosomes also reduces the ratio of Zn to Cu. These results demonstrate diagenesis has an impact on the chemistry of melanosomes; this must be considered when interpreting the trace element chemistry of fossil melanosomes.

Experimental taphonomy of melanosomes: impact on trace element chemistry

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Melanosomes are micron-sized organelles that in extant vertebrates are rich in the pigment melanin. Fossil melanosomes are a major focus of palaeobiological research as they can inform on pigmentary coloration in ancient animals. The chemistry of fossil melanin, however, is poorly understood. Our recent research shows that melanosomes in fossils can (but do not always) contain abundant Cu, which has been proposed as a biomarker for melanin, but that melanosomes in extant vertebrates commonly contain low amounts of Cu. The origins and nature of the Cu in fossils is unknown. Here, we apply an experimental approach to resolving this issue using controlled laboratory experiments. We matured melanin extracts from the skin and liver of the African clawed frog (*Xenopus laevis*) in distilled water and in a Cu-rich solution at 220 °C, 130 bar for 24h and analysed the residues using synchrotron X-ray fluorescence (XRF) and X-ray absorption near edge structure (XANES). Our experiments reveal that Cu concentrations are much higher in experimentally matured melanosomes from the skin than in the liver. Both samples are depleted in Fe following maturation. These results strongly suggest the presence of tissue-specific diagenetic pathways for melanin and the potential to reconstruct original tissue chemistry in fossils. Future experimental studies will provide a deeper understanding of the impact of diagenesis on melanin trace metal chemistry in order to better interpret preserved chemical signatures in fossils.

CAIs give the Solar System's age of 4567 Myr, but are they from the Solar System?

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Chondritic meteorites are fragments of planetesimals (baby planets) that accreted within a disk of dust and debris surrounding the very young Sun. They are made of a kind of cosmic sandstone, typically comprising chondrules, metal grains and dust compacted together to make hard rock. Some of them also contain white granules called calcium-aluminium-rich inclusions (CAIs).

CAIs are highly depleted in volatile elements, and are thought to have condensed from outflows of very hot cooling gas streaming from the infant Sun. Most of them were made in a brief time interval lasting <20,000 years. Their consistent and precise Pb-Pb age of 4567 million years is widely taken to be the age of the Solar System. They are found almost exclusively in so-called carbonaceous chondritic meteorites which are fragments of planetesimals that probably accreted far out in the disk, beyond the orbit of Jupiter. Their transport to beyond Jupiter is an unresolved issue. So-called x-winds, putative low-angle outflows emanating from the Sun, have been tentatively invoked.

Observations in star-forming regions in the galaxy today, and numerical models of star formation in huge gravitationally-collapsing clouds of gas and dust, show that tight clusters of stars with the same age and presumably with similar chemical and isotopic compositions are common. If the Sun were born in a cluster, CAIs that condensed in outflows from one of its sibling stars may have peppered its disk beyond the orbit of Jupiter. Unusual isotopic features of CAIs can be reconciled with this idea.

Field measurements of extreme coastal waves on intertidal platforms using pressure sensors - Issues and Advances

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Recent research has shown that interaction with bathymetry can lead to wave height amplification of up to a factor of 12. These extreme waves are important for coastal erosion and very large boulder movement but long-term field records in such high-energy conditions are challenging to acquire, and very scarce. Over three winters (2016-2019) we deployed custom-built pressure sensors in the intertidal zone at three locations, varying from a near vertical cliff to a flat bedrock platform, on the Aran Islands off the west coast of Ireland. Reconstruction of surface elevation from pressure sensor measurements in shallow water is difficult. Hydrostatic pressure assumptions do not return accurate wave heights and even recently published nonlinear corrections are sensitive to filtering and do not cover the case of partially or fully breaking waves. Solving these problems is vital for understanding the interplay between high-energy waves and rocky coastlines. We present attempts to apply surface reconstruction methods to field data and numerical simulation results to assess the accuracy. Results highlight the need for independent validation and alternative measurement techniques.

Microstructural and physiochemical processes influencing fracture sealing in geothermal systems

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Geothermal power offers a sustainable source of clean energy, and such resources are constantly developing as the global community moves progressively towards diverse energy portfolios. Efficient and sustainable production of geothermal reservoirs are dependent on a number of factors. An interconnected fracture system is essential for heat and fluid migration within the reservoir, particularly in crystalline host rocks where innate permeability is low. Over time, numerous fluid-rock interactions within these networks lead to mineral nucleation, attachment and growth, eventually resulting in partial or complete fracture sealing i.e. reservoir scaling. Such a process inhibits geothermal fluid transport, reducing resource productivity. Therefore, it is imperative that we understand the interwoven physiochemical, thermodynamic, and hydraulic factors which govern fracture sealing mechanisms on a range of scales.
This work presents the initial findings of a microstructural study focused on geothermal veins from Kibiro, Uganda. Electron backscatter diffraction carried out on sealed fractures containing these crystals offers key insights into the nucleation and growth processes of calcite. Microstructural characterisation of these sealed fractures has shown that the crystals preferentially nucleate on sites where certain minerals are present in particular orientations, electing to attach and grow on pre-existing crystallographic templates in the fracture wall, similar to epitactic mineral growth. Initial results indicate that calcite crystal growth in particular, exhibits a preferential crystallographic orientation on sites where nucleation occurs on pre-existing adularia crystals. This could indicate the crystallographic template offered at locations where adularia is occurring serves as a potential control for calcite growth processes.

Investigating the biochemical fidelity of fossil feathers using sulfur X-ray absorption near-edge spectroscopy (XANES)

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Fossil feathers provide key information regarding macroevolutionary processes such as the dinosaur-bird transition and the origin of flight. Despite extensive research on the macro- and microstructure of fossil feathers, the chemical preservation of keratin – a sulfur-rich protein that is the primary molecular component of feathers – is poorly understood. Existing immunochemical evidence for fossil keratin is not widely accepted and most studies do not consider the impact of taphonomy. Here we use sulfur X-ray absorption near-edge spectroscopy (XANES) to explore changes in keratin chemistry during controlled laboratory experiments simulating decay, burial, and sulfurization (a common diagenetic process). Our taphonomic experiments used black feathers from the domestic chicken, *Gallus gallus*, which were decayed for up to 12 months, matured at temperatures up to 250˚C, and/or incubated in sulfide-rich media to promote sulfurization. Our results show that decay has minimal impact on sulfur chemistry and that progressive maturation is associated with progressive oxidation of sulfur: peaks for cysteine and cystine dominate spectra for untreated and decayed feathers, whereas cystine, sulfonate and especially organic sulfate dominate spectra for more matured samples. In contrast, sulfurization yields a complex suite of sulfur compounds, including sulfides. These data demonstrate that sulfur speciation can be used as an indicator of the taphonomic history of fossil feathers and provides a model for the degradation of keratin disulfide bonds under various taphonomic conditions. Our experiments have broader implications: sulfur XANES may be used to test the fidelity of preservation of fossil feathers, identifying fossils to target for future biochemical studies.

Comparing the relationship between sand fraction and connectivity using different conventional facies modelling methods

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The ability to generate geologically realistic reservoir geomodels is an important step in predicting reservoir behaviour. In situations where the reservoir sands are treated as permeable and the shales impermeable, the relationship between the volume of connected sand and the proportion of sand can be described by percolation theory, where at a particular sand fraction (the percolation threshold) a cluster spanning the entire model is formed. A percolation threshold of 27% net sand exists for randomly distributed 3D objects. At sand fractions below this threshold, the system is disconnected and above this value the connectivity rapidly rises. Subsequent work has shown that because of non-randomness such as compensational stacking, many geological systems are poorly connected at high net sand fractions.

While previous studies investigating this relationship between connectivity and sand fraction have focused primarily on object-based methods this study considers four different conventional geostatistical modelling techniques; object-based modelling, sequential indicator simulation, truncated Gaussian simulation, and multiple-point statistics. As expected, all geostatistical modelling methods are controlled by the random percolation threshold, whereby once a sand fraction of 27% is exceeded the system becomes entirely connected. In the case of sequential indicator simulation and truncated Gaussian simulation the percolation threshold is lower. Therefore, it is impossible to

model low connectivity at sand fractions greater than 27% using any of the geostatistical modelling methods in a regular grid. A different approach must be taken when modelling high net:gross systems with poor connectivity.

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The origin and nature of a pervasive vein system within The Burren, Clare.

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Limestones of the Burren are transected by sub-vertical veins, from ca 0.1mm up to 50cm thick, defining a strongly clustered and scale-independent system in which predominantly N-S veins are transected by longer NNE-trending veins. Vein infills are mainly calcite, but with subordinate amounts of quartz, sulphide and fluorite particularly in the south-central part of the area. Thinner and shorter veins are planar and discontinuous in map view, sometimes forming en-echelon arrays, with thicker veins forming better connected and more complex structures which extend for several kilometres across the Burren. Veins with exotic infills are generally both longer and thicker structures appearing to be spatially associated with, or up to 5km to the north of, a 5km wide zone of Variscan monoclines. Individual veins are vertically persistent and the same structures are seen throughout the exposed ca 1200m thick Carboniferous sequence, from Courceyan limestones through to Namurian Clare Group clastics. The veins are mainly extensional, sometimes with a component of sinistral displacement particularly on NNE-trending veins, displaying fibrous growth through to hydraulic fracturing and brecciation. Their formation is attributed to the valving of overpressured fluids within Lower Carboniferous basins during N-S Variscan compression. Sulphide infills are attributed to the scavenging of underlying basement rocks or hydrothermal Zn-Pb deposits during the inversion of post-rift sequences overlying Lower Carboniferous normal faults.

Abstracts for Undergraduate Poster Presentations

Abstracts are listed in alphabetical order by first author

Using Airborne LiDAR to identify and map glacial geomorphology and landforms in Co. Roscommon.

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High resolution Digital Terrain Models (DTMs) generated via airborne LiDAR surveys are being utilized for the purposes of mapping glacial geomorphology across Irelands midlands and north-west, to gain a better understanding of ice-sheet dynamics that occurred during the Midlandian glaciation event.

During this study, a high resolution DTM of an area of Co. Roscommon was generated from LiDAR cloud point data and the resulting image exposed a series of multi-scale landforms. These landforms were mapped within a GIS environment and used to interpret the possible ice-sheet dynamics that shaped the landscape during the Midlandian.

This study adopted a regional approach, thus allowing for an in-depth analysis of two regions within the DTM; each of which contained landforms of different scales. Analysis of these regions showed that Region A – located centrally, contained what was interpreted as a large drumlin field tracking a NW-SE orientation across the study area. Region B - a comparatively smaller area to the north, was home to what was interpreted as a minor ribbed moraine sequence tracking a perpendicular orientation to that of the large-scale landforms; a characteristic of such moraine sequences.

By studying the morphology of these landforms, a possible north-west direction of ice-flow was interpreted; however, based on LiDAR data alone and without further ground truthing, this interpretation could only be speculated.

Thanks to the resolution of the DTM and the clarity of the landforms that were exposed, this study highlights the benefits of using LiDAR as a tool for mapping glacial geomorphology and landforms.

Magnetic Fabrics and Remnant Magnetism of the Fair Head Sill, Co. Antrim: Testing Emplacement Linked to the Great Gaw Fault

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Geophysical data from the TELLUS survey and offshore seismic surveys have identified ENE-WSW trending lineaments close to the north coast of County Antrim. These lineaments represent crustal scale faults that controlled the ascent and emplacement of Palaeogene magmas. The Palaeogene Fair Head Sill (FHS) in North County Antrim, crops out adjacent to the ENE-WSW trending Great Gaw Fault (GGF). This project aims to test whether the emplacement of the FHS was controlled by the GGF. Anisotropy of Magnetic Susceptibility (AMS) is used to determine magma flow fabrics in the FHS. Samples from outcrops along the trace of the GGF reveal steeply plunging maximum susceptibility axes and ENE striking, steeply dipping magnetic foliations. Thermomagnetic analyses indicate a predominantly paramagnetic carrier (likely pyroxene and/or biotite), leading to the fabrics being interpreted as 'normal'. Thus the magnetic lineation indicates steeply plunging magma flow consistent with a feeder dyke. Magnetic fabrics elsewhere, however, reveal steeply plunging maximum susceptibility axes, but thermomagnetic analyses suggest the presence of single domain magnetite. This means that the magnetic fabric is inverse or intermediate so the magnetic lineation is not vertical, as within the feeder dyke zone, but subhorizontal. Further tests to determine the magnetic grain size fraction using partial anhysteretic remnant magnetism (PARM) will confirm the differing magnetic carrier and palaeomagnetic analysis of the natural remnant magnetism will test whether these different outcrops are of the same intrusion.

A mineralogical and geofluids study of gold bearing quartz veins from the north-west of Ireland

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Gold, a valuable material important in finance, medicine and technology, is a resource that has been explored and mined for since the 1980's at Cavanacaw and Curraghinalt, County Tyrone, Northern Ireland. Both deposits are hosted in Dalradian metasediments and despite their relative proximity and similar history, massive differences exist between these two deposits and the fluids which formed them. This project aims to carry out an investigation into samples from both gold deposits in order to gain a greater understanding of the fluid conditions and sources circulating within the crust as these deposits were created.

Results show that Curraghinalt samples have a very clean appearance with little brecciation of the quartz within the veins which are ideal for fluid inclusion analysis. Cavanacaw samples contain high amounts of a dark material which is a result of the sericitisation of feldspars to white micas and are highly brecciated, creating a very dirty, highly obstructed sample that is extremely challenging to work with. From hand-sample and thin section observations I interpret the Cavanacaw deposit as having a much more complex hydrothermal history than Curraghinalt due to the high sericite content and heavy brecciation. Fluid inclusion analysis of both deposits places them within the orogenic deposit clan and I estimate formation depths of between 5 and 10 km in the mesozone at temperatures of 200-350°C with a salinity range of 0.5-2 eq. wt. % NaCl at Cavanacaw and 150-350°C with a salinity range of 6-14 eq. wt. % NaCl for Curraghinalt.

Airborne Electromagnetic Datasets from the Tellus Programme: Quantitative Analysis of the Role of the Flight Altitude Parameter on the Resulting Subsurface Inversion Models

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The effect of flight altitude on the inverted electrical conductivity (or its inverse, resistivity) models obtained from the Airborne ElectroMagnetic (AEM) frequency-domain systems is investigated. This is achieved using AEMPY, the Python toolbox written and developed by the Dublin Institute for Advanced Studies. One-dimensional inversion of synthetic data and measured Tellus Test Line data is carried out using stochastic and deterministic inversion approaches to understand this effect. It was found that signal amplitude at the receiver significantly decreased with increasing height for both sets of data. Synthetic data in particular showed that AEM data acquired at altitudes over 100 m should be inverted with caution, as only the altitudes below this matched true model parameters within reasonable error. Real data (Tellus Test Line data) inversion results were compared with the electrical conductivity model obtained from inverting ground electrical resistivity data. Comparisons proved that the resulting subsurface models from data acquired at altitudes above 100 m were not representative of the subsurface.

Ground Penetrating Radar investigation of Rathcroghan, Co. Roscommon

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Ground Penetrating Radar (GPR) is a non-destructive geophysical technique suited to the investigation of subsurface archaeological structures. The focus of this project was the ancient royal site of Rathcroghan in County Roscommon. With a basal diameter of 89m and height of approximately 5m, Rathcroghan Mound lies as a main circular earthwork of the landscape. Known as the "Tara of the West", the pre-Christian site is closely linked to the ancient royal sites of Navan Fort (Co. Armagh), Knockaulin (Co. Kildare) and Tara (Co. Meath). Using a 250MHz GPR, the eastern and western edges of Rathcroghan Mound were surveyed, in order to complete the 3D GPR mapping of the mound performed by undergraduates of Earth and Ocean Sciences NUI, Galway over the last three years. It was aimed to investigate the subsurface structure of the mound with implications for how and why it was constructed. The resultant GPR anomalies indicated the presence of a one metre deep infilled ditch surrounding the base of the mound. Under the ground surface and forming the entire outer edge of the mound, an approximately three metres thick external wall was identified. Naturally occurring ground truth confirmed the presence of the external limestone wall. Similar anomalies were seen within the mound, possibly indicating a complex internal structure with walls and/or stone structures arranged similarly to the spokes of a wheel with the in-between space infilled with soil.

Abstracts for Poster Presentations

Abstracts are listed in alphabetical order by first author

Characterizing the TELLUS Airborne EM anomaly over the Longford down inlier, Ireland through hyperspectral core scanning

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The TELLUS airborne survey detected an anomalous high EM reading over the Longford down inlier, Ireland. These results represent the Ordovician-Silurian Moffat Shale Group, an assemblage of NE striking fault-bound terrigenous carbon-rich mudstones. It is postulated that the EM high is due to elevated concentrations of graphite or sufides, although there may be other explanations. A GSI drilling program produced core samples of the Moffat Shale Group and through simple hand-held resistivity testing the EM anomaly was confirmed to be related to the shales, though inconsistent. Some units of the Moffat Shale Group in the region did not produce an EM response. This drillcore containing the Moffat Shale units has been analysed with a hypospectral camera.

This projects aims to use the drillcore and hypospectral measurements to deduce the cause of the EM response and to gain greater insight into the depositional and alteration history of the Moffat Shale. If graphite and/or sulphides cause the EM response a correlation to enriched metal contents in shales could be apparent, and may have implications for exploration of black shales using airborne EM. Moreover, the production of comprehensive hypospectral imagery may prove a valuable, efficient method of analysing core prospectively in active exploration licenses, in addition to legacy drill holes.

Integrating Gravity and Surface Elevation With Magnetic Data: Mapping the Curie Temperature Beneath the British Isles and Surrounding Areas

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In this work, we study the lithospheric structure of the British Isles using a methodology that allows for forward modeling of the Curie temperature depth based on seismic, elevation and gravity observations within an integrated geophysical-petrological approach (LitMod3D). We compute 3D thermal models and self-consistently determine the density in the mantle based on temperature, pressure, and bulk composition. Finally, we derive Curie temperature depth maps and forward calculate magnetic anomalies at the airborne level (5 km altitude) using a spherical magnetic modeling software (*magnetic tesseroids*) to estimate the geothermal magnetic signal. Our results show lateral lithospheric variations across the model domain, with Great Britain being characterized in general by thicker and colder lithosphere, especially in the south-east, and the thinnest and warmest lithosphere being located beneath west Scotland, Northern Ireland and in the north-west oceanic area. Our estimated Curie temperature depth map resembles the values obtained using other techniques (spectral method and surface heat flow inversion) in some areas, but discrepancies are notable in general. We determine that the effect of typical lateral temperature variations (i.e., Curie isotherm depth) accounts for 5–15%, on average, and up to 70% locally of the crustal magnetic signal at the airborne level. Our lithospheric models are in general agreement with published seismic tomography models as well as other geophysical studies.

The link between stress, pore pressure, and subduction dynamics: Implications for offshore geohazards and resource development

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The Hikurangi Subduction Margin (HSM) of New Zealand is well-known for its variable seismic behaviour along strike, and across the Pacific-Australian subduction interface. Plate motion appears to be accommodated by a combination of slow slip events and slip in earthquakes. The mechanics of slow slip earthquakes and their relationship to seismic slip are not well constrained, and so they represent a challenge to better quantification of hazard posed to the New Zealand, and for the development of resource related infrastructure in the area. This project seeks to explore the interlinked role of stress, pore pressure and subduction dynamics along and across the HSM to establish the potential role stress field variability may play in the spatial distribution of seismic behaviour along the HSM plate interface.

To investigate the interplay between stress, structure, and the geomechanical and seismic behaviour of the HSM, we will utilise borehole data from a recent International Ocean Discovery Program (Expedition 372) in transect across the HSM, and from a number of industry exploration wells drilled predominantly in the hanging-wall of the HSM. We will utilise borehole image logs, geophysical logs, mud weight information, well-testing, and drill core information to characterise the full stress tensor and its spatial variation at the HSM. This will allow us to explore whether slow slip earthquakes and plate interface locking impact the character of the contemporary stress field, and also investigate the role that longer term tectonic deformation processes (e.g., millions of years) associated with subduction play in the modern-day stress field.

Geological evolution and complex magmatic history of the Hatton Basin, northeast Atlantic Ocean

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The Hatton Basin is located next to the continent-ocean boundary in the Irish offshore, east of the Hatton passive volcanic Continental Margin. Little is known about its structure and evolution within the context of the North Atlantic opening, given the lack of modern geophysical data.

Here we use modern multichannel seismic (MCS) data acquired with a 10km-long streamer, together with DSDP- and potential field data to explore the formation processes of the Hatton Basin. The MCS and DSDP data suggest the presence of four sedimentary megasequences bounded by regional unconformities, ranging from possibly Cretaceous to Holocene in age. The seismic data indicates that one major syn-breakup, and some minor post-breakup magmatic phases influenced the evolution of the Hatton Basin.

Potential field data shows NNE-SSW trending lineaments of positive anomalies, extending from the center of the basin towards the southern end. The locations of the mapped paleo-volcanoes in the basin are spatially coincident to these anomalies. These observations, combined with the parallel, linear nature of the anomalies suggest the presence of deep-seated feeder dikes in the crust. The dike intrusions sourced a fissure system during the Late Paleocene–Early Eocene through inherited zones of weaknesses in the crust reactivated by Mesozoic rifting, causing along-axis variation in volcanism in the basin.

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Heavy metal analysis of peat using ETV-ICP-OES: A highly efficient technique for direct solid sampling

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Heavy metal aerosols produced by industrial and domestic activities such as mining and fossil fuel combustion, and natural sources such as volcanic eruptions and dust storms can be preserved in peat by atmospheric deposition. Analysis of heavy metals in peat is usually carried out by ICP-MS following ashing and acid digestion; however this process is time consuming and may preclude analysis of volatile elements. Electrothermal Vaporisation (ETV) has been shown to be a fast and effective method of sample introduction for inductively coupled plasma mass spectrometry (ICP-MS) and optical emission spectrometry (ICP-OES) (Kaveh *et al*, 2014; Masquelin *et al*, 2013; Resano *et al*, 2006). We present preliminary results of volatile heavy metal analysis of solution standards, coal standard reference materials (SRM's) and peat samples of known composition using ETV-ICP-OES in order to demonstrate the potential of ETV for high sensitivity, accurate heavy metal analysis. Calculated concentrations are compared with known compositions to determine the method's accuracy, and sensitivities are calculated for a number of elements of interest. The advantages of ETV-ICP-OES/MS are significant. The lack of digestion for solid samples allows for quicker and more economical analyses, while also lessening the risk of contamination and loss of volatile elements during ashing and acid digestion. A low detection limit and an ability to analyse samples up to 4mg is an attractive prospect for both industry and research, especially where solid samples are concerned.

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SWEMDI_1.0: Space Weather Electromagnetic Database for Ireland.

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The Space Weather Electromagnetic Database for Ireland (SWEMDI) was funded by the Geological Survey Ireland (GSI, www.gsi.ie) to develop a digital database with key information for the understanding and constraining of Ireland's electromagnetic (EM) properties that are relevant to: 1) constrain and mitigate the impact of space weather effects on technology, and 2) characterize the geology beneath Ireland. The database is divided in eight packages: 1) Details about the sites where EM data was acquired, 2) raw and clean EM time series, 3) EM tensor relationships, 4) 3-D electrical resistivity model of Ireland's lithosphere, 5) Modeled electric and magnetic field variations during geomagnetic storms, 6) Conferences and publications, 7) reports, and 8) scripts, in Python, to read and plot the data from SWEMDI_1.0 database. SWEMDI_1.0 will be publically available from mid 2019 from GSI and later from EPOS (www.epos-ip.org). This database will have direct impact on research into the so-called space weather hazards that solar activity can cause in ground-based infrastructures, and to the study of present day Ireland's lithosphere.

SKS Seismic Anisotropy Observations in Mid-Plate South America : Investigating Mantle Flow and Effects of Cratonic Keels

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Seismic anisotropy at stable areas gives important information about past and present tectonic events, and helps us in understanding patterns of upper mantle flow. The measurement of shear wave splitting (SWS), at individual stations, from core refracted phases (such as SKS phases), indicates the amount and orientation of the seismic anisotropy in the upper mantle.

We add extra measurements extending to all Brazilian territory, especially in the Pantanal and Parana-Chaco basins, as part of the FAPESP "3-Basins Thematic Project". The results from both temporary deployments and from the Brazilian permanent network provide a more complete and robust anisotropy map of the South America stable platform. We compare our results with different anisotropy proxies: absolute plate motion (HS3-NUVEL-1A), upper mantle flow (Hu et al., 2017), azimuthal anisotropy from surface waves, and geologic trends. We observe a poor correlation of the anisotropy directions with geological trends and a better correlation with the mantle flow model. Therefore, our observed anisotropy is mainly due to upper-mantle flow, with little contribution from frozen lithospheric anisotropy. Also, deviations from the mantle flow model are due to flow surrounding cratonic nuclei not used in the model: the keel of the São Francisco craton and a possible cratonic nucleus beneath the northern part of the Paraná Basin. Large delay times at the Pantanal Basin may indicate a stronger asthenospheric channel, a more coherent flow, or a thicker asthenosphere. Small delays beneath the northern Paraná Basin may indicate thinner anisotropic asthenosphere beneath the thick Paranapanema block.

The Formation, Evolution and Characterisation of a Tunnel Valley System in the Southern Irish Sea: an Investigation of Wicklow Trough

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Several submarine channel features have been previously identified on the Irish Sea seafloor including Beaufort's Dyke, Lambay Deep, Codling Deep and Wicklow Trough. These bathymetric features are distinctive from the surrounding seafloor by their steep depth and morphology and have been described as major incisions, enclosed deeps and tunnel valleys. Lambay Deep, Codling Deep and Wicklow Trough are believed to be part of a late- to post-glacial, rectilinear drainage network and likely represent a series of processes with varying stages of ice- excavation and meltwater discharge related erosion.

Here, we focus on data gathered from the Wicklow Trough. We use the spatial integration of multibeam echosounder and sparker seismic data, supplemented by benthic grab samples, vibrocores and digital seabed photography, to characterise its present day morphology and sub-surface structure.The current sub-surface sedimentary architecture of Wicklow Trough exhibits a moderate level of lateral variability some slump deposits on the flanks. Currently the data invokes a time transgressive model with headward erosion during ice sheet retreat accompanied by pressurised subglacial meltwater discharge. At present the seabed within Wicklow Trough is highly dynamic and variable consisting of large, actively migrating sediment waves throughout along with scour pits and coarse sediment deposits.

With additional analyses, we aim to further investigate the formation and development of Wicklow Trough. In addition, we aim to discern the development of Wicklow Trough within the broader tunnel valley/glacial drainage system and relative to past ice-sheet dynamics. Similarly, we discuss post-glacial environments of the Wicklow Trough and assess its current geomorphology and active processes. As a result of this study, we will contribute to the growing understanding of British and Irish ice-sheet development and post-glacial, Holocene environments in the Irish Sea.

Sediment Connectivity in Modern Deepwater Turbidite Systems: Examples and Implications

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Popular models of deepwater turbidite fans often portray zones of sediment bypass at one or more locations throughout the system. However, many of these facies models are based primarily on outcrop data, which may not always allow the overall context of the system to be observed. This study examines recent seafloor and core data with the goal of improving our understanding of sediment connectivity in these deposits, which often form parts of economically important hydrocarbon systems. By examining several modern examples of attached and detached systems from a source-to-sink perspective, the larger-scale controls on sediment bypass and potential stratigraphic trapping can be examined at a scale not possible in ancient deposits. Initial results suggest a correlation between the system's connectivity, the slope gradient, and the dominant grain

size present, where finer-grained systems are more likely to be detached. Such observations appear to be consistent with existing models of flow efficiency, although further seafloor observations are necessary. Our observations also suggest that deepwater sand bodies may also become detached through secondary erosion, wherein canyons and the upper reaches of channels are destroyed by later slope failure or reworked by contour currents, effectively isolating more distal parts of the system. Future work will compile further examples in order to more robustly test which other factors are positively associated with upslope sand terminations.

Exploring the characteristics of the Tuaheni Landslide Complex, Hikurangi Margin, offshore New Zealand

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Most recorded landslides on Earth are usually thought of as catastrophic collapses of ground material occurring on land, but many landslides also occur under water, for instance on continental slopes. The Tuaheni Landslide Complex (TLC) on the Hikurangi Margin, off New Zealand's East Coast, fits into that category. The TLC represents a less understood style of submarine mass movements; it shows evidence of slow and repeated deformation. During IODP Expedition 372, a core and LWD (Logging While Drilling) data were retrieved at the TLC (U1517C). Combined with previously acquired 3D seismic reflection and bathymetry data, these datasets improve our knowledge of the internal structure, deformation mechanisms and depositional processes of the landslide deposits. Initial observations of core U1517C have led to the characterisation of five distinct sedimentary units, of which Unit II (3 to 40.74 mbsf) and Unit III (40.74 to 66.38 mbsf) are thought to be two distinct parts of the TLC. On the 3D seismic data, they appear as two specific seismic units separated by a distinct reflector of negative impedance. Despite the apparent two-part structure of the TLC, further investigation of the seismic data seems to indicate that the lower debris unit may be in fact continuous with sediments located under the mid-Tuaheni Ridge Quaternary succession, beyond the margins of the TLC. This new hypothesis requires us to reconsider the depositional history of the TLC. We interpret the extent of this unit on seismic data, its depositional mechanism and its relationship with the overriding slide deposit.

Radon Potential as a diagnostic tool for indoor radon hazard mapping

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At over 56% of the annual effective dose, radon is the primary source of ionizing radiation exposure received by the Irish population. Although the average indoor radon concentration in Ireland has been reduced since introduction of the 1997 Building Regulations, it currently stands at 77 Bq/m^3, which is significantly higher than the worldwide average of 39 Bq/m^3. Globally, radon is the second leading cause of lung cancer after tobacco smoking, with approximately 300 radon-related lung cancer cases in Ireland every year.

Here we present a methodology to calculate the Radon Potential of a specific geographic area. This is based on *in-situ* radon concentration and permeability measurements. Both parameters are measured at a depth of 80 cm in the sub-soil in order to minimize atmospheric influence. Permeability measurements are made by timing the duration of extraction of 2 lit of soil gas, whereas radon concentrations may be determined using a pulse ionization chamber detector. Such a protocol is capable of producing two separate measurements every 15-20 minutes. Here we present data from the Cooley Peninsula (Co. Meath) and Castleisland (Co. Kerry) and demonstrate that Radon Potential is an effective predictor for indoor radon. Our research indicates that Radon Potential is a useful mapping tool for areas with a low population density, or regions where land use has been rezoned for residential housing (i.e. where indoor radon measurement are few or non-existent). Areas with high Radon Potential can adopt radon preventative measures in new buildings, thereby reducing the radiological hazard to occupants.

Eastern North Atlantic Mid-to-Late Holocene transition: Palaeoceanographic evidence and implications for atmospheric modes.

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There is increasing evidence that accelerated warming at high-latitudes is associated with increased climate variability at mid-latitudes, including the frequency and intensity of storms. However, due to short instrumental records our understanding of how ocean-atmosphere dynamics operate during warmer than present climates remains limited. Here we present a palaeoceanographic investigation of the mid-to-late Holocene transition (7.5 thousand years) to test the hypothesis of an eastward shift of the Icelandic Low under warmer than present climate scenarios. Reconstructions of bottom water temperatures (BWT) and stable oxygen isotopes (Mg/Ca, $\delta^{18}O$) using the benthic foraminifera *Hyalinea balthica (H. balthica)* reveal warmer than present BWT of up to 2.6 ± 0.7°C and heavier $\delta^{18}O_{sw}$ values of up to 0.5 ± 0.3 ‰ on the Irish Continental shelf until circa 4.1 ka. We infer from these results that Atlantic waters were more prevalent in the eastern edge of the subpolar gyre (SPG) and link this oceanographic signature to an eastward shift of the Icelandic Low. We then place our local record into an extra-regional context, using a combination of modern observations and existing-palaeo records, which enables us to assess the impact of changing atmospheric modes on ocean-atmosphere climate linkages within the North Atlantic Region. The enhanced influence of warm Atlantic waters recirculating along the boundaries of the SPG under this scenario, would potentially have enhanced melt rates of marine-terminating glaciers on the east Greenland Shelf.

Investigating acoustic noise propagation across various continental margin settings

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Anthropogenic noise in the ocean, as classed by the Marine Strategy Framework Directive, is a pollutant and thus Ireland holds the responsibility of quantifying and monitoring this noise in Irish waters. Offshore seismic exploration of hydrocarbons involves generating pulsed airgun signals

targeted vertically at the subseafloor below. A side effect of airgun use is horizontally propagating noise in the water column that attenuates with distance from source. Noise levels proximal to source may be harmful to marine life, while distal levels can vary from appreciable to negligible, depending on multiple parameters including distance, topography, sea surface roughness and substrate densities.

The main aim of this project is to investigate controls on airgun noise propagation across the Irish continental margin. Objectives include comparing various margin conditions, i.e. submarine canyon vs typical slope, on noise propagation and to assess hydrographic controls, e.g. internal waves, on that propagation. This summer an acoustic/hydrographic survey was successfully carried out, involving deployment of a fixed mooring hydrophone array and noise generation using a seismic airgun. Although postprocessing and analysis is still underway, preliminary results suggest that canyons may focus rather than disperse incoming sound. Complete analysis will quantify variation in noise levels (or transmission loss), in varying topographic and hydrographic settings across the continental margin. Results shall provide regulatory bodies, industry and NGOs with evidence-based research on characteristics of anthropogenic noise propagation.

Correlated petrographic and isotopic studies (S, Pb) of high-grade Zn-Pb mineralization in the Island Pod orebody, Lisheen deposit, Ireland

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Irish Zn-Pb deposits are a type of carbonate-hosted mineralization, typically occurring adjacent to normal faults. Ore deposition occurred due to the replacement of Lower Carboniferous limestones, triggered primarily by fluid mixing.

The Lisheen deposit (23 Mt @ 13.3% Zn & 2.3% Pb) in the southern Irish orefield consists of several stratabound orebodies, which are strongly controlled by an extensional, left-stepping, ramp-relay fault array. The Island Pod (0.4 Mt @ 20% Zn & 1.6% Pb) is a small satellite body, that has a weaker structural control than other Lisheen orebodies. It is located distally from feeder faults which are found along the southern boundary of Lisheen mineralization and are thought to have introduced the metal-bearing hydrothermal fluids.

We present the first detailed petrographic and paragenetically constrained S-Pb isotopic study and mineral chemical analysis of the Island Pod mineralization. A basic sulphide mineralogy of pyrite-sphalerite-galena is observed for the Island Pod, with several paragenetically distinct stages of calcite and dolomite also noted.

A homogenous Pb isotopic signature in galena has been observed throughout the Island Pod, regardless of paragenetic stage. Additionally, $\delta^{34}S$ data suggest a dominantly bacteriogenic source for S in the Island Pod. Furthermore, mineral chemical studies of all sulphide phases throughout the Island Pod deposit have revealed low trace element concentrations (Cd, Ni, As, Co, etc., typically < detection limit), consistent with a distal location from suspected feeder faults in the main Lisheen orebody.

Using in-situ mineral geochemistry to safeguard the integrity of building structures: An Irish example.

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The presence and reactivity of the mineral pyrite has caused extensive structural damage to thousands of homes across the country. In an attempt to combat this problem, the National Standards Authority for Ireland (NSAI) has emplaced a testing procedure whereby all Irish rock aggregate must have a total sulphur (TS) value <1%., thus minimising the amount of pyrite allowed in Irish rock aggregate.

Through carrying out detailed geochemical analysis, such as LA-ICPMS, we have found that pyrite within Irish aggregate contains a wide range of trace element impurities such as; Ag, As, Co, Cu, Mo, Pb, Sb, Se, and Zn, in varying proportions. The presence of these trace elements and their connection to an increased reactivity potential may provide a novel new geochemical testing procedure to determine the quality of rock aggregate used in Irish houses.

Additionally, the trace element geochemistry of pyrite from Irish rock aggregate appears to vary from quarry source to quarry source. This variation can be observed both elementally and isotopically. By implementing these analytical techniques, a form of geochemical detective work can be carried out to link the geochemical composition of pyrite from a house that has experienced structural deformation, to the geochemical composition of pyrite from of its quarry source. By geochemically linking a quarry source to rock aggregate found in the foundations of a house, we can advise engineers and construction companies on the areas where good quality rock aggregate can be sourced.

Tara Deep Preliminary Observations: Setting, Mineralogy and S Isotopes.

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Tara Deep is the latest major discovery by the Boliden Tara Mines Exploration Department, which significantly adds to the world-renowned Navan-cluster of deposits. Sitting three kilometres to the SE of the Navan deposit, at a depth of 1.2-1.9 km, Tara Deep has a currently inferred resource of 18.2 Mt grading at 7.6% Zn and 1.6% Pb (Boliden Summary Report, 2018).

Mineralisation occurs primarily in two Lower Carboniferous lithologies: 1) Micrite and associated calcarenite units, hosting ~90% of the total resource (Ashton *et al.,* 2018). 2) Pale Bed-rich conglomerates in the hanging walls of the G and S faults in the NW Zone.

Sphalerite and galena dominate in a 5:1 ratio. Gangue consists of calcite, dolomite, pyrite, marcasite and barite, in decreasing order of abundance. Textures highlight complex episodic mineralisation events that display considerable reworking, fracturing, dolomitization, open space infill, and selective replacement.

S isotope analyses outline two dominant populations of δ^{34}S in sulphides, -14 to -4 ‰ and +4 to +15 ‰. The lightest δ^{34}S subgroup is interpreted as the product of bacterially mediated reduction of seawater sulphate during the Lower Carboniferous (Fallick *et al.,* 2001). The latter heavier values are

considered to represent sulphide which entered the deposit with the metalliferous hydrothermal fluids, sourced dominantly from the Lower Palaeozoic basement (Boyce *et al.,* 1993).

Both textural and sulphur isotope data reveal the dynamic nature of mineralisation at Tara Deep, and vary in proportion and distribution based on the intensity of mineralisation, the nature of the host rocks, structural controls, and controlling depositional processes.

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PS-InSAR analysis of Sentinel-1 data for detecting ground motion in temperate oceanic climate zones: a case study in the Republic of Ireland

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Regions of temperate oceanic climate have historically represented a challenge for the application of satellite-based multi-temporal SAR interferometry. The landscapes of such regions are commonly characterized by extensive, seasonally-variable vegetation coverage that can cause low temporal coherence and limit the detection capabilities of SAR imagery as acquired by first generation satellites. In this work, we exploited the enhanced resolution in space and time of the Sentinel-1A/B SAR satellites to detect and monitor ground motions occurring in two study areas in the Republic of Ireland. The first, is a ~1,800 km2 area spanning the upland karst of the Clare Burren and the adjacent mantled lowland karst of east Galway. The second, is an area of 100 km2 in Co. Meath spanning an active mine site. The available datasets, consisting of more than 100 images acquired from 04/2015 to 03/2018, were processed by using the Permanent Scatterer approach. The obtained results highlight the presence of small-scale ground motions in both urban and natural environments with displacement rates up to -17 mm/yr. Localized subsidence was detected in recently built areas, along the infrastructure, and over the mine site, while zones of subsidence, uplift, or both, have been recorded in a number of peatland areas. Furthermore, several measured target points indicate the presence of unstable areas along the coastline. These results demonstrate the feasibility of adopting multi-temporal interferometry based on Sentinel-1 data for the detection and monitoring of mm-scale ground movements even over small areas in environments influenced by temperate oceanic climate.

Relating Catchment Lithology to Minor and Trace Elements in Irish Rivers

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Ninety-one river water samples were collected between 20 February and 5 August, 2018 from all the major catchments in Ireland as part of a Fulbright fellowship research project to W.B.Lyons. The samples were filtered within a few hours and analyzed at The Ohio State University for major, minor, and trace elements in order to assess the importance of land type and catchment lithology on

elemental concentrations. Although there is not enough space to present all the results, some of the significant findings will be discussed. The Na:Cl ratios indicate that marine aerosol contributes a significant amount of solutes to the rivers, however, the F/Cl is higher than seawater and Br/Cl is lower than seawater in the majority of the samples. These ratios indicate the introduction of F through carbonate mineral weathering and either the removal of Br in the vegetation/soils or the production of soluble organic species (not measured by our methods). In contrast to observations in large global river basins, there was no significant relationship between Mo and sulphate concentrations, indicating sulphide mineral dissolution is not a major source of Mo. In general, U values follow Ca concentrations, especially in carbonate-dominated lithologies. High U values were measured in rivers draining the southeast and south central portion of the country. Ba and Sr are strongly associated with Ca, although Ba concentrations appear to be limited by barite solubility in some streams. Future efforts will compare data generated in this study to ongoing TELLUS research, particularly with the soil geochemical maps.

Seismic reflection imaging of the crust using ambient noise autocorrelations

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Passive seismic imaging provides novel, low-cost and environmentally friendly tools for mineral exploration. Autocorrelation of ambient seismic noise brings out the reflections of body waves at discontinuities within the crust. We have tested an autocorrelation analysis technique in different locations and depth ranges. The autocorrelation functions are complex and signal-rich. Using lower frequencies at different seismic stations on Archean cratons around the world and in Ireland (Ireland Array seismic network), we are able to image the Moho in most locations, which is important in order to validate the method. We also apply the autocorrelation analysis to an array of 21 broadband seismic stations, deployed for a year in the Boliden Tara Mines area. Higher frequency signals reveal intra-crustal discontinuities and complex structure within the economically important sedimentary layer. Using numerical forward modelling, we have identified what the primary arrivals on them are, setting the stage for waveform modelling.

Enhancing the Operational Capacity of the Irish National Seismic Network

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The Irish National Seismic Network (INSN) currently operates six seismic stations distributed around Ireland that record and stream data in realtime, hosted at the Dublin Institute for Advanced Studies (DIAS), and jointly funded by DIAS and the Geological Survey of Ireland (GSI). Additionally, the British Geological Survey (BGS) operates a station in Northern Ireland. Each year the INSN records hundreds of local seismic events, of which the vast majority are quarry blasts. Under the GSI's shortcall research program, tools have been developed at the INSN to enable the discrimination between naturally occuring local earthquakes and quarry blasts using seismic waveform data. In addition, a local earthquake magnitude scale has been developed for Ireland and its offshore regions using local earthquake waveform data. We outline how these tools have been incorporated into the daily operation of the INSN, enabling analysts to accurately characterise each local seismic event recorded by the network. Finally, the INSN is expanding its network from six to twelve permanent network stations in Ireland. We show preliminary site locations for the new seismic stations and the predicted effects on the local magnitude detection threshold of the network.

Three-dimensional electrical conductivity characterisation of Furnas and Fogo Volcanoes, São Miguel Island (Azores archipelago, Portugal), by magnetotelluric data

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Accurate imaging of shallow subsurface features provides crucial constraints on understanding the dynamics of volcanic systems. The island of São Miguel, Azores (Portugal) is dominated by volcanioes and pose a threat to humans in terms of elevated CO_2 and also seismic swarm activity. At Furnas Volcano, intense circulation of volcanic fluids at depth leading to high CO_2 outgassing and flank destabilisation poses considerable threat to humans. Presented is a novel 3-D electrical resistivity model developed from 39 magnetotelluric soundings that images the hydrothermal system of the Furnas Volcano to a depth of 1km. The resistivity model delineated two enhanced conductive zones, one at 100m and another at 50m depth, separated by a resistive layer. The shallow conductor has conductivity less than 1 S/m, which can be explained by clay mineral surface conduction with a mass fraction of at least 20% smectite. The deeper conductor extends across the majority of the survey area and is located at depths where smectite is generally replaced by chlorite and being interpreted as aqueous fluids near the boiling point and infer temperatures of at least 240°C. The less conductive layer found between these conductors is probably steam-dominated and coincides within the mixed-clay zone found in many volcanic hydrothermal systems. A new extended study, following recent fieldwork aimed at providing insights into deep electrical conductivity structure of Furnas Volcano will be presented together with broad-band data from over 50 stations across the central volcanic system of São Fogo Volcano, where seismic swarm activity has been centred.

Chemical anomalies in stream sediments associated with lithium pegmatites in Leinster, SE Ireland

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An unexposed belt of Li-Cs-Ta-enriched (LCT) pegmatites of the albite-spodumene sub-type intrudes the East Carlow Deformation Zone along the margin of the S-type Leinster batholith. An increasing demand for Li for Li-ion batteries resulted in current exploration by Blackstairs Lithium Limited.

Re-analysis of geochemical data from stream sediments collected in the 1980s [1], allows assessment of the potential of stream sediment chemistry for LCT pegmatite exploration. Stream sediments regionally sample the catchment area corresponding to their respective sampling points. For geospatial analysis, stream lines were delineated from a 25-m digital elevation model and Tellus sample locations were snapped to the nearest stream lines. For each sample, catchments were delineated. Before data analysis, Tellus stream sediment data was transformed in four different ways (log, log-normalized, additive log-ratio, centred log-ratio). The data was corrected for baseline geochemistry by adopting a linear regression approach, where bedrock composition is inferred from the composition of all catchments and the areal proportions of the respective underlying mapped lithologic units [2].

Tantalum shows prominent (>2 SD) and less prominent (>1 SD) anomalies for residuals of measured and predicted Ta concentrations for several catchments with known LCT pegmatite occurrences. Tin

shows anomalous concentrations (>1 SD – >2 SD) for most of the catchments with Ta anomalies and/or in neighbouring catchments. Caesium is highly variable in the granitic plutons themselves. While Cs is anomalously high in catchments at and SW of Aclare, only a few catchments of other LCT pegmatite localities show anomalies at the 1 SD level.

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3-D Magnetotelluric Imaging of the Lithosphere beneath Ireland

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The present day lithospheric structure beneath Ireland is largely the result of the combination of tectonic and magmatic processes since Proterozoic times. While the crustal structure in Ireland is reasonably well known, particularly over the Irish segment of Iapetus Suture Zone, the uppermost mantle structure of Ireland is less constrained, having as a major debate on hypothetical thinning of the lithosphere from south to north. In the framework of Space Weather ElectroMagnetic Database for Ireland (SWEMDI), project funded by Geological Survey Ireland, we acquired long-period magnetotelluric data at over twenty stations. This new MT data together with the existing dataset at over thirty stations (ISLE-MT – Irish Magnetotelluric Lithosphere Experiment) across Iapetus Suture Zone have been modelled in 3-D. In this work, we present for the first time electrical conductivity distribution in the lower crust and the uppermost mantle of the entire island. The resulting electrical conductivity models are compared with the seismic velocity models of Ireland.

Study of the Palaeoenvironments and Geological Setting of the Kilbride Peninsula, County Mayo

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The aim of this research project was to look at the geology of the Ordovician and the Silurian Rocks found on the Kilbride Peninsula in County Mayo, Ireland. Using previously published evidence and observations in the field, the palaeoenvironments that would have contributed towards the formation of the series have been identified, as well as the later tectonic forces that acted upon them were investigated. To gather observations, a month was spent mapping a section of the peninsula from the village of Finny to the outstanding feature of the Doon Rock. This included bed structures, fossils preserved in the rocks.

Utilising the data and observations from this study, the existing theories regarding the structure of the South Mayo Trough being a fore-arc basin has been challenged. A new theory has been purported in the current study, which proposed that the formation of the South Mayo Trough may in fact be related to the closing and movement of a back-arc basin that was going through similar actions to that observed in the current day Japan Sea. The presence of fossils was further used to

back up these views on the changing palaeoenvironment as the land transformed from continental to deep marine.

In conclusion, the arc basin structure is that of a back-arc basin that has been sealed off and allowed for deposition of sediments. These sediments deposited during the Silurian Period, show a transition from a period of sea transgression to regression during the deposition of the sedimentary series.

The role of the continental shelf on ocean induced seismic surface waves generated offshore Ireland

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Ocean wave generated seismic noise, also called microseisms, are characterized by a strong acoustic/seismic coupling at the sea floor. Since particularly defined by steep bathymetry, we look at the continental shelf or steep margin slopes control on seismic noise Rayleigh waves and Love waves recorded on land. To do so, we compare land seismic array data with 3D numerical simulations to show the effects of both bathymetry and sediment changes associated with the continental shelf. Our 3D synthetic model comprises a broad area of the Irish offshore including key features such as the Rockall Trough and the Porcupine basin. To better characterize changes in the seismic wavefield generated from different "ocean noise" source locations, multiple areas of the model are investigated separately. The simulated wavefield recorded on synthetic seismograms enables us to look at the effect of the water column, sediments thickness but also steep gradient changes in bathymetry and sediments. Whereas Rayleigh waves are broadly observed in the simulations, Love waves become only significant for specific source locations. Understanding the radial and transverse seismic wavefield is important as both Rayleigh and Love waves will exhibit different sensitivity to the underlying velocity structures.

This project is part of the Irish Centre for Research in Applied Geoscience (ICRAG), funded under the SFI Research Centres Programme and is co-funded under the European Regional Development Fund.

Submerged Landscapes of Ireland

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The importance of submerged archaeological sites has been growing steadily more apparent as human activity at sea has intensified – particularly with respect to marine construction projects that can disturb the seabed. In order to assist with responsible marine planning, maps of now-drowned landscapes that may have been occupied by ancient humans such as those during the Palaeolithic and Mesolithic are required in order to identify areas of potential archaeological significance.

EMODnet is an initiative of the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) as part of its Marine Knowledge 2020 strategy and is supported by the EU's Integrated Maritime Policy. The EMODnet project aims to assemble marine data from various sources to unlock fragmented and hidden marine data resources and to make this information publicly available. The programme includes information for bathymetry, geology, chemistry, biology, physics, habitats and human activities of Europe's seas.

EMODnet Geology comprises a consortium of 36 organisations from 30 countries and aims to compile information about the geology of the European seabed and sub-seabed, coastal behaviour, marine geohazards, minerals and submerged landscapes. As partner, Geological Survey Ireland has committed to share all known information on marine features around Ireland that suggest a previously subaerial environment. These features will be part of a seamless, harmonised map of hidden landscapes across all European seas and will be available on the EMODnet web portal. INFOMAR, Ireland's marine mapping programme provides a baseline data set from which we derive information on Ireland's submerged landscapes.

Spatio-temporal analysis of long term/short term shoreline change rates using remote sensing approaches

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Key words: shoreline, foredune, erosion/accretion, remote sensing

Quantifying shoreline changes due to the natural processes and anthropogenic activities and its spatio-temporal pattern is a fundamental task for various coastal studies undertaken by coastal zone managers and scientists. This investigation was carried out to determine the erosion/accretion rates and pattern as well as factors contributing to shoreline changes along 12 km stretch of shoreline from Blackwater to Wexford Bay along County Wexford. Decadal scale shoreline change rates were estimated using 1953, 1972, 1995, 2000, 2005, 2012 and 2018 aerial/satellite imageries within GIS environment. Shore normal transects (ca. 300) at a spacing of 50 m alongshore was used to determine the shoreline erosion/accretion rates. To determine the End Point Rate and Linear Regression of rate of change, the Digital Analysis Shoreline Analysis System (DSAS) was used. The results revealed erosion rates of ca. 1.7 m.a-1 in the Northern reaches (vicinity of Blackwater), ca. 0.2 m.a-1 along central portion and ca. 0.4 m.a-1 accretion along the Southern reaches (Raven Beach and Forest). Based on the long term and short-term field observations, the major controls on the evolution of beach dune system along the study area may be ascribable to the presence of soft sediment cliffs, sediment supply by river Slaney to Wexford Bay and its northward transport through hydrodynamic processes. In addition, short term coastal evolution has been quantified using remote sensing approaches on a seasonal scale using differential GPS, Terrestrial Laser Scan and UAV. Initial results from these approaches will be also presented in this poster.

GEO-URBAN - Identification and assessment of deep GEOthermal heat resources in challenging URBAN environments.

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The GEO-URBAN project is funded by the European Union's Geothermica ERA-NET Co-fund with the aim of identifying and assessing the potential for geothermal energy exploitation in urban environments. This three-year study is conducting an initial assessment of the potential for geothermal energy in two study areas, Dublin City, Ireland and Valles, Catalonia, Spain. A multi-disciplinary geophysical exploration strategy has been developed for the targets to overcome the

challenge of anthropogenic noise in the urban environment. A combination of electromagnetic methods (including magnetotellurics and controlled source electromagnetics) will be utilised in conjunction with passive seismic methods (including, H/V and ambient noise cross-correlation). The two test regions are comprised of hard rock reservoirs, which are characterised as having low primary porosity. The procurement of accurate geological data, and in particular data regarding geological structures, is paramount to the exploitation of reservoirs dominated by secondary porosity, where fluid flow at depth is controlled by the interconnectivity of these structures. Geological models of each study area will be developed and the multi-disciplinary survey data will be a key dataset in assessing the potential resource at both study sites. Identifying these water bearing structures at depth will in turn help to de-risk the drilling phase of any future commercial geothermal operations. The deliverables of the Geo-Urban project include a commercialisation and policy strategy. This strategy report will use the geological conceptual models and an economic assessment of the prospective geothermal targets to provide a practical planning roadmap for the exploitation of geothermal energy in Dublin and Vallès.

The Iapetus suture zone in Ireland

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Evidence preserved in Ireland for the later stages of Iapetus ocean closure suggests a tectonic model that has important differences from the closure history along strike in Newfoundland.

The Upper Ordovician – Wenlock sedimentary tracts of the Southern Uplands – Down– Longford Terrane formed an accretionary prism against the Laurentian margin. Outboard, the Grangegeeth Terrane is a Laurentian continental fragment with an Ordovician volcanic arc formed above a second subduction zone. During late Ordovician time, it formed the southern margin of the Rathkenny basin of Moffat Shale facies mudstone interbedded with volcaniclastic horizons. Together these were overstepped in the Wenlock by Laurentian-derived greywackes and became the southernmost tract of the accretionary prism.

On the southern side of Iapetus, Floian arc volcanism in the Bellewstown Terrane was followed by volcanic quiescence. Renewed late Middle to Upper Ordovician arc magmatism includes c. 464 Ma extensional rhyolites and a deformation event at c. 460 Ma. The rapid switch from extension to compression records failed rifting of Ganderia followed by renewed compression during continuing subduction under a north-facing arc.

In the Newfoundland sector of Iapetus, a Ganderian volcanic arc migrated across the ocean in mid-Ordovician times to accrete to Laurentia, leaving a Ganderian passive margin. In Ireland, the late-accreted arc on the Laurentian margin formed on a Laurentian microcontinent. Supra-subduction extension of Ganderia did not form an ocean basin and Ganderia had an active margin throughout late Ordovician times. Iapetus was narrow by Katian times, but subduction-related magmatism continued into the Wenlock on both margins.

Thermodynamically constrained joint inversion of seismic refraction, surface elevation and gravity data for crustal composition and structure: application to the Porcupine Basin

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Information on chemical composition and thermodynamic state of the subsurface is the ultimate goal of geophysical inversion. To reduce the associated uncertainties, joint interpretation/inversion of heterogeneous datasets is crucial; realistic uncertainty analysis requires probabilistic approach. Here we present a framework for probabilistic joint inversion of seismic traveltimes, surface elevation and gravity data. Primary unknowns of our inverse problem are proportions of mineral phases within the crystalline crust, geometry of the crustal layers and Moho, and serpentinite content in the uppermost mantle. Such parameterization allows for consistent integration of the observables: elastic moduli and density are predicted from mineral physics using pressure and temperature satisfying the thermodynamical constraints. To sample generally multimodal posterior probability density function (PDF) of the model parameters efficiently we adapt Markov chain Monte Carlo algorithm with Parallel Tempering. We then analyze the posterior PDF using Gaussian mixture model. As a feasibility study, we perform inversion of 2D synthetics based on wide-angle seismic data from the RAPIDS4 profile (Porcupine Basin) and available satellite gravity and bathymetry. Results suggest that crustal thinning and mantle serpentinization at the Porcupine Arch and mineral composition of the upper crust should be well constrained by the available data.

Deciphering the mineral-scale record of planetary scale processes

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Main Group Pallasite meteorites originated in the earliest differentiated bodies in the Solar System, with an age of 4.5 Ga. Both textural and chemical heterogeneity within individual samples and across the group is not fully understood. While existing oxygen isotope data suggests that Main Group Pallasites all originated from the same local neighbourhood in the early Solar System, the number of parent bodies involved in their origin remains elusive due to diverse cooling rates.

Diverse formation mechanisms have been proposed, with most falling between two end-member scenarios: either Pallasites represent the core-mantle boundary of a differentiated body where mantle olivine and core metal coexisted, or, alternatively, they are the remnants of an impact between a stripped metallic body with the olivine mantle of another planetesimal.

In this study, we investigate the distribution and concentration of elements across texturally varied olivine to constrain the thermal history of Pallasite meteorites. Pallasite olivine grains have been mapped using Energy-Dispersive X-Ray Spectroscopy (EDS) and calibrated with quantitative spot analysis using an electron microprobe, with crystal orientation obtained through Electron Backscatter Diffraction (EBSD). Combined with improved modelling of the cooling rates of small planetary bodies, these data allow new estimates for the thermal history of the parent body, which constrain the number of parent bodies required to produce the heterogeneities observed and may reveal earlier processes than those recorded by metallographic cooling rates.

The Next Generation of Irish Geoscientists: Exploring Attitude And Understanding Towards Geoscience At Junior Secondary Level In Ireland

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The world is facing a future where issues relating to Earth Science are increasingly important, including climate change, energy and resource management (e.g. water, mining), and natural disasters. Earth Science is included for the first time in the new Junior Certificate Science syllabus. The disposition of the next generation of citizens, as future voters and as future geoscientists, is vital if Ireland is to meet the challenges of rising temperature, rising sea levels, and rising incidences of natural disasters. This ongoing mixed-methods study of student engagement with and understanding of Earth Science in Irish secondary schools uses Children's Research Advisory Groups (CRAGs) to include the voices of students. These CRAGs are convened in representative schools in the study and comprise students representative of the participants of the study. The CRAGs are consulted at multiple stages, including before the pilot survey and after results are compiled, and their input guides key decisions within the project, including the language used in the survey, the format of the information provided to schools, and the conclusions drawn. The aim is to measure Irish Junior Certificate student attitudes towards Earth Science as global and Irish citizens; how they conceptualise human interdependence with and on the planet; and how they consider themselves in different ways connected to or independent from the Earth, the study of Earth Science, and students or children their age elsewhere on the planet facing similar challenges in the era of climate change.

Geophysical remote sensing of subsurface properties for sustainable agricultural management

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The acquisition of sub-surface data for agricultural purposes is traditionally achieved by in situ point sampling in the top 2m over limited target areas (farm scale ~ km2) and time periods. This approach is inadequate for integrated regional (water catchment ~ 100 km2) scale management strategies which require an understanding of processes varying over decadal time scales in the transition zone (~ 10's m) from surface to bedrock. With global food demand expected to increase by 100% by 2050, there are worldwide concerns that achievement of production targets will be at the expense of water quality.

In order to overcome the limitations of the traditional approach, this PhD project will combine airborne and ground geophysics with remote sensing technologies to access surface and subsurface permeability variations at multiple spatial scales. It will address this problem in the context of providing tools for the sustainable management of agricultural intensification envisioned in Food Harvest 2020 and Food Wise 2025 and considering the EU Habitats and Water Framework Directives (WFD), Clean Air Policy and Soil Thematic Strategies.

The work will use existing ground based geophysical and hydrogeological data from Teagasc Agricultural Catchment Programme (ACP). Two additional sites will be selected over karst and sand/gravel aquifers in consultation with the Geological Survey of Ireland's Groundwater Section

with co-located ground and airborne electromagnetic data. Work will then focus on upscaling results from ACP to WFD catchment scale. This upscaling will require modification of traditional satellite remote sensing conceptual frameworks to analyse heterogeneous, multi-temporal data streams.

Temporal variability of cold-water coral habitats from the Porcupine Bank Canyon NE Atlantic, using ROV-vibrocoring, CT-scanning and PSA: preliminary results.

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Cold water corals (CWCs) trap current-suspended particles from their environment, which become deposited in and around the coral framework. This results in the growth of topographic features called CWC mounds, which contain a record of paleoenvironmental change through time. Here, we present a project within the MMMonkey_Pro (www.marinegeology.ucc.ie) research programme, which focuses on the temporal development and paleoenvironmental history of CWC habitats in submarine canyons (reefs, gardens, mounds and coral-derived tallus slopes). This poster presentation shows work completed to date on this project which started in January, 2018.

A number of ROV-mounted vibrocore samples have been retrieved from a range of CWC habitat types within the Porcupine Bank Canyon (PBC), NE Atlantic. These cores have been scanned using dual energy computed-tomography (CT) following, and further developing, a novel methodology (see Titschack *et al*., 2015; 2016). This has created comprehensive imagery of the internal architecture of the CWCs, as representative of reef development stages. The extrapolated data is processed using Amira software and coral core-specific algorithms (Titschack *et al.* 2015), revealing variables such as matrix:coral ratio, coral-fragmentation, coral-fragment orientation and size. The cores have been further logged and subsampled for high-resolution laser granulometry and composition ($CaCO_3$% and Organic%). In early 2019, a chronostratigraphic framework will be constructed by subjecting planktonic foraminifera and coral pieces to ^{14}C AMS and U/Th dating, respectively. Moreover, planktonic foraminiferal assemblages will be classified.

This unique multidisciplinary ensemble approach, will uncover the controls on mound cessation and development related to the dual energy, CT-identified reef development stages. For the first time, we aim to shed light on what controls the formation of different CWC habitats in the PBC.

Biogeochemical modelling of soil organic carbon - insights into the processing procedures of selected atmospheric input data: Part I – an example from E-OBS climate datasets

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Biogeochemical models are often used for assessing the dynamics and changes in soil organic carbon (SOC) stocks and greenhouse gas (GHG) emissions [1], with atmospheric data representing crucial inputs [2]. This work is performed under larger EPA funded SOLUM project, which uses the ECOSSE

process-based biogeochemical model for SOC modelling for Ireland [1]. ECOSSE requires (among others) the climate data inputs for the period simulated [2]. Presented are insights into the processing procedures of gridded climate data in order to use them as inputs into ECOSSE. Data were extracted from the E-OBS daily gridded observational climate dataset for Europe [3]. The extracted data were in *netCDF* format and further processed [3] in R v.3.5.2 [4] using adapted R-scripting [5] and R-packages ("*ncdf4*", "*raster*")[4]. E-OBS provides daily 1950-2017 data (e.g. maximum- and minimum-temperature, precipitation) with standard errors included, but with limited spatial resolution (0.25° regular grid) and without potential evapotranspiration (E_T) [3]. E_T is a required input in ECOSSE, and needs to be further modelled from extracted and processed climate data.

Acknowledgements
The Soil Organic carbon and Land Use Mapping (SOLUM) project (2016-CCRP-MS.40) is funded under the Environmental Protection Agency Research programme 2014-2020.

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Biogeochemical modelling of soil organic carbon - insights into the processing procedures of selected atmospheric input data: Part II – atmospheric nitrogen deposition from EMEP datasets

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Biogeochemical models applied for modelling the soil organic carbon (SOC) stocks and greenhouse gas (GHG) emissions require (among others) the atmospheric data inputs [1]. Such is the ECOSSE model used in a larger EPA funded SOLUM project [1], which in addition to climate data also requires the input of atmospheric nitrogen deposition (ND) [2]. Presented are insights into the processing procedures of ND data extracted from EMEP (2000-2016 yearly EMEP-MSC-W data, 0.1° resolution) [4] in order to use them as ECOSSE inputs. ND data in *netCDF* format [4] were further processed in Python 2.7 [5] using "*netCDF4*" module [6] and an adapted "*EMEP_NetCDF_data_to_csv*" script [7]. ND was computed for each year as a sum of all oxidised and reduced N (including wet- and dry- N) for all grid centroid points extracted for Ireland. As ECOSSE requires a single ND input values (and not time-series), the average 2000-2016 ND was calculated for each centroid grid-point from individual year-values and further processed in ArcGISMap10.6.1 [8].

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The Soil Organic carbon and Land Use Mapping (SOLUM) project (2016-CCRP-MS.40) is funded under the Environmental Protection Agency Research programme 2014-2020. Thanks go to Dr. M. Williams (TCD) for his suggestions/advice.

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Preliminary LA-ICP-MS AFT & AHe Results Offshore West of Ireland

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In the Irish Atlantic Margin (IAM) large uncertainties remain about the exact timing, magnitude and causes of the main uplift and erosion events since the main rifting phase. The project aims to better constrain these exhumation events by modelling thermal histories from a large number of locations on the IAM using two low-temperature thermochronometers: apatite fission track analysis by LA-ICP-MS (LAFT) and apatite (U-Th)/He (AHe) from multiple samples along vertical profiles (i.e. boreholes).

Three sampling campaigns have now been successfully completed, two at the Petroleum Affair Division (PAD) core store in Dublin and one at the Ifremer core store in Brest (France). Our dataset is composed of 76 individual samples (63 cuttings, 4 cores and 9 seabed samples). A sub-set of the samples have already been processed and partially analysed for AFT and AHe results. Despite careful sample selection, only a small percentage of them will actually be usable for thermal history modelling (mostly due 1) low yield of apatites in some Lower Cretaceous and Eocene sands; 2) poor apatite quality in some samples: heavily fractured grains, very small grain sizes; and 3) loss during laser ablation due to loose etched grain). We present here preliminary results for well 13/03-1 in the Donegal Basin and well 26/26-1 in the North Porcupine Basin.

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Surface Deformation from Stalled Magma

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This project aims to characterise inter-eruptive mechanisms of deformation in stalled magma bodies. As of 2017, surface deformation has been observed at approximately 220 volcanoes, as a response to active volcanic processes. These processes vary from eruptive and non-eruptive magmatism, to non-magmatic contributions from overlying hydrothermal systems, and from the settling of extrusive products. Modern techniques, such as Interferometric Synthetic Aperture Radar, have facilitated a surge in geodetic observations. From the geodetic record, we identify approximately 20 examples of surface displacement from “stalled” magmas. We consider a magma body as stalled once there is no evidence of further migration following intrusion (e.g. no seismicity or density changes). Surface deformation attributed to such magmas most often occurs at a steady rate of millimetres to centimetres per year, and is expected to last for extended periods of years to even decades.

Here, we investigate the effect of magma crystallisation on magma body volume, and its corresponding effect on surface displacement. The crystallisation of denser-than-melt minerals, and volatile exsolution during “Second Boiling” drive such volumetric variations in the magma body. We use MELTS phase equilibria software to model volume change across a range of magmatic compositions. For each composition, we consider the effect of anhydrous crystallisation, volatile fractionation, and crystallisation style on volume change and displacement profile. We aim to validate our results by comparison to examples from the geodetic record. This will allow us to map out the parameter space over which a crystallising magma causes measurable deformation at the Earth’s surface.

A Quaternary Geological Map at 1:10,000 scale for the Keady Region, Northern Ireland.

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This work presents a 1:10,000 scale mapping sheet for the Keady region in south Armagh. A high-res (0.4 m) Structure-from-Motion (SfM) Digital Surface Model (DSMs), created from digital aerial imagery, allows us to map glaciated landforms and superficial sediment lithofacies.

The hi-res SfM-derived DSM allow for the straight forward differentiation of glacial diamicton (till), river alluvium, lake alluvium, peat and bedrock, the major lithofacies units across the mapped domain. The Keady region is dominated by ribbed moraines, drumlins, streamlined bedrock and subglacial meltwater channels. A N-S orientated tunnel valley through Poyntzpass on the eastern side of the mapped domain links Lough Neagh to the north with Carlingform Lough to the south. There is a transition across the mapped domain from NW to SE; (1) SW-NE orientated ribbed moraines dominate the north-western region, (2) NW-SE orientated drumlins dominate the central area, and (3) NW-SE orientated streamlined bedrock and large-scale glacial lineations characterise the south-west. This latter zone is dominated by the major bedrock feature in the region, the Slieve Gullion ring dyke.

The geomorphological change across the mapped domain is indicative of a change in ice-sheet bed conditions, transitioning from a polythermal basal regime to a warm-based fully deforming bed. The restriction of large-scale streamlined bedforms to within the ring dyke leads to the inference that ice streaming is both topographically and geologically controlled. The ring dyke acts as a sticky spot, limiting the draw-down of streaming ice from the Irish Sea ice stream to the southwest.

Palaeoenvironmental reconstruction from the mineralogy of the Pliocene Camp dels Ninots maar lake sediments (Catalan Volcanic Zone, NE Iberia)

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The Camp dels Ninots Maar Lake (Pliocene, La Selva basin) provides a remarkable climate record that allows one to compare external climatic proxies with mineralogical changes recorded in the lake. High resolution mineralogical analyses by means of powder X-ray diffraction (XRD) were conducted at the 75-m long Can Cateura well core. The core, obtained from a well drilled in the centre of el Camp dels Ninots maar-lake, was first studied by Jiménez-Moreno et al., (2013), who performed a biostratigraphic and paleomagnetic analysis to study the late Pliocene climate in the western Mediterranean area. The aim of the present work is to investigate how precisely long-term climate variations affect the mineralogy of a maar lake by comparing the compositional variation of different mineral assemblages with the palynological analyses (in particular Abies pollen) provided by the work of Jiménez-Moreno et al. (2013). It is concluded that enrichments in nontronite and other detrital

minerals such as quartz and feldspars correlate with wet periods (Abies peaks and arid taxa lows). Conversely, intervals enriched in carbonates (mainly dolomite) correlate with dry periods (Abies lows and arid taxa peaks). This cyclical variation is attributed to humidity variations. In periods with relative high rainfall, clastic input would be enhanced (hydrologically open lake), while in periods of low rainfall ionic concentrations would substantially increase (hydrologically closed lake), giving rise to primary or early diagenetic dolomite as the main authigenic precipitate.

Structural style and timing of the inversion structures in the Celtic Sea basins (offshore Ireland): Insights from the Mizen Basin.

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The Celtic Sea basins lie on the continental shelf between Ireland and north western France and consist of a series of ENE - WSW trending elongate basins that extend from St George's Channel basin in the east to the Fastnet basin in the west. The basins, which contain Triassic to Neogene stratigraphic sequences, evolved through a complex geological history that includes multiple Mesozoic rift stages and later Cenozoic inversion. The Mizen basin represents the NW termination of the Celtic Sea basins and consists of two NE-SW trending half grabens developed as a result of the reactivation of both Caledonian and Variscan faults. Previous studies in the Mizen basin and surrounding areas have been based on 2-D seismic datasets. The present work sheds new light on the Mizen basin structure and evolution based on 3-D seismic reflection data combined with wireline log and biostratigraphic data 3-D seismic coverage and a syn-tectonic stratigraphic sequence that is much better preserved than in the basins to the east makes this area an excellent location to study and understand the style and timing of inversion of the Celtic Sea basins .As for most of the Celtic Sea basins, the Mizen basin experienced a period of major erosion during the Palaeocene attributed to tectonic uplift. Cenozoic Alpine inversion affected the study area from Middle Eocene to Miocene times causing reverse reactivation of the basin bounding faults and the formation of NW-SE-striking dextral strike-slip faulting. The different styles of deformation observed during extension and inversion are, to a large extent, controlled by the orientation of Variscan structures that localised strains throughout the evolution of these basins.

Petrophysical Characterization of Highly Polarizable Rocks from the Moffat Shale Group (Ireland)

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The geological situation in the north of Ireland, especially concerning the origin of the Moffat Shale Group, has long been under discussion. The Tellus Project (Geological Survey Ireland, GSI) is supposed to bring new insights into the regional geology by means of geophysical and geochemical surveying. Airborne electromagnetic measurements revealed high-conductivity anomalies that had have been interpreted as the response of a black shale.

In order to petrophysically characterize the Moffat Shale a laboratory study using material from two boreholes was carried out. The investigations included density and porosity as well as Spectral Induced Polarization (SIP) in the frequency range from 10^{-4} to 10^{5} Hz.

The sample material can be categorized into two groups. A mudstone-like rock type showed weakly frequency-dependent, porosity-driven conductivities with strong anisotropy, which could be explained by the deformation of the pore channels by compaction. On the other hand, samples taken from the black shale were characterized by strong polarization effects producing high phase shifts especially at low frequencies, and a strong conductivity increase towards higher frequencies.

The high polarizabilities are due to the carbon as well as pyrite, which are both abundant in the black shale. A two-component Cole-Cole model was used to explain the data. The derived Cole-Cole parameters could be used for further interpretation. Complementary SIP measurements on crushed material led to the assumption that the polarization effects are mainly controlled by the texture of polarizable components and not only by their volume fraction. A geochemical analysis of selected samples supported those findings.

A New Raman Microscopy Facility at the School of Biological, Earth and Environmental Sciences, UCC.

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The School of Biological, Earth and Environmental Sciences (BEES), UCC have recently added a Raman microscope to their Microbeam Laboratory. The microscope, funded through an SFI Opportunistic Award, is designed to facilitate a wide variety of projects associated with the Earth Sciences. It also has the ability to provide analysis across multiple disciplines and the potential to generate a sustained income through commercial application. The microscope, a Renishaw Qontor, uses laser based technology to measure Raman spectra for generating high resolution mineral signature. It has the ability to measure samples with no prior preparation, including those with uneven surfaces. Current projects utilising this facility include fingerprinting stone aggregates, heavy mineral analysis, exceptional fossil preservation in volcanogenic sediments and vein and sediment-hosted ore deposits. The data set produced by the microscope can be utilised by a variety of methods for analysis and visualisation. Furthermore, the microscope is highly modular, providing an opportunity to unleash its full potential for geoscience research.

Improving the Groundwater Geochemistry Toolkit for Mineral Exploration

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Geochemical sampling (rock, soil and water) is one of the most valuable techniques employed by the mineral exploration industry to find new deposits. Assessing groundwater chemistry is particularly useful for vectoring towards potential mineralisation; properly contextualised groundwater data can provide insight into flow patterns and controls, the age of the water and the lithologies it has moved through. Better sampling techniques (e.g. U.S. E.P.A., 1996) and recent advances in approaches to the statistical analysis of geochemistry data (e.g. Aitchison, 1994 and Blake et al., 2016) have allowed for a more comprehensive understanding of water/rock interactions in the subsurface. With this in mind it may be prudent to produce a procedure that can be followed, allowing for the greatest

dividend from groundwater sampling in the context of mineral exploration and groundwater management. This procedure would include best practice for the collection and analysis of groundwater samples as well as a description of how to get the most out of the subsequent data using advanced statistics and mapping techniques. Presented here is an example of a potential procedure using groundwater geochemistry data from Lisheen, Co. Tipperary, a known carbonate-hosted massive sulphide lead/zinc deposit, to demonstrate the value of the methods employed.

Northern Ireland one 14 new Regional Geological Visualisation Models

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A new 3D bedrock geological model for Northern Ireland is one of 14 new Regional Geological Visualisation Models (GV Models), which have been produced by the British Geological Survey (BGS) to provide interactive, user-friendly tools for exploring the UK's geology in three dimensions. The GV Models depict geology at regional to national-scale, and the interactive tools are designed to facilitate visualisation of the subsurface environment and enhance conceptual understanding. The GV Models are designed for use on desktop/laptop computers.

The GV Models are based on the national fence diagram of the UK (Waters et al. 2015) with additional cross-sections developed along the regional boundaries, the BGS 1:625 000 scale digital bedrock geological map of the UK (DiGMapGB-625), and the BGS 1:250 000 scale marine bedrock map. Geologists' cross-sections have made use of publically available data from, for example, deep boreholes, regional LithoFrame 3D model surfaces, regional memoirs and reports and other open access publications. UK3D cross-sections have been combined with digital terrain, bathymetric and topographic data to develop 3D 'block models' of the upper 1.5 km of the crust.

Users can explore a region's geology by switching on/off individual blocks, hiding or displaying groups of geological units, and zooming and rotating to view the blocks from any angle. The model legend provides information about the geological units, and select functions link to additional sources of information including the BGS Lexicon and scanned records of key boreholes that have informed the model's development.

The GV models can be downloaded via the following page of the BGS website:

www.bgs.ac.uk/research/ukgeology/nationalGeologicalModel/GVModels.html

WATERS, CN, TERRINGTON, RL, COOPER, MR, RAINE, RJ and THORPE S. 2015. The construction of a bedrock geology model for the UK: UK3D_v2015. *British Geological Survey Open Report*. OR/15/069.

In-situ S isotope analysis reveals genetic links between Irish-type deposits and related geochemical halos

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At Navan, the Thin Bedded Unit (TBU) at the base of the Upper Dark Limestone consists of alternating sequences of black shales, siltstones and calcarenites. Here, seafloor exhalative sulphide deposition overlying the Tara Deep deposit has been identified.

In-situ laser S isotope analysis has been performed on petrographically well-characterized samples of TBU-hosted mineralization. Four mineral assemblages have been identified: (1) Laminated pyrite: comprises thin layers of framboidal pyrite and minor interstitial sphalerite hosted in black shales. Sulphides have mean $\delta^{34}S$ value of -23‰; (2) Pyritized calcarenite: is widely distributed and occurs as fossil replacements by pyrite with mean $\delta^{34}S$ of -13‰; (3) Replacive assemblage: occurs as late remobilizations both crosscutting, and parallel to, the bedding overprinting the early laminated pyrite. It comprises mostly marcasite, with minor pyrite, sphalerite, chalcopyrite, galena, stibnite, arsenopyrite and pentlandite, with mean $\delta^{34}S$ of +10‰; and (4) Hydrothermal cherts: comprising thick microcrystalline quartz bands rimmed by dolomite, associated with marcasite, pyrite, sphalerite, chalcopyrite, galena, Ni-sulfosalts and stibnite with mean $\delta^{34}S$ of +16‰.

Geological record, detailed petrographic and S isotope analysis indicate overlapping of diagenetic and multi-phase hydrothermal sulphide mineralization in the TBU. First, light $\delta^{34}S$ in both laminated pyrite and pyritized calcarenites suggests a sulfate-reducing bacteria origin within sediments during early diagenesis. Later, anomalous values of chalcophile elements, linked to hydrothermal cherts and replacive heavy sulphides, suggest hydrothermal exhalation during early-mid diagenesis. Similarities in mineralogy and S isotope compositions suggest genetic links between the TBU mineralization and Tara Deep deposit, hence, TBU mineralization may therefore be a geochemical halo to Tara Deep.