



# The Ussher Society

**Abstract Volume**

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## PURPOSE

1. To promote research into the geology, geomorphology and other aspects of geoscience in South-West England and geologically related areas.
2. To hold an Annual Conference at various places within south-West England where those engaged or interested in this research can meet both formally, to hear original contributions and progress reports, and informally to effect personal contacts.
3. To publish the proceedings of the Annual Conference and other papers relating to geoscience in South-West England.
4. To organise field excursions.
5. To encourage other geoscience-related activities which the Management Committee may from time to time deem appropriate.

## CONSTITUTION

*Membership* is open to anyone with an interest in geoscience in South-West England on written application to the Secretary and payment of the relevant subscription.

An *Annual Business Meeting* shall be held during each Annual Conference and shall elect a Management Committee and two auditors for the succeeding year.

*Subscription* shall be set by the Annual Business Meeting and shall be due on 1<sup>st</sup> January each year.

The affairs of the Society will be managed by a *Management Committee* consisting of a Chairman who shall hold office for not more than two consecutive years and who shall not be eligible for re-election to the office for a further two years; a Vice-Chairman who shall serve for the first year as Chairman-elect and, after two years as Chairman, for one further year as retiring Chairman; a Secretary, a Treasurer, an Editor and a Website Manager, any of whom may be eligible for re-election and who on leaving office shall normally retain Committee membership for one additional year and four others, any of whom might be eligible for re-election up to a maximum term of three years. The Committee shall have powers to co-opt.

*Amendment of the Constitution* may be effected by simple majority vote at the Annual Business Meeting.

Revised Constitution approved at the Annual Business Meeting St Ives January 2008.

The Ussher Society

## ABSTRACTS



### THE SCOTT SIMPSON LECTURE

#### ALL ABOUT THE TIMING: BRINGING GEOCHRONOLOGY IN SW ENGLAND UP-TO-DATE

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Robust chronological frameworks are fundamental for underpinning and testing geological models. It is now over 20 years since the geology of SW England has received any substantial attention from geochronological research. Over this period analytical capabilities in geochronology have made significant advances in the areas of accuracy, precision and spatial resolution. With new tools available, it is now time to take a fresh look at the temporal framework of SW England.

With a primary focus on the post-Variscan granite magmatism of S.W. England, I will review the limitations of preceding geochronological data sets and how modern techniques are rising to the complex challenges that these rocks pose for deriving robust ages. On the basis of a recently developed, high-precision, zircon U-Pb dataset we can now re-evaluate the regional model for the progression of magmatism across the SW England batholiths at a ~100 kyr resolution. At this level of precision, we can now identify the punctuated nature and discrete events of magma emplacement that correspond with patterns in magma type. Additionally, the new data set addresses



*Figure 1. Roborough Stone forming the window dressings on the south side of the nave of the church of St James the Less, Kingston.*

some long-standing chronological issues of magma bodies associated with magmatic hydrothermal activity such as the timing of Cligga Head, the Wheal Remfry brecciation event, and the emplacement of the Hemerdon stock.

Ever deeper insights into granite petrogenesis are now being revealed by integrating the latest geochronology with state-of-the-art Lu-Hf tracer isotope techniques at the sub-crystal scale. These new data allow us to evaluate time-resolved contributions of both crust and mantle sources over the lifetime of the batholith and provide interesting new perspectives on the origins of different granite types and their associations to different ore types (Sn and W).

Finally, we will look to the future to see how the advances in geochronology are providing new opportunities to better constrain our models for metamorphism, stratigraphy and ore genesis across the region.

### ROBOROUGH STONE

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Vesicular quartz porphyry, called Roborough Stone, is widely used in the west and south of Devon for the dressings and less commonly the quoins of medieval churches. The distribution of the stone in buildings is described and discussed and LiDAR elevation data is used to identify many of the quarries from which the stone was formerly won.



*Figure 2. A linear depression marking one of the former Roborough Stone quarries where it crosses the 11th fairway of Yelverton Golf Course.*

## REDMOOR TIN-TUNGSTEN PROJECT UPDATE

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The Redmoor project is located in the Kelly Bray area, east Cornwall. It consists of multiple lode-style and sheeted vein targets, hosted in 'killas' slates and prospective for tin, tungsten, and copper. Significant mining activity took place at Redmoor from the 1700s to 1943. More recently, the area was the subject of exploration during the early 1980's, when South West Minerals (SWM) carried out extensive diamond drilling and surface exploration.

Following a review of all data, Cornwall Resources (CRL) identified further exploration potential, leading to a 20-hole (7,046 m) diamond drilling program which ran between March and October 2017. The CRL team is now working to produce an upgraded resource for the Redmoor project, focussed on a potential future underground mine. This presentation includes an overview of the mineralisation at Redmoor, a summary of the results of the 2017 drilling programme, and a brief review of current research collaborations.

## 3D RECONSTRUCTION OF HOLOCENE SEDIMENTS AT SEVERNSIDE

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A synthesis of the results of site investigations into the Holocene deposits across Severnside was presented by the author to the Society in 2015. Since then, more detailed work has been carried out, including Cone Penetration Testing (CPT) on a 25 m grid over 16 hectare site, together with investigation of adjacent sites. This has allowed the full thickness of the Holocene sediments to be mapped out in 3D in great detail, and kilometre log cross-sections to be created.

The sediments contain 6 thin peat bands – referred to informally as P1 (youngest) to P6, which are widespread and act as markers. The 4 youngest peats have radiocarbon dates from archaeological investigations of between 5210–4840 Cal BP and 1020–840 Cal BC, but the dates of older 2 are unknown. P6, and to an extent P5, are basal peats resting on bedrock, and may be diachronous. There is sufficient data to quantify and correct for post-depositional compaction beneath of all the peats.

The sediments gradually infilled and covered a drainage network in the bedrock, with the highest point on a small island covered by the time of P3; the older P6 to P4 being truncated against the bedrock slope. As noted by previous workers, sand-bearing strata are restricted to the lower part of the sequence, the disappearance of sand coinciding with deposition of P3. Although mostly presenting a simple layer cake stratigraphy, the layered sediments are cut by infilled channels. In the lower part these are typically sand-filled, with locally developed heterolithic deposits of sand and clay, and are up to 200 m wide and 5 m thick. They are often capped by peat P3, showing the channels to have been infilled by 3970–3790 Cal BC. A younger clay-filled meandering channel between 25 m and 75 m wide and up to 5 m deep could be traced for over 500 m. This cuts down through and thus post-dates peats P2 and P3, but formed the southern edge of P1, suggesting that the channel was active during deposition of peat P1 (1020–840 Cal BC).

The study shows the power of CPT testing in reconstructing these environments. Such studies have recently been carried out in the Netherlands.

## AGE AND PETROGENESIS OF THE LUNDY GRANITE: PALEOCENE INTRAPLATE PERALUMINOUS MAGMATISM IN THE BRISTOL CHANNEL, UK

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The Lundy granite forms part of the Lundy Igneous Complex which is the southernmost substantive expression of the British Cenozoic Igneous Province (BCIP). Its Qz + Pl + Kfs + Bt ± Grt ± Tpz mineralogy and peraluminous character contrast with other BCIP granites farther north but are similar to the granites of the adjacent early Permian Cornubian Batholith. We present the results of mapping, petrographical and mineral chemical analysis, and the first U-Pb zircon ages for the granite ( $59.8 \pm 19.0$  –  $58.4 \pm 0.4$  Ma) and cross-cutting dykes ( $57.2 \pm 0.5$  Ma) which confirm a Paleocene age 20 for magmatism. Zircon inheritance is limited but two cores imply the presence of Lower Palaeozoic igneous rocks in the unexposed basement of S.W. England. The anomalous southerly location of the Lundy Igneous Complex is a consequence of mantle melting arising from the superposition of localised lithospheric extension, related to intra-plate strike-slip tectonics, with the distal ancestral Icelandic plume. Granite generation primarily reflects crustal partial melting during the emplacement of mantle-derived melts. The change in geochemical character between the Lundy granite (peraluminous) and other BCIP granites (metaluminous/subalkaline) indicates a fundamental crustal source control between contrasting peri-Gondwanan and Laurentian basement provinces.

## THE UNITED DOWNS DEEP GEOTHERMAL POWER PROJECT: AN OVERVIEW OF THE GEOLOGY

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The United Downs Deep Geothermal Power Project will be the first geothermal power project in the United Kingdom. The project is being developed by Geothermal Engineering Ltd (GEL) and is co-financed by the European Regional Development Fund, Cornwall Council and private investors. The project will drill two deep wells from a site within the United Downs Industrial Estate, a few miles to the east of Redruth in Cornwall, UK. The wells will form part of a demonstration system to produce between 1MW and 3MW of electricity.

This presentation will summarise the geological setting of the project. The wells will target a significant NNW–SSE striking fault zone identified as the Porthtowan Fault (PTF). The fault belongs to the family of cross-course structures that helped to accommodate oblique closure of the Variscan Orogeny but which, in some cases, may have originated during the Devonian extensional phase. Some may also have been active during the granite intrusion and again in the Cenozoic (as seen on the Sticklepath Fault in Devon). The PTF is a ~20 km long (minimum) zone of dextral strike-slip faulting with individual fault strand displacements of ~30 to 40 m recorded in the mine plans around United Downs. It is spatially correlated with hot water springs observed in mine workings in the area and also

with historically-recorded oil seeps, suggesting a long history of natural permeability and associated fluid flow.

The wells will be drilled from surface initially through the Devonian slates and are expected to penetrate the Carnmenellis Granite within the top kilometre. The injector will be drilled to ~2.5 km and the producer to 4.5 km where ambient temperatures are expected to be around 1900 C. The previous ‘Hot Dry Rocks’ Project at Rosemanowes near Penryn in the 1980s investigated geothermal potential at ~2.5 km, however the United Downs Project will venture deeper into Variscan geology and reveal a wealth of new information. Pre-drill uncertainties associated with the geological conditions at this depth will be reviewed.



### IS THERE A HIDDEN TERRANE BOUNDARY IN SOUTH-WEST BRITAIN? EVIDENCE FROM LAMPROPHYRE GEOCHEMISTRY

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More than 40 late-Variscan lamprophyres are found in SW Britain as potassic, volatile-rich dykes and minor intrusions, with ages of 285–295 Ma. Lamprophyres probably represent low-degree, hydrous melts from metasomatised mantle from the base of the lithosphere. As shown here, in areas where they are regionally extensive, they may be used the map terrane boundaries in the deep lithosphere.

In terms of Nd and Sr isotopes, the lamprophyres form two distinct groups with a regional distribution: lamprophyres from North Devon fall on the mantle array, with  $\epsilon_{\text{Nd}290} > 0$ . Lamprophyres from southern Devon and Cornwall are offset from the mantle array towards higher  $87\text{Sr}/86\text{Sr}$  and have  $\epsilon_{\text{Nd}290} < 0$ . The boundary between the two groups follows the southern margin of the Culm Basin. This boundary probably marks an hitherto un-recognized terrane boundary in S.W. Britain.

S.W. Britain is typically considered as part of Eastern Avalonia, or as a separate Gondwana-derived terrane. However, high- $87\text{Sr}/86\text{Sr}$  lamprophyres are common south of the Rheic Suture, where the isotopic signature is caused by old, recycled sediments in the mantle source. Isotopically, lamprophyres from south of the proposed terrane boundary are indistinguishable from similarly-aged lamprophyres in Armorica. It seems therefore that most of S.W. Britain’s lithosphere could be Armorican rather than Avalonian.

### RECONSTRUCTING PALAEOENVIRONMENTS IN ARCHAEOLOGY: THE FORAMINIFERA AND OSTRACODS OF THE BURTLE BEDS, DURING MIS 5e

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A multidisciplinary palaeoenvironmental analysis was undertaken on a new exposure of the Burtle Beds Formation, Somerset, England. This exposure (AD1) offered the opportunity to apply new analytical techniques, to investigate coastal conditions of the Bristol Channel during the last interglacial period of Marine Isotope Stage (MIS) 5e. This is an important interglacial period for archaeologists to understand, due to the atypical lack of human occupation in Britain. A new Amino Acid Racemisation date was taken from the bottom of this new sequence using the mollusc *Peringia*, which indicated an age of late MIS 7/MIS 5e. Palaeoenvironmental reconstructions were made using the ecological characteristics of fossil foraminifera and ostracods. Geochemical trace element analysis was employed; focussing on the Mg/Ca and Sr/Ca content of the ostracod *Cyprideis torosa*. This analysis was used to infer past salinities, which were found to range from 7–17.5‰ and temperatures, which were found to range from 13.8–26.6°C. These were reasonable values given that MIS 5e is known for its warmer climate than modern day Britain. This paper demonstrates how micropalaeontological analysis can be used to understand the nature and dynamics of coastal marine environments, in relation to how such environments could affect human presence in a landscape.

### TOURMALINE AS AN INDICATOR OF THE MAGMATIC-HYDROTHERMAL TRANSITION IN THE LAND’S END GRANITE

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Tourmaline is a common mineral throughout the granites of S.W. England. It occurs in multiple textural and structural varieties, including veins, quartz-tourmaline orbicules, massive quartz-tourmaline rocks (MQT), pegmatitic pockets, and disseminated in the granite. Field relations indicate both magmatic tourmaline and post-magmatic, hydrothermal tourmaline, occurring as disseminated grains and veins, respectively. In addition, more genetically complex textures and structures are observed as gradual exsolutions of quartz-tourmaline rocks within the granite, with or without associated veining. These appear on the cm scale and up to several meter large bodies. Such structures are observed in localities several km apart, and are a regional feature. Occasionally, the gradual transition from granite to MQT to miarolitic tourmaline or a pure tourmaline zone, can be observed over tens of cm. The microtextures are strongly linked to the macroscopic textures,

reflecting the diverse processes that formed the different tourmaline occurrences. Cassiterite can be correlated with specific tourmaline generations, whereas tin concentrations in other tourmaline-rich rocks are less than 100 ppm, and these rocks are not a part of the mineralizing events of the Land's End granite.

### THE CHANGING LANDSCAPE OF THE LIZARD PENINSULA: ANALYSING AN 800 YEAR OLD POLLEN ARCHIVE FROM THE EDGE OF GOONHILLY DOWNS

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A palynological investigation of a 125 cm core from a sediment-filled mill pond close to Erisey Barton farm on the S.W. edge of Goonhilly Downs is presented here. Radiocarbon dating suggests that the core consists of sediments deposited over the past approximately 800 years, so the pollen diagram provides detail of the vegetational changes on the Lizard plateau since at least the thirteenth century. Four distinct pollen assemblage zones have been identified that may be explained by socioeconomic changes in Cornwall resulting in changes of land use. During the early part of the period represented there are sustained changes in the spores and herbaceous pollen consistent with changes in the grazing and arable regimes in the vicinity of the mill pond. These are associated with a period of rapid population growth. These changes are followed by a period of approximately 600 years of relative stability of the palynological record but with the filling of the pond with water and then sediment clearly demonstrated by the rise and fall of the pollen of aquatic species. With the expansion of coniferous plantations in the nineteenth century there are indications of a reduction of arable agriculture followed by evidence of management by burning.

### FURTHER THOUGHTS ON THE SANDSTONE 'DYKES' AND HEAD DEPOSITS OF BERRY HEAD

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Berry Head forms the southern boundary of Tor Bay and is an important National Nature Reserve and Site of Special Scientific Interest. Almost all the northern face of the headland has been quarried and exposes a number of important features including the so-called 'Neptunian Dykes' (Richter, 1966). These follow both N-S and ESE-WSW trends and can be seen both in the quarried faces of the headland, but also on the foreshore at Shoalstone Beach and between Broadsands and Elberry Cove. Some of these fractures are mineralized while others include sandstones (presumed Permian) and fragmented calcite vein material. Also in the old quarry and along the coastline behind Shoalstone Beach are a series of Head deposits, overlying the irregular surface of the underlying limestones. These contain layers of fine, brecciated limestone, unlithified sands and occasional layers with large angular blocks. Also incorporated within the Head deposits are large blocks of 'dyke' material, some of which contain the mineralized margins of the 'dykes'.

### References

Richter, D. 1966. On the New Red Sandstone Neptunian dykes of the Tor Bay area (Devonshire). *Proceedings of the Geologists' Association, London*, **77**, 173–186.

### HOLOCENE SEA-LEVEL RISE AROUND JERSEY

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A series of cores, collected between the east coast of Jersey and the French coast, record the sea-level rise during the Holocene. Core OVC-18 contains a sequence of marine silts and clays that rest on a thin peat that has been radio-carbon dated as 8860±30 years B.P. These saltmarsh, estuarine and marine silts and clays contain abundant and diverse assemblages of foraminifera that record the transition from a terrestrial to an open marine environment. Using mono-specific assemblages of foraminifera the  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  stable isotope record of this transition has been determined. In samples from around 2000 years B.P. is an occurrence of maerl (rhodophytes or red calcareous seaweeds) which is also recorded in many estuaries along the Brittany coast and around Brest. The uppermost samples contain the slipper limpet, *Crepidula fornicata*, which invaded the area in 1962 and which confirms the age of these marine clays. Below the bed of peat there are grey-coloured silts that contain mid-Eocene foraminifera but as these a generally quite abraded, may have been transported into younger sediments. This foraminiferal assemblage includes taxa (such as *Alveolina*) that are normally associated with the Middle Eocene Climatic Optimum (MECO).

### LOWER JURASSIC PALAEOCLIMATE: BREATHING NEW LIFE INTO THE BURTON ROW BOREHOLE

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Understanding the driving forces and consequences of changing climate in the geological past is of paramount importance to understanding the long-term effects of modern anthropogenic change. Palaeoclimate research in the Jurassic has focussed on geologically short and isolated 'tipping point' events such as the Toarcian Oceanic Anoxic Event (TOAE). However, the causes of long-term climate instability remain unknown; particularly in the understudied and climatically disturbed Pliensbachian–Sinemurian stages. In order to address this, an expanded and biostratigraphically well constrained sedimentary record through this interval is needed to construct a detailed age model and high geochemical proxies. The Burton Row borehole, drilled in the 1970's on Brent Knoll in Somerset, is one such expanded and biostratigraphically well constrained sedimentary record containing the lower Jurassic Charmouth Mudstone Formation and Blue Lias stratigraphy; including strata not exposed on the Somerset coast. The initial breaking of the core to establish this detailed biostratigraphical framework led to many considering the borehole lost to modern

science. However, applying modern geochemical techniques to the remaining sedimentary material offers great promise in investigating the lower Jurassic long-term climate variability. Presented here is preliminary sedimentological and geochemical investigation of the Pliensbachian to Sinemurian aged strata of the Burton Row borehole and a plan of future work that aims to further reinvigorate Burton Row and other stratigraphical boreholes in the BGS borehole repository.

**AN OPERATIONS UPDATE OF SOUTH CROFTY MINE AND A VIRTUAL FLY THROUGH OF THE UNDERGROUND WORKINGS OF THE CAMBORNE-REDRUTH MINING DISTRICT**

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The talk will comprise two halves; the first of which will outline continuing operational developments at South Crofty Mine, with respect to continued work being undertaken to reopen the mine. The second half of the talk will concentrate on the construction of the three dimensional computer model of the mines of Cornwall and West Devon. An outline will be given of the procedure that has been used from obtaining the plans and sections of mine workings to the final animated models. The talk will conclude with a showing of an animation entitled the ‘Mines of the Camborne /Redruth Mining District’.

**THALLIUM: AN INDICATOR OF LARGE SCALE FLUID MOVEMENT IN THE MENDIPS?**

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The release of the Gbase stream sediment data for the whole of SW England has confirmed a large thallium anomaly in Somerset and Avon, unique in England, although previously known in the same area from the Soil Atlas of England and Wales (Rawlins *et al.*, 2012). A viable mechanism for its formation is the leaching of large volumes of feldspar-rich rock along faults and concentration in sulphides. The spatial distribution suggests this was a broad process that gave rise to Sr mineralisation in N. Somerset as well as Pb-Zn mineralisation in the Mendips. The timing is open to question but was post mid-Jurassic. A similar high amplitude Tl anomaly has been reported from Polish Pb-Zn deposits hosted in Jurassic lithologies.

This anomaly will be compared with lower amplitude Tl anomalies in Cornwall associated with some Pb-Zn deposits and granites, previously partially reported by Law and Turner (2011). As thallium is highly toxic these anomalies could have environmental impact.

**Acknowledgment**

Gbase data are used under licence from the British Geological Survey.

**References**

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- Rawlins, B.G., McGrath, S.P., Scheib, A.J., Breward, N., Cave, M., Lister, T.R., Ingham, M., Gowing, C. and Carter, S. 2012. *The Advanced Soil Geochemical Atlas of England and Wales*. Keyworth, Nottingham: British Geological Survey. [<http://www.bgs.ac.uk/gbase/advSoilAtlasEW.html>]

**A NEW RECORD OF A BASAL JURASSIC BELEMNOID SQUID FROM SOMERSET, SOUTH-WEST ENGLAND**

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The recent find of a remarkably complete specimen of a belemnoid squid from near the base of the Jurassic System on the West Somerset coast, provides new anatomical evidence of taxonomic affinities, which are absent in the only other specimen recorded from a similar horizon in the area. The new specimen, from the Planorbis Subchronozone of the Planorbis Chronozone, includes arm hooklets, ink sac and a partial phragmocone. The former are of particular significance, as they indicate that the two known specimens have affinities with the genus *Clarkeiteuthis* Fuchs *et al.* (2013), previously known from the Late Triassic to the Early Pliensbachian. The significance of new specimen for studies of the origins and diversification of teuthid cephalopods will be discussed.

Fuchs, D., Donovan, D.T. and Keupp, H. 2013. Taxonomic revision of “*Onychoteuthis*” *conocauda* Quenstedt, 1849 (Cephalopoda: Coleoidea). *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, 270/3, 245–255.

**THE JET PROJECT AND THE MOCHRAS BOREHOLE: BUILDING A NEW GENERATION TIMESCALE FOR AN EARLY JURASSIC WORLD**

Page, K.N.<sup>1</sup>, Hesselbo, S.P.<sup>2</sup>, Ullmann, C.V.<sup>2</sup>, Szucs, D.<sup>2</sup>, Hudson, A.<sup>2</sup>

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The Llanbedr, or Mochras Farm borehole (drilled 1966-1967), is one of the UK’s most iconic boreholes as it unexpectedly revealed a uniquely thick sequence of around 1.3 km of Lower Jurassic rocks on the coast of North Wales. Although, a multidisciplinary report was published, several of the studies were essentially preliminary. In addition, as most of the core was broken-up, to recover macrofossils, archived materials are incomplete and, hence, modern techniques such as cyclostratigraphic time-calibration cannot be carried out. Realisation of the potential for such studies in one of the thickest known, biostratigraphically well-controlled Lower Jurassic sequences led to a proposal in 2009 to drill a second Mochras borehole. By 2016, this had led to the establishment of the JET – Jurassic Earth Systems and Timescales – international project within the context of the ICDP (International Continental Scientific Drilling Programme). Having secured funding from ICDP and NERC, drilling is now due to start in late 2018. As well as providing a timescale for the entire Lower Jurassic, outputs will be relevant to the origins of the modern Earth system including the causes and effects of large igneous provinces, marine anoxia, changes in oceanic carbonate chemistry, and origins of the modern biota, including marine plankton. The classic coastal exposures of Lower Jurassic rocks of south-west England will continue to inform this process, as well as providing a potential testing ground for some of the results.

### APPLICATION OF REMOTE SENSING DATA FOR EVALUATION OF ROCKFALL POTENTIAL FROM A QUARRY SLOPE

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In recent years data acquisition from remote sensing methods has become more readily available to the UK quarry sector. This study demonstrates how such remotely captured data may be used to evaluate and back analyse rockfall potential in a blocky rockmass. Comparison of data obtained from several aerial LiDAR and photogrammetric campaigns taken over a number of years (2011 to date) provides evidence for rockfall evolution from a slope within an active quarry operation. Further investigation through analysis of point cloud data obtained from terrestrial laser scanning was used to characterise the orientation of discontinuities present within the rock slope. Both aerial and terrestrial LiDAR data was subsequently used for kinematic analysis, development of surface topography models and rockfall trajectory analyses using both 2D and 3D numerical simulations. The analysis undertaken demonstrates the effectiveness of the existing rockfall barrier and edge protection and shows how remotely captured data can be used to inform back analyses of the underlying failure mechanism. The investigation also provided additional insight into the advantages and limitations of the different methods of data acquisition for slope stability analyses.

### A DISCOVERY OF COBALT MINERALS AT PORTHTOWAN: HOW DOES IT FIT INTO THE CORNISH COBALT MINING STORY?

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Although cobalt mineralisation has been noted in Cornwall and Devon in the mining literature, there are limited details of its production and paragenesis; detailed mineral studies of cobalt are almost non-existent. This study examines previously unrecorded cobalt mineralisation at Porthtowan, Cornwall, near old workings that are part of the Wheal Lushington group of mines. A small number of massive sulphide/gangue samples (taken from a larger sample suite) were analysed using QEMSCAN®, which found that samples contained up to 50% cobaltite, along with chalcopyrite, bornite, galena, sphalerite, acanthite, erythrite, matildite, chlorargyrite and other primary and secondary mineral species. This assemblage is typical of a sub-type of crosscourse mineralisation, with secondary species a result of weathering and supergene alteration, complicated by seawater infiltration due to the coastal location. While the number of samples is limited, the detail of the mineralogical assemblage is significant, as it is the first time such an assemblage has been subjected to this level of scientific scrutiny in Cornwall.

### CORNISH LITHIUM: EXPLORATION FOR A NEW METAL IN AN OLD MINING REGION

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Brines containing elevated lithium values from hot springs in Cornwall were first reported by Miller in 1864, and were subsequently recognised in many tin and copper mines which were worked until the end of the 20th century. With increased interest in renewable energy sources and rising demand for batteries for electric vehicles, the lithium contained within these deep Cornish brines is now of significant interest. The growth in the electric vehicles (EV) market and the demand for Li-ion batteries that followed has completely changed the prospects for lithium mining worldwide and, potentially, in Cornwall. In 2016, the number of EVs on the road rose to over two million worldwide, marking a significant jump over the last decade from less than 200,000 on the road in 2006. These numbers are expected to grow significantly over the coming two decades ahead of outright bans on the sale of internal combustion engine (ICE) vehicles by many governments, including that of the UK.

Recent advances in lithium extraction technologies, without the use of solar evaporation, now offer the potential to extract lithium from brine at much lower levels of concentration. Not only do these technologies have a much smaller environmental footprint than traditional evaporation ponds, but they will also make the process much more efficient. By identifying lithium bearing brines at depth, Cornish Lithium aims to drill extraction boreholes into large 'cross-course' fault structures which are believed to act as conduits for permeable fluid flow.

Cornish Lithium has successfully secured rights to extract lithium from brine over an area of approximately 300km<sup>2</sup> in Cornwall. The company believes that the presence of lithium bearing brines in the County may now represent a commercial opportunity and recently raised £1m to further its exploration efforts.

### TRILOBITE FAUNAS, FACIES AND EXTINCTIONS IN THE TYPE AREA OF THE DEVONIAN SYSTEM, SOUTH-WEST ENGLAND

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Investigations into trilobite faunas from the Middle Devonian to lowest Lower Carboniferous in south-west England has revealed a clear relationship between faunas and the facies within which they occur. This relationship is controlled by geographical and temporal factors which may be related to the development of a succession of deposition margins across the region during the Devonian. Overall, however, the facies indicate a general deepening, which is turn reflected in a drop in the diversity of the faunas and morphological changes, such as the loss of eye facets in certain groups. The former changes, characterise the Devonian extinction phase, with records in south-west England, showing that the Calymenina (as *Homolonotus*) disappeared in the region by the end of the Lower Devonian, Odontopleurida, Lichidae and Cheirurina in the Late Givetian, the Ilaenina (as Thysanopeltidae) in the Lower Frasnian, the Harpina in the Middle Frasnian and the Phacopina at the end of the Famennian. As globally, only the Proetida survived into the Carboniferous.

## TIMING & ORIGIN OF THE CROWNHILL INTRUSION IN THE CORNUBIAN ORE PROVINCE

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The understanding of dynamic granite magmatism and magmatic-hydrothermal ore-forming processes in the Cornubian Ore Province is limited by an incomplete magmatic record and its relationship with hydrothermal processes and mineralization. The opening of Drakelands Mine (2015) has renewed interest in unravelling felsic magmatism and associated Sn-W-sulphide mineralization. Directly adjacent to the Sn-W muscovite granite at Hemerdon lies the Crownhill Intrusion, comprising biotite and tourmaline-muscovite granite. This study provides the first whole-rock geochemistry and U-Pb geochronological dataset of Crownhill. All granites are peraluminous (A/CNK > 1) and reveal alteration trends between biotite and tourmaline-muscovite granites due to decreasing Ti and HFSEs and increasing Al and LOI. A decoupling is observed between wolframite and cassiterite, where cassiterite occurs in association with interstitial metasomatic tourmaline, whereas wolframite occurs as isolated crystals within the groundmass, perhaps exclusively from the earliest phase of granite magmatism. Polyphase zircons from Crownhill granites yield  $288.9 \pm 1.7$  Ma for resorbed cores (e.g. Hemerdon, Bodmin and Carnmenellis), whereas oscillatory-zoned rims produce  $275.9 \pm 2.3$  Ma (Dartmoor, St Austell and Land's End). As the granites undergo the magmatic-hydrothermal transition, exsolved borosilicate fluids promote the remobilisation of ore minerals causing them to appear spatially, and temporally associated.

## REGIONAL LINEAMENT DETECTION FROM TELLUS SOUTH WEST AIRBORNE GEOPHYSICAL DATA: ADVANTAGES OF A NEW BASE-LINE DATASET

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The geology of southwest England has a complex history. In the last circa. 400 Ma, the region has been subject to a series of extensional, collisional and strike-slip tectonic regimes. The resultant fault system has two main fault trends, approximately E-W and NW-SE with subordinate fault sets trending N-S and NE-SW. The complicated network of faults is further convoluted by numerous phases of reactivation. Regionally, present geological mapping of these faults is either inconsistent or incomplete often due to poor outcrop exposure inland.

Airborne geophysics from the Tellus South West survey provides near-complete data coverage over the region. The airborne magnetic, radiometric and LiDAR data all measure subtle differences in rock properties that can be used as proxies for mapping fault zones.

Novel methods in lineament detection have been developed using Object-Based Image Analysis (OBIA) techniques. The OBIA method creates “image objects”, or regions of pixels in a dataset, to be mapped as one entity rather than attempting to map on a pixel-by-pixel basis. By analysing the three airborne datasets and merging the resulting image objects an integrated map of lineaments has been produced. These lineaments infer the existence of faults that may not be obvious from conventional mapping techniques.

Understanding the present day fault system and the inherent structural geology is paramount for new growth in the resources industry for Cornwall and Devon. The world-class tin-copper and tin-tungsten mineralisation is directly controlled by reactivated faults during the Permian. Fault-hosted geothermal aquifers are currently being investigated for geothermal energy potential which fundamentally requires a knowledge of regional fault systems. The prospect of extracting lithium from geothermal brines adds further value to these targets. Therefore, an objective and consistent lineament map of the region is an invaluable exploration tool for identifying prospective fault systems.

