ABSTRACTS OF OTHER PAPERS/POSTERS PRESENTED AT THE ANNUAL CONFERENCE, JANUARY 2017

THE SCOTT SIMPSON LECTURE

THE MID-CARBONIFEROUS TERRESTRIAL DIVERSIFICATION EVENT

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This talk will explore a new episode in the History of Life that I have coined the “mid-Carboniferous terrestrial diversification event”. The event commenced in the late Serpukhovian (327 Ma) times and peaked in mid-Baskhirian (318 Ma) times, utterly transforming terrestrial communities in a very short interval. It coincided with the onset and initial zenith of Gondwanan Glaciation, which, undoubtedly, exerted a significant driving force on the terrestrial evolution in two ways. First, repeated cycles of marine transgressions, linked to glacio-eustatic fluctuations, facilitated wave after wave of marine animals to invade coastal swamps, only for them to be become stranded in freshwater environments inland as seas regressed. This process of marine-terrestrial species transfer led to a massive step-wise increase in the richness of terrestrial ecosystems, establishing essentially modern trophic systema. Second, tropical cooling led to widespread aridification and the establishment of continental drylands, which, in turn, encouraged the rise of drought-adapted conifers and reptiles, communities that would come to dominate Pangaea for the next 200 million years. In the talk, we discover the spectacular evidence for this previously overlooked event in the History of Life, in the course of a virtual fieldtrip through the Carboniferous basins of beautiful Atlantic Canada.

STANNON AND PARK – TWO CHINA CLAY PITS ON BODMIN MOOR

Colin Bristow

China Clay History Society, Cornwall Geoconservation Group

Stannon china clay pit lies in the north-western part of the Bodmin Moor biotite granite and Park lies close to the southern margin. Until a few years ago the combined production capacity was around 200,000 tpa of filler and ceramic clays. Following the cessation of china clay production the pits have filled with water and become important reservoirs belonging to South West Water. Both pits lie on important fractures in the granite, associated either with the NW–SE strike-slip fault regime which affects SW England, or with diapiric uplift of the granite, or both. The intersection of fractures and lineaments, particularly where there has been transfer of throw from one fault to another, is a favoured locality for deep kaolinization, because of pervasive macro- and micro-fracturing at these locations enhancing the overall permeability and allowing access for altering hydrous fluids. Identification of fractures and significant lineaments within the granite can be accomplished by studying maps, stereoscopic aerial photographs and aerial and ground geophysics. Shallow kaolinization and growan formation is pervasive under the marshy waterlogged areas of the moor, known as ‘slads’, probably caused purely by weathering.

Stannon china clay pit is aligned along a prominent ENE-WSW fracture, down-throwing northwards, marked by a massive quartz vein; probably caused by diapiric uplift of the central area of the granite. An extensive deep area of white kaolinized granite adjacent to this vein is surrounded by a zone of iron oxide stained granite; the iron having probably originated from deferruginization of biotite in the central area. Stannon is notable because there is very little tourmaline present, unlike most other china clay pits in SW England, and in this respect resembles kaolin deposits in Brittany and elsewhere. However, in the deepest part of the pit, nodules of pyrite have been found, superficially similar to those in the chalk. At shallower levels these are oxidized and resemble the iron concretions found in most china clay pits.

Park china clay pit lies on the intersection of a NW–SE dextral strike-slip fault with an E–W lineament. The strike slip fault could be seen in the pit to have a throw not exceeding a few tens of metres, judging by the displacement of a narrow east-west elvan. In the nearby valley at Temple a similar small displacement of an E–W elvan by a NW–SE fault can be demonstrated. This is further evidence that the major displacements on strike-slip faults affecting Palaeozoic rocks south of the granite, were largely pre-granite.

Late Devensian (MIS 3–2) SW England: The Big Picture

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Recent work on the British-Fennoscandian Ice Sheet (BFIS) has greatly refined the palaeogeography of its margins in its south western sector. Similar work has also been published for the north-west sector (Norway and Barents Sea) and the north eastern sector (Finland and Russia). These and wider studies have suggested significant localised diachrony in the behaviour of the ice sheet during the Late Glacial Maximum (LGM) in its western, northern and eastern margins. The south west of England is a particularly interesting limit being the most southerly extent of the ice and highly influenced by the North Atlantic. Previous, and some recent studies, have highlighted seemingly anomalous environmental conditions at the glacial margins. New sites in SW England will be evaluated in this context with a view to tackling some fascinating questions relating to local climatic conditions near, and at the ice margins, and the responses of terrestrial organisms including humans to these conditions. To what extent was the ice sheet margin an attractor rather than an unproductive polar desert? Both advances in geochronology and palaeoenvironmental techniques are particularly pertinent to furthering our understanding of the BFIS around the LGM in South-West England.

The Geology of the Somerset Coastline around Watchet

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A complete section of continental Triassic deposits passing upwards through Rhaetian beds to fully marine Liassic rocks is exposed along the coastline of Somerset between Blue Anchor Bay in the west, through Watchet and eastwards to Kilve. The succession has been subjected to folding and faulting, related in large part to the creation of the Bristol Channel.

The sedimentology of the Triassic Mercia Mudstone, Blue Anchor and Langport beds and the Lower Jurassic strata exposed in this coastal section may be summarised as follows: the Triassic deposits comprise continental red beds rich in alabaster whilst the Lower Jurassic sediments are characterized by alternating metre-thick shale beds interbedded with limestones. A range of sedimentary environments was responsible for these sediments from arid continental to evaporitic coastal and littoral deposits to ammonite-rich open marine deposits.

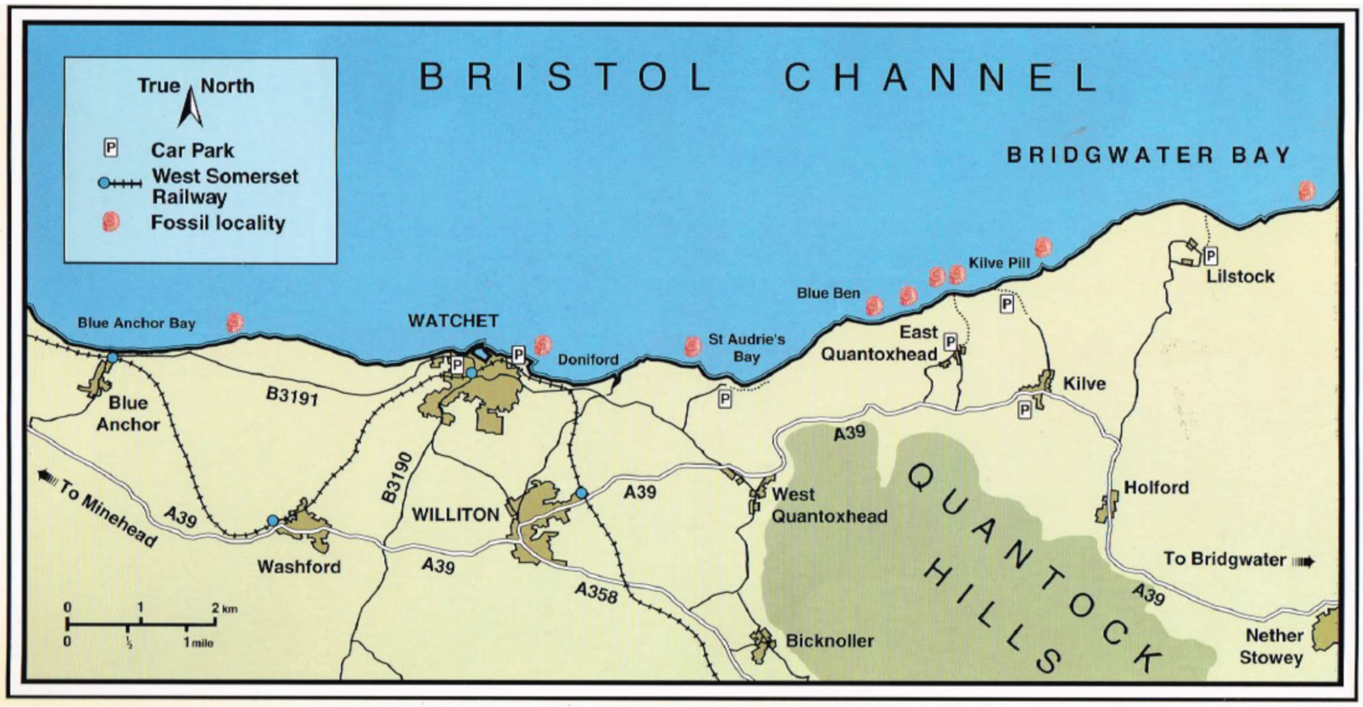

Figure 1. *Location Map; thanks to Andrew King, Somerset County Museums Service (1997)*

The area is located along the margins of the Mesozoic to Tertiary, E–W and NW–SE trending East Bristol Channel and Central Somerset basins (Whittaker, 1973: Lloyd *et al.*, 1973: Kamerling, 1979). The basins sit on Carboniferous and Devonian basement deformed by N-S oriented compression during the Variscan Orogeny. The surface trace of the WNW-ESE to E-W trending Variscan Front Thrust lies to the north, running across southern Wales and through the southern coast of the Bristol Channel north of the Mendip Hills (Chadwick, 1986). This important structure and other related thrusts give the basement a distinct E–W trending structural grain. They produce prominent southward dipping reflections on seismic sections and may be responsible for northward decreasing gravity anomalies (Brooks *et al.*, 1977; Chadwick *et al.*, 1983; Chadwick, 1986; Donato, 1988; Brooks *et al.*, 1988).

The East Bristol Channel and Central Somerset Basins link the Main Bristol Channel Basin (Kamerling 1979), located to the west, with the western portion of the Wessex Basin (Chadwick, 1986), located to the east. The lateral boundaries between these basins are often marked by NW–SE trending faults such as the Sticklepath Fault, which cuts across Devon. It is possible that the Watchet-Cothelstone-Hatch Fault (Whittaker, 1972) of North Somerset separates the East Bristol Channel and Central Somerset basins. The Main Bristol Channel and Wessex basins preserve strata from Permian through to Tertiary in age while, due to uplift and inversion, Upper Jurassic (Portland Sandstone; Lloyd *et al.*, 1973) and Middle Jurassic are the youngest preserved strata in the East Bristol Channel and Central Somerset basins respectively.

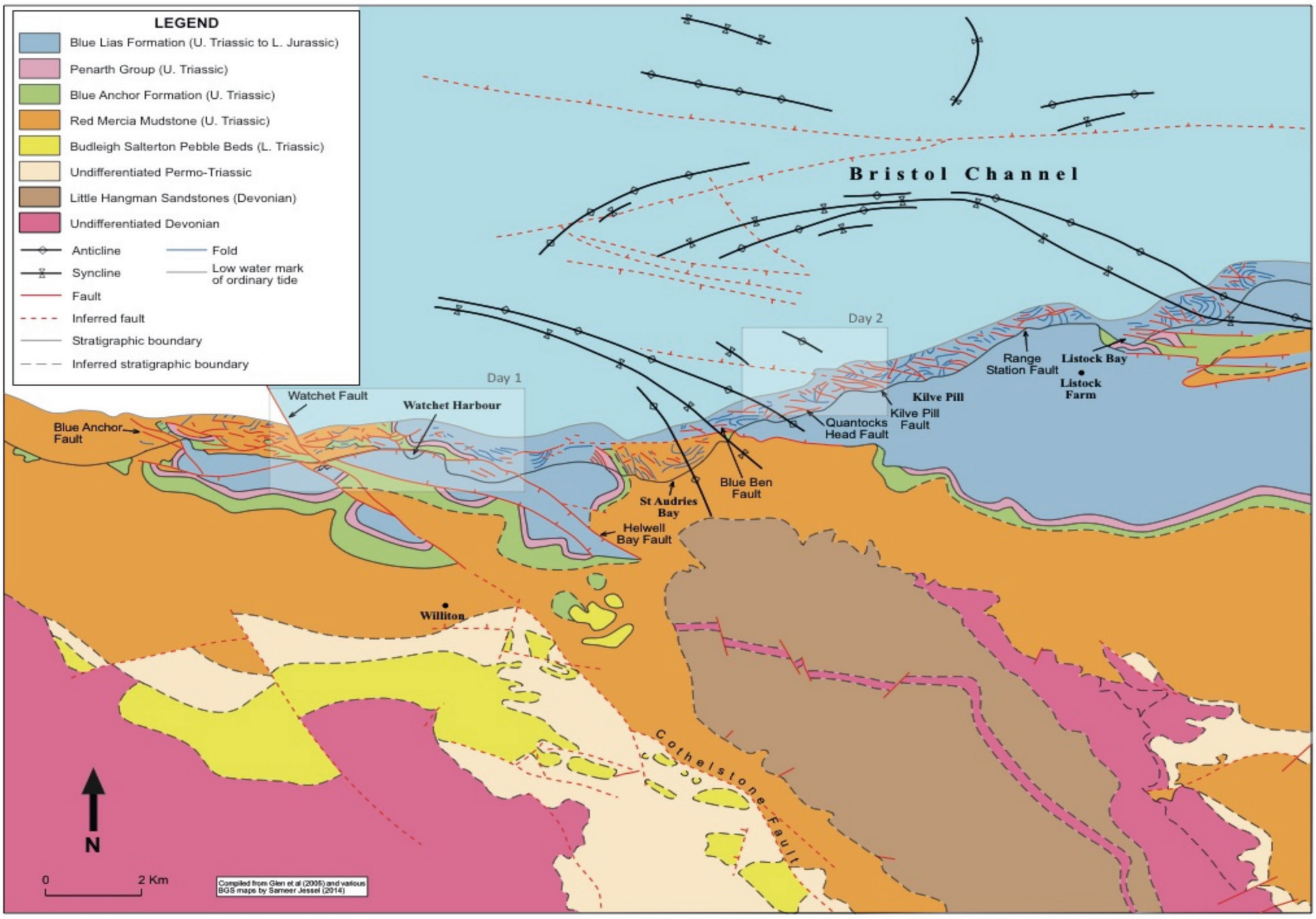

Figure 2. *Geological map of the coastal area around Watchet (compiled from Glen* et al.*, 2005 and published BGS maps). Correlation of mapped onshore and offshore structural alignments is tentative and requires more research.*

Normal, strike-slip and thrust faults are all exposed along this section and, together with stratigraphic evidence, these can be used to establish the changing stress conditions through time. The structures displayed bear witness to three phases of deformation: namely: Permian - Lower Cretaceous extension; Lower Cretaceous – Cenozoic inversion; Cenozoic strike-slip deformation. The situation is complicated by evidence for some earlier strike-slip deformation and compelling evidence for structures related to expulsion of salt.

Despite extensive research along this coastline, it is notable that onshore structure, derived from outcrops and satellite imagery, has not been integrated with the structure of the offshore as known from seismic surveys, at least not in published literature. Given current commercial interest in the Liassic shales along this coastline, this would seem to be a serious omission, particularly as one might think it relevant to have a good grasp of the structure of this region if fracking wells are to be drilled just a short distance along strike from the planned Hinkley C nuclear power station.

The geology and history of geological mapping of Milverton and Wiveliscombe, West Somerset

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The deep red soils of the area of Milverton and Wiveliscombe are derived from bedrock composed of Triassic continental red beds, mainly sandstones and shales of the Mercia Mudstone Group. Deposition in desert conditions is responsible for this coloration, the oxidised iron minerals of the desert deposits giving it its distinctive hue. Pebble beds within these strata contain clasts transported in a vast river system and derived from the Exmoor region and from far to the south in the Armorican Massif, in what is now France.

William Smith was one of the first geologists to illustrate the geology of West Somerset on a geological map. His mapping was refined by De la Beche in 1842, by Ussher of the Geological Survey in 1877 and by Woodward in the mid-1880s. Later Geological Survey maps illustrate changing conventions in stratigraphic nomenclature and cartography.

The red soils are fertile and suitable both for arable and for grazing. It was De la Beche, who noted that "The red marls, with their higher variegated parts adjoining the Lias, would appear very favourable for the growth of apples; and cider obtained from their range is commonly found to be very excellent…..".

Some geological controls on the North Devon coastline

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The North Devon coastline from Exmoor to the Cornish border trends NE-SW, but in a series of embayments running E–W (Bridgwater Bay – Exmoor – Morte Point), N–S (Morte Point - Appledore), E–W (Appledore - Hartland) and then N–S from Hartland Point (Fig. 1). The detailed interaction of coastal erosion with the geology operates at 3 scales: major faults, local lithologies and detailed structuring.

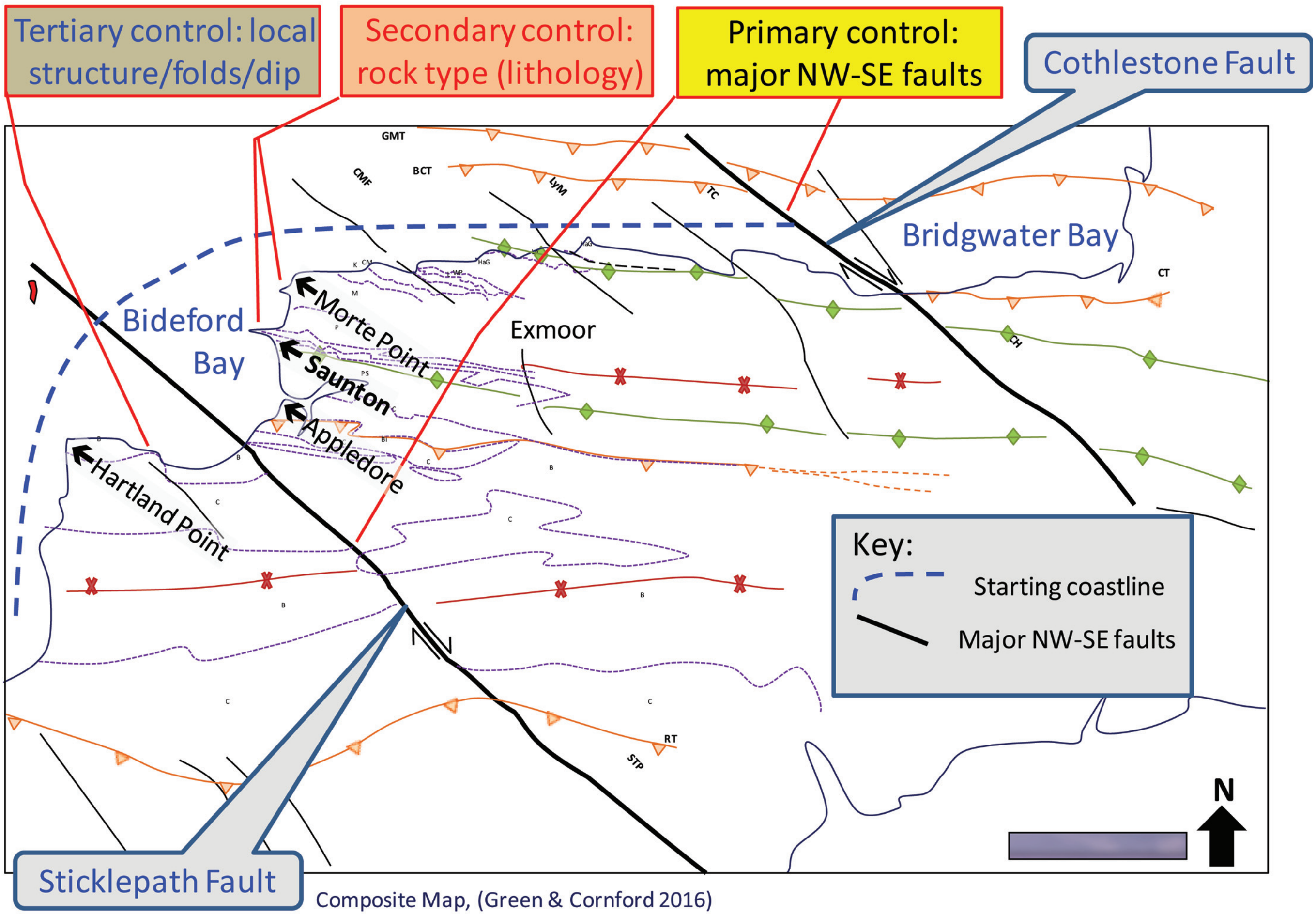

Figure 1. Three scales of geological control on coastline and coastal landscape.

The control on the primary indents in the coast appear to be the dominant NW–SE faults (Sticklepath and Cothlestone dominantly strike-slip faults), which weaken the rocks, and provide an opportunity for the Atlantic swells to erode out the main embayments (Bideford and Bridgwater bays).

The next geological control is rock type (lithology). The major headlands are the stronger sandstones (e.g., Baggy Sandstones) and the embayments are dominated by the mudstone intervals (e.g., Bideford Formation in Bideford Bay).

More subtle controls on erosion are seen when walking the coastal path and captured by the recent publicly available Lidar surfaces (Fig. 2). This shows that despite coastal orientation, the river channels run at right angles to the current (and arguably transient) coastline. It is noted that the regionally significant Sticklepath Fault has only a minor expression at the coast.

A third level of coastal erosion, more commonly studied in the east of the county, is shown as a series of rotated terraces, well identified by the Lidar data (Fig. 3). This surface identifies three levels of fault-related rotational slips: the top of the current cliffs

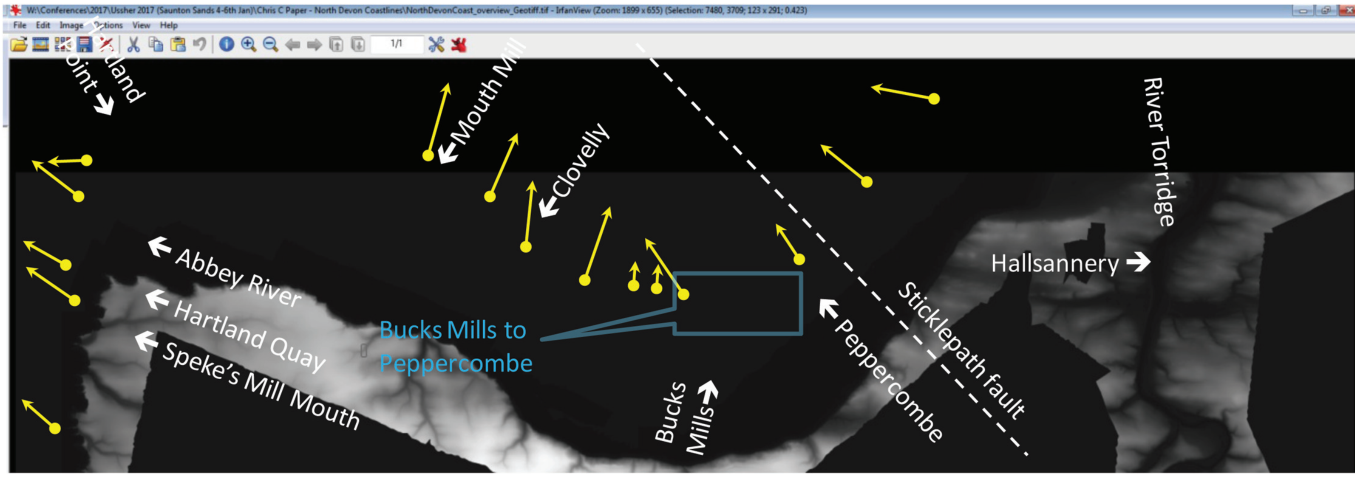

Figure 2. *Lidar panels for the North Devon coast from the Cornish border to Appledore.*

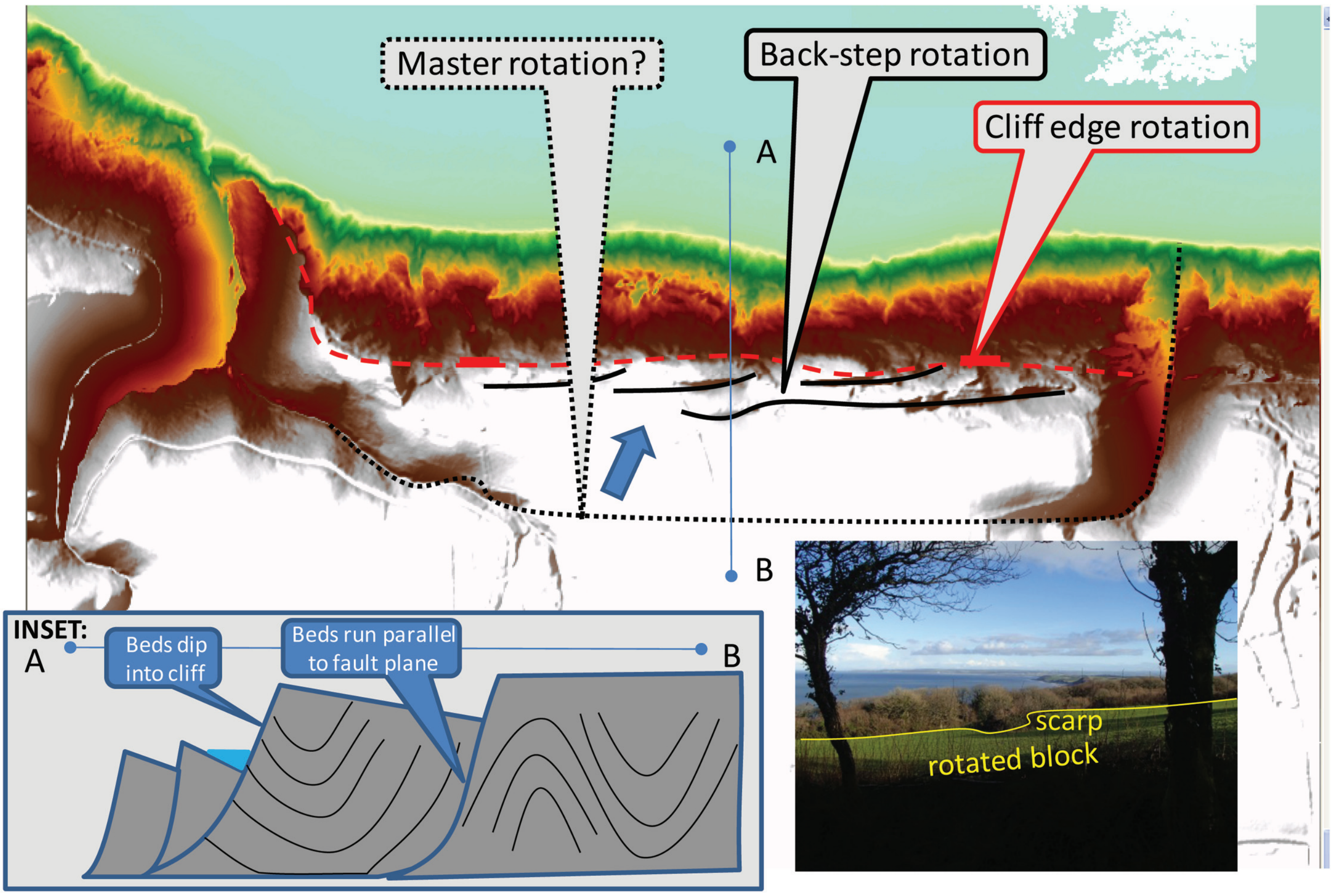

Figure 3. *Colour-enhanced Lidar image of the coast from Bucks Mills to Peppercombe showing a series of rotated terraces back from the present day cliff and a ground truthing view from the blue arrow.*

form a scarp and non-vertical trees growing from the back scarp points to recent movement. Additional rotated terraces lie inland of the current cliff edge, but tree growth shows no rotation: over the last few years permanent water has ponded in these back-stepping rotations, pointing to an impermeable seal to the controlling fault. Surprisingly, in the fields farthest from the cliff the Lidar suggests a back master rotation scarp which ground truthing shows as controlling a shallow stream bed.

In terms of planes of weakness, the E–W striking folds on the north-facing coast will expose north dipping (dipping with the cliff) and south dipping beds (dipping into the cliff) to the wave action as the coast is progressively eroded (see cartoon in Fig. 3, inset). The timing of these preserved rotated slippages remains uncertain, but it seems possible that the movement is quite old, and associated with hydraulic head (or ice loading?) during the last (Devensian) glacial period.

The erosion on the N-S coast south of Hartland Point attacks the folded beds edge on. Here the embayments are on the 100s of metre scale (e.g. the much visited Warren Beach at Hartland Quay: Childs and Cornford, 1989), and appear controlled by local faulting. The focus of erosion varies from late stage Variscan faulting such as the Hartland Quay fault, or thrust faults breaking through the crest of anticlines where compressional stress can no longer be accommodated by folding.

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Reconstructing palaeoenvironments in archaeology: The foraminifera and ostracods of the Burtle Beds, Somerset, during MIS 5e

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In Somerset, England, there is a formation of Pleistocene raised beach deposits, named the 'Burtle Beds'. In the village of Greylake a new exposure of the Burtle Beds has been opened (Fig. 1) and it was decided that a new campaign of sampling should be undertaken. The deposits were horizontally bedded and almost totally undisturbed.

The Burtle Beds are an important Quaternary Formation in the UK and there has been much debate about their age range. The formation comprises 8 m of silts and clays, overlain by sand and gravel units interspersed with shell beds. The bottom half of the sequence is particularly under-studied and it is thought to date to Marine Isotope Stage (MIS) 7 (~243,000 BP). However, the upper 4 m (Middlezoy Member) are the focus of this paper. The Middlezoy Member is known to date to the last interglacial period (MIS 5e 129,000-116,000 BP), the top 3 m of which have been given an Amino Acid Racemization (AAR) date by Kirsty Penkman in 2015. A new AAR date will be taken from the bottom of the Middlezoy Member as part of this project.

The main focus of this research project is a micropalaeontological investigation of the foraminifera and ostracods from the exposed sequence. This will be used to reconstruct the past environment of the coast of South West England, near Glastonbury. Foraminifera are single-celled protists that live in marine and estuarine environments. Ostracods are a class of Crustacea that live in fresh, brackish

Figure 1. *Exposure of the Burtle Beds at Greylake, Somerset. The tape measures 3.65 m.*

and fully marine environments. These tiny organisms are sensitive to environmental change and each species is habitat specific. The tests of foraminifera and the shells of ostracods are composed of calcium carbonate, and can survive within sediments for millennia, given the right preservation conditions.

The deposits were sampled from the 3.65 m exposed section from a farmer's pit, which he had been digging to quarry sand (Fig. 1). One litre grab samples were taken every ~20 cm from the entirety of the exposed thickness. These samples were then processed to extract the foraminifera and ostracods from within the sediments. This involved breaking down the sediment and wet sieving to remove the clay fraction. This was followed by dry sieving, to separate the sample into fractions ready for picking. The samples were then studied under a microscope and the foraminifera and ostracods extracted, by picking 300 specimens per proxy, per sample.

After extraction, the species of each specimen can be identified. An environmental reconstruction can be built from an understanding of which specific environment each species inhabited. Geochemical trace element analysis will also be conducted on the ostracod species *Cyprideis torosa*, in order to attempt to reconstruct past salinity levels and temperatures using Sr and Mg content.

The MIS 5e Ipswichian interglacial is a particularly interesting time period in the history of human occupation in Britain. For the past one million years, human ancestors have colonised and abandoned Britain repeatedly in cycles, a behaviour which is determined by climatic fluctuations. Interglacials are important to understand from an archaeological perspective, because these warmer periods have a significant effect on; the changing adaptions hominins have to different environments, and hominid access to and from the British Isles from mainland Europe.

Stringer (2006) highlighted that there have been at least nine separate waves of colonisation for Britain and it has been inhabited during every interglacial of at least the last 500,000 years, except one; MIS 5e. MIS 5e is an enigma because the climate and environment was suitable for human occupation in Britain, but there appears to be an absence of archaeological remains. Humans were present along the coasts of Northern France (e.g., Caours, in the Somme valley (Antoine *et al*., 2006)), but seemingly not in Britain.

This research intends to explore the environmental conditions of England in MIS 5e, with the aim of adding to the wider pool of knowledge. Using this body of knowledge, it may be possible to infer the impact the environment had on the behaviour of humans, and why they were absent at this time.

Remaining research questions:

- What were the coastal conditions like around South-West England, during MIS 5e (125,000 BP)?
- Could these environmental conditions have an impact on human presence in Britain, in MIS 5e?

Acknowledgements

This project was initiated by Dr John Whittaker (Natural History Museum Associate), Prof. Tony Brown (Southampton University) and Dr Tom Hill (Natural History Museum), and their help in advising me on the project has been invaluable. A grant from the Ussher Society is acknowledged. This was used to facilitate the fieldwork and sample processing, as well as an Amino Acid Racemization date. Final thanks to Dr Matt Pope and Prof. Jonathan Holmes, as my dissertation supervisors.

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Coastal Change in North Devon AONB

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The Character of our Coast was a project developed in partnership between Beaford Arts and the North Devon Coast Areas of Outstanding Natural Beauty (AONB). Through support from the Sustainable Development Fund of the North Devon AONB, the project brought together rarely seen historical images of the North Devon coastline along with a detailed contemporary study that aimed to demonstrate the impact we have had on our coastal landscape over the past century.

The much-loved work of photographer James Ravilious is widely known. For seventeen years James, who died in 1999, worked as a photographer-in-residence for the Beaford Centre. Over 70,000 negatives document the landscape and communities of rural North Devon during the 1970's and 1980's, part of which are now publically available through the Beaford website (http://www.beaford-arts.org.uk/archive/).

In addition, James added his collection of older images to the Archive, images collected, amongst others, from local Women's Institute members. Working closely with his colleague George Tucker, James re-photographed images dating back as far as the late 1800's, building what is now known as the 'Beaford Old Archive'. As part of 'The Character of our Coast' project, Beaford Arts launched 'Contribute to our Coast' to provide a platform to add image-specific information and public discussion on the issues raised by the project (http://www.beaford-arts.org.uk/index.php?id=5).

The AONB Perspective

The special qualities of the AONB's coastal landscape have been under recent scrutiny with the completion of a formal Seascape Character Assessment in 2015 (http://www.northdevon-aonb.org.uk/projects/seascape-character-assessment). This considers the natural and human interactions with land and sea that create the distinctive character of the coastline. The photographs and descriptions highlighted significant changes to the landscape during over 100 years covered.

As AONB Manager Jenny Carey-Wood reflects: "Technical documents aren't for everyone and planning discussions can be contentious, but people love images of places they know and many would be surprised to see what has changed and why over the last 20, 50 or 100 years."

From his work on the Seascape project and liaising with the Beaford Arts team to identify key coastal photos, the author noticed two distinct changes over the last century. Whilst, in many places, little may appear to have changed, in some areas such as the coastal resorts, there has been significant landscape change as these settlements have sprung up. Natural changes due to climate effects such as storms, cliff falls and sea level rises can be clearly seen from the images in the James Ravilious Collection and the Beaford Old Archive compared with today's images.

When the project commenced we used the many images captured in our own AONB Photographic Archive to compare and contrast with the Beaford Archive, but as the project progressed in 2016, the author went back to the exact location that the original photos were taken, in order to make direct comparisons.

As a result, we were able to notice in some cases little change, whilst in other locations profound change (Fig. 1). The most dramatic of change was noticed in the level of built change and the various snapshots in time allowed us to draw some conclusions with regards to the effectiveness of AONB designation and protection. Some places along the coast exhibited some change in terms of erosion and the effects of the coastal processes, in particular within Bideford & Barnstaple Bay in places like Westward Ho! and Saunton, while in other photographs little if anything had appeared to change.

Conversely, some of the photographs revealed a quite subtle but profound change, one of the more noticeable being an increase in woodland cover, due changes in farming practice over the past 50 years.

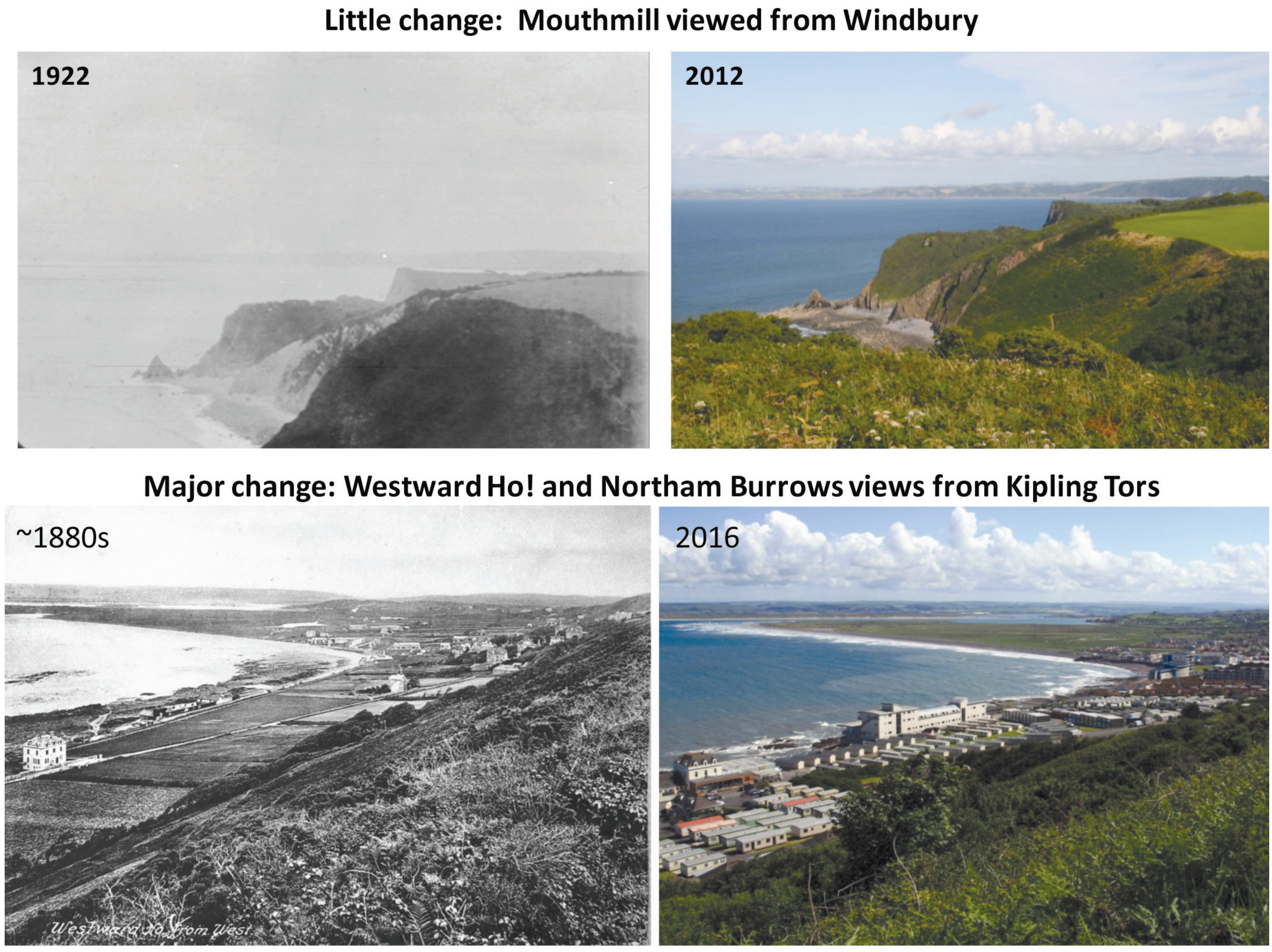

Figure 1. *Comparison of coastal areas exhibiting little apparent change (upper, Mouthmill) with areas showing major changes due mainly to building (lower, Westward Ho!).*

Geological investigations for coastal protection and landslide remedial works at Lyme Regis, Dorset

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The south coast resort of Lyme Regis can trace its origin back for over 1000 years to a fishing settlement sited on a small, flat-topped promontory that was largely protected from the effects of marine erosion by a cliff of Jurassic Blue Lias Formation. The town has a history of building protective sea walls. On the west side of the town, the thirteenth-century Cobb wall protecting the harbour is thought to be the oldest working breakwater of its type in the country. The path between the town and the harbour ran along a sea front of low, degraded cliffs in mudstones that were prone to landslide and rapid marine erosion, and the area was not built on. The Victorian fashion for seaside resorts caused the town to expand, and areas that had previously been avoided because of the risk of erosion or instability were developed. The central part of the town and the western and eastern margins have for many years been threatened by a combination of marine erosion and active landslides (Fig. 1).

Multidisciplinary studies instituted by West Dorset District Council as part of a succession of environmental improvement plans included geological surveys and an extensive drilling programme. The most recent works, Phase IV, included the stabilisation of landslides abutting the eastern side of the town and the construction of a new sea wall. Part of the Phase IV area, Church Cliffs and East Cliff and the adjacent intertidal area fall within the Jurassic Coast' World Heritage Site. The geological importance of the exposures is also reflected in their designations as Geological Conservation Review sites for Lower Jurassic stratigraphy, fossil fishes and fossil reptiles. In addition to the geological data gathered in advance of the design of the engineering works, the drainage and wall-foundation excavations were geologically monitored as the works progressed.

Figure 1. *A landslide in February 1962 destroyed several houses and damaged the promenade and sea wall. Despite being stabilised, the risk of future landslide movements and undermining of the sea wall during storms prevented development of the sea-front area for the next 50 years.*

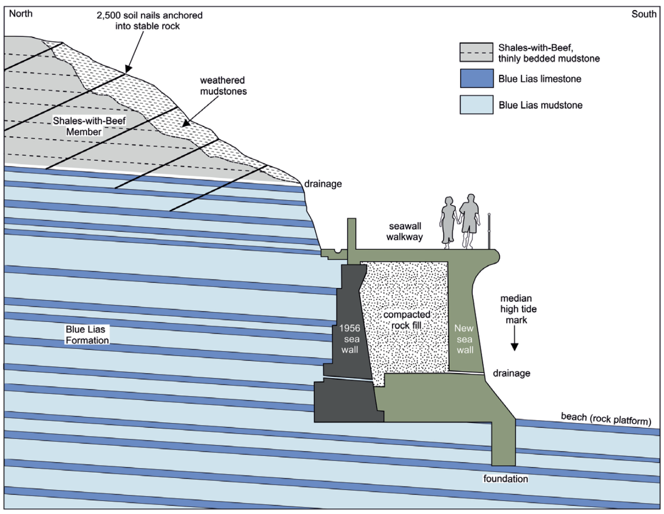

Figure 2. *The new sea wall on the east side of the town will protect the cliff and the old sea wall from further erosion, will stabilise landslides that were a threat to housing and Lyme Regis church, and provides safe easy access to the fossiliferous intertidal rock platform.*

Concerns expressed at the design stage that the works might destroy or make inaccessible some unique part of the stratigraphical succession proved unfounded. Not only were the engineering works designed to avoid damage to the geological value of the site, most unusually for such works some features were included to enhance the geological interest. The sea wall (Fig. 2) was designed to resist storm damage for a minimum of 60 years without the usual protective outer layer of rock armour and/or imported beach deposits. Since the completion of the new sea wall in July 2014 the intertidal area fronting the wall has been almost entirely sediment free with the result that the geology is currently better exposed than at any previous time on record. As a result, the intertidal rock platform has continued to be the most important source of Jurassic fossil reptiles in the UK.

New insights into the late Quaternary evolution of the Bristol Channel, UK

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Detailed investigations over the past half-century have revealed remarkable evidence of the morphology and geology of shelf seas adjacent to northwest Europe. For the British Isles this work has provided important insights into the relationship of the Quaternary sequences to those on land in adjacent regions and the interaction of land and sea through the period. The Bristol Channel (Fig. 1) is one area that, although it has received some attention has not been systematically investigated as a whole, apart from by the surveyors of the British Geological Survey, who have published a map and accompanying memoir (Tappin *et al*., 1994).

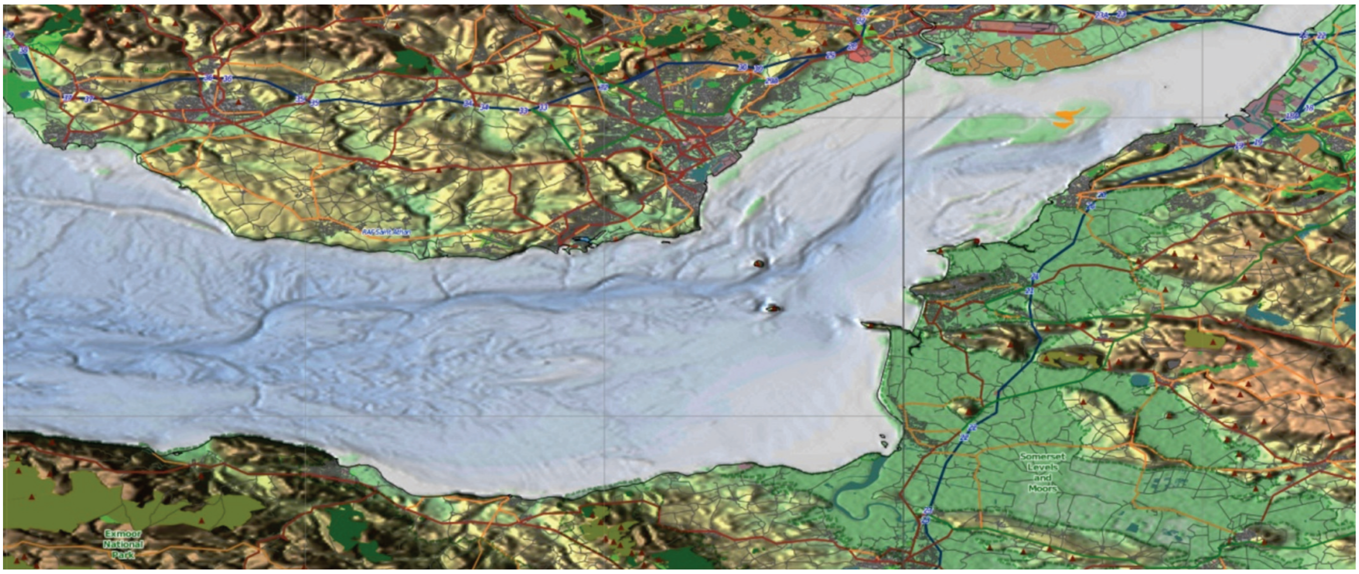

Figure 1. *The bathymetry of the Bristol Channel, modified from the European Marine Observation and Data Network project (EMODnet 2016).*

A synthesis of new publicly-available borehole and bathymetric data, combined with a wealth of other existing disparate data sources reveals new insights into the Pleistocene history of the Bristol Channel area. Sediment boreholes throughout the Bristol Channel confirm the area was glaciated in the Pleistocene. Till is present underlying marine deposits and, in some areas, is visible morphologically as submerged moraines. In the central and eastern Bristol Channel the submerged valley course of the palaeo-Severn is very clear in new high-resolution bathymetric surveys (Fig. 1). This former river course and associated tributaries cross-cut through glacial sediments in the Bristol Channel.

This presentation examines the entire Bristol Channel area from Lundy and Swansea Bay in the west to the Severn Estuary and surrounding land areas. The palaeo-Severn catchment is also investigated and linked with the evidence from the Bristol Channel.

At least three phases of glaciation can be recognised in the Bristol Channel region. The earliest recorded glaciation (?Middle Pleistocene) occurs in the Inner Bristol Channel where ice filled the entire area between the Vale of Glamorgan and Somerset and reached beyond the Severn Estuary to a point between Bristol and Weston super Mare. A second phase where ice overrode Lundy and deposited thick accumulations of glacigenic sediments in the Outer Bristol Channel dates from earlier in the Middle Devensian (Marine Isotope Stage: MIS 4/3). The most recent glaciation dates to the Late Devensian (~MIS 2) and is associated with the southern limits of the last Welsh Ice Cap in South Wales. This event has produced a striking submarine morphology in Swansea Bay. Here, two end moraine assemblages are evident, the inner moraine dating to the Late Devensian. Glacial retreat began at *c*.16 ka.

The Bristol Channel contains a bedform morphology that reveals clear evidence of major fluvial systems. The most striking feature is the evidence for the palaeo-Severn channel which is visible on high-resolution bathymetry throughout the inner and central Bristol Channel. This palaeochannel cross-cuts earlier deposits, including glacial sediments and is overlain in the Outer Bristol Channel by thick accumulations of marine sands.

Whilst the long-term evolution of the Bristol Channel has been influenced by tectonic processes, the morphology of the current channel has been directly shaped by glaciation and subsequent fluvial processes during the Pleistocene. This was followed by inundation by rising sea levels in the early Holocene with the River Severn retreating to its current course leaving a palaeo-River Severn Channel clearly imprinted in the submarine bathymetry of the Bristol Channel.

It is evident therefore, that Pleistocene glacial and fluvial activity, combined with subsequent post-glacial sea transgression, directly account for current morphometries of the Bristol Channel and Severn Estuary, and the current geography of SW British Isles.

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The burial and thermal history of the Devono-Carboniferous of North Devon

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Prior studies concerning the burial history and thermal history of North Devon have indentified the general trends through the Devonian–Carboniferous but also some anomalous results which have remained largely unexplained. One of the common limitations of such studies has been their scope which has commonly focused on individual sub-basins as indentified by Leveridge and Hartley (2006). This study looks to consider North Devon with a more holistic approach considering both the geological history of the Culm and North Devon Basins (Whittaker and Leveridge 2011).

$\%R_{oil}$ & IC_{equiv} →	N	Mean	StdDev
Bude Fm	74	2.97	0.73
Bideford Fm	21	2.65	0.39
Crackington Fm	71	3.21	0.76
Coddon Hill Chert	--	--	--
Pilton Shales	6	3.61	0.73
Upcott Slates	3	3.59	0.32
Pickwell Down Sst	7	4.77	0.73
Morte Slates	13	5.83	1.08
Ilfracombe Slates	36	6.15	0.86
Hangman Sst	15	6.09	0.67
Lynton Fm	4	6.25	1.01
Tavy Basin	15	4.88	0.52

Table 1. *Lithological succession in North Devon.*

A newly compiled structural map across North Devon along with a newly considered structural analogue from the Central Wyoming Salient Fold-Thrust Belt (Fig. 1) have the ability to shed light on North Devon's burial history, while also explaining:

- The spatial patterns of maturity values
- Oddities highlighted in historical datasets
- The timing of geological events
- The sedimentary sequence below the Culm Basin

Such a Central Wyoming Salient Fold-Thrust Belt analogue supports a tectono-sedimentary model which recognises northward-propagating thrusts shedding sediment forward into its own foredeep basin, which in turn is being carried on the back of the next forward-breaking thrust. This process is seen across Devon and Cornwall (Leveridge and Shail, 2011), with the Culm Basin representing such a foredeep fill. The 'North Devon Basin' may thus be thrusted from the south rather than sedimented from the Old Red Sandstone continent to the north.

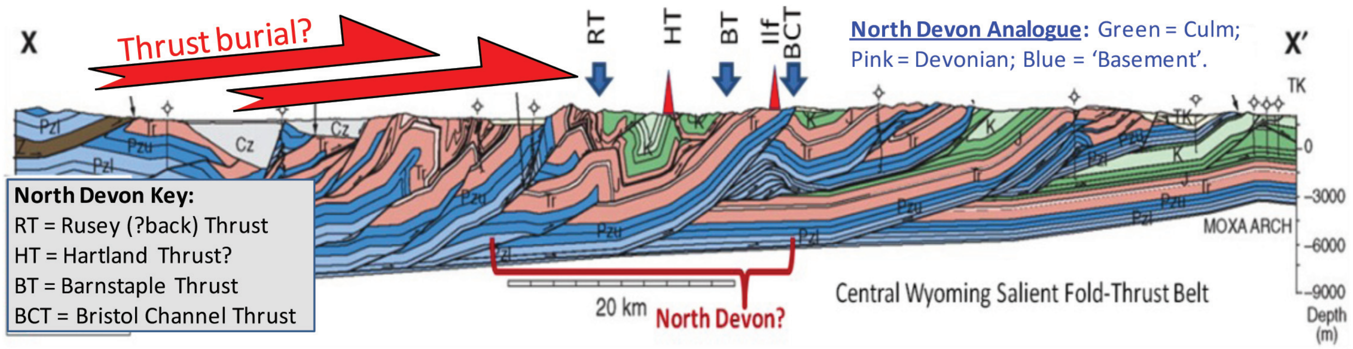

Figure 1. *Analogous structural thrust model for the formation of present-day North Devon. The presence of thrust faults bounding the Culm Basin allows the repetition of older Devonian sediments ahead and behind it. Red triangles = 1-D model locations.*

The sedimentary basin fill has been logged for the Culm Basin (3 km) and estimated for the more deformed North Devon Basin (6.2 km). These sediments, attributed compactional behaviour, heat capacities and thermal conductivities based on gross lithology mixes, are used to model the temperature history of the basins through the late Carboniferous–early Permian (Variscan) burial event. These 1-D thermal models can be calibrated by fitting the modelled with the measured thermal maturity based on the coal rank parameter vitrinite reflectivity (%Ro) and clay mineral illite crystallinity (IC).

Presented per stratigraphic units there is seen a systematic increase in thermal maturity data from the youngest Carboniferous Bideford Fm. (2.65 %Ro; semi-anthracite) to the lowermost Devonian Lynton Formation (6.25 %Ro; meta-anthracite) (Knight, 1990: Unpublished PhD Thesis, University of Southampton). When plotted against depth and compared with an average trend, palaeo-burial depths range from 7.2 km (Bideford) to 9.7 km (Lynton) deeper than today (Fig. 2). The absence of a break between the Carboniferous Culm Basin and Devonian North Devon Basin fill indicates that both matured below a common thermal blanket of now-eroded thrust burial.

The thrusted 'thermal blanket' required to calibrate these 1-D models demands some 210-290°C of temperature increase from late Carboniferous to early Permian. The Variscan granites (Dartmoor, Bodmin, Lands End, Scilly, etc.) possess early Permian cooling ages ranging from 293–275 Ma with no systematic age relationship along the batholiths from SW to NE. Granite

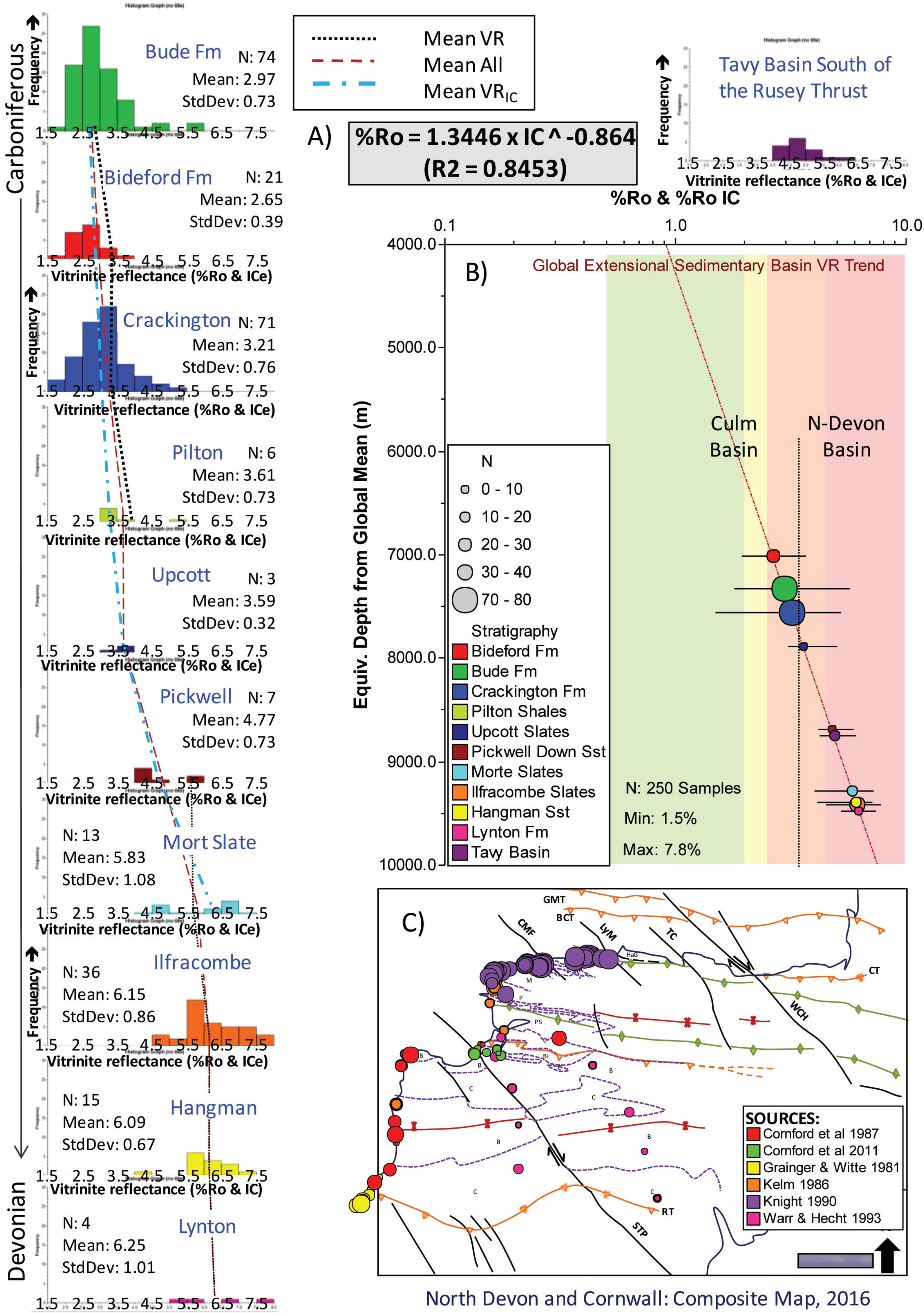

Figure 2. *Vitrinite reflectance (%Ro) & Illite Crystallinity (IC) equivalents by stratigraphy showing a systematic increase with depth from Carboniferous to Devonian: A) %Ro histograms across the North Devon, Culm and Tavy basins; B) %Ro mean values vs. Depth at maximum palaeo-burial; C) North Devon %Ro & IC data, locations & sources relative to structures.*

emplacement and cooling respectively thus coincides with the forward propagation and then erosion of the thrust slices. This temperature increase may have initiated melting by taking pre-thrust burial of siliceous Basement from (say) 15 km (= 450°C @ 30°C/km) to 25 km (i.e., +250°C) and hence granitization at 700°C. The granite cooling ages may reflect the uplift and erosion of the thrust cover.

In conclusion, we are now considering two models:

1. That the thermal maturity, now observed in the Devonian of the North Devon Basin, was achieved prior to emplacement by a forward-breaking thrust and independently of that observed in the Culm Basin fill: lower maturity Culm may underlie Exmoor's Devonian.
2. That the 6-10km of now missing geology that once sat above the current Variscan unconformity is an over-thrust package burying both the North Devon and Culm basins to their observed levels of thermal maturity.

The required additional thrust burial could have initiated thermal granitisation as could adiabatic granitisation during the uplift and erosion episode.

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Jurassic onychites (hooks from squid-like cephalopods) associated with statolith occurrences in the Wessex Basin, southern England

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Modern coleoid (squid-like) cephalopods have arms that carry arrays of both suckers and hardened, organic, hooks (onychites). Fossil arm hooks have been known since their description by Sternberg in 1823, although he identified them as plant remains. During the 20th Century there were a number of brief descriptions of hooks but it was a major paper by Kulicki and Szaniawski in 1972 which listed 22 morphotypes from the Jurassic of Poland. Other descriptions have shown that similar hooks are recorded in New Zealand and the Falkland Plateau. In many museum collections (Leeds Museum, Bristol Museum, NHM London, NHM Paris, *etc*.) there are examples of soft-bodied preservation of squid-like cephalopods, but few descriptions of the associated hooks and statoliths (ear bones). Newly displayed material in 'The Etches Collection' in Kimmeridge includes at least 6 specimens from Dorset (Kimmeridge Clay Formation, Kimmeridgian–Tithonian), several of which show the hooks in place. The new data from the Wessex Basin, together with that from elsewhere, show that the form of the hooks may be species-diagnostic and if this is the case, then it may be possible to determine the ranges of known species in parts of the Jurassic succession with no records of soft-bodied preservation.

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The Western Channel Observatory: new data on benthic foraminifera in the plankton, sea floor assemblages and new records of silicoflagellates in the English Channel

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The Western Channel Observatory was established by Plymouth Marine Laboratory and maintains two autonomous buoys (L4 and E1) that are located to the south of Plymouth in the English Channel. These two locations are now monitored continuously and there is regular sampling of the water column and the sea floor at both locations, together with other sea floor samples from 'Hillsand' (near the Eddystone Rock) and Cawsand Bay. In winter/spring 2015–2016 a number of major storms affected the English Channel, attracting public attention as they were given personalized names. Storm Imogen on the 8th February was particularly felt in the area between the Lizard (69 mph gusts), Portland (69 mph gusts) and the Isle of Wight (81 mph gusts). Plankton samples collected from site L4 on the 10th February contained large numbers of benthic foraminifera, with a range of species being recorded. Interestingly, many of these specimens were in-filled with sediment, showing that these individuals had been lifted from the sediment surface and, even weighted by sediment, were raised into the surface waters in an area of 50 m water depth. Rare specimens of a silicoflagellate (plankic algae with siliceous skeletons) were also recorded. During 2016, benthic sampling of the L4, 'Hillsand' and Cawsand Bay sites continued, providing further information on the distribution of benthic foraminifera in the local area.

Structural controls of Pb-Ag-Zn mineralisation at Combe Martin, North Devon

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Pb-Ag-Zn mineralisation at Combe Martin has previously been described as a Sedimentary Exhalative (SEDEX) deposit (Scrivener and Bennett, 1980; Benham *et al.*, 2004). The argentiferous galena and sphalerite is formed in quartz-carbonate veins and has been historically worked. Despite excellent exposure at Combe Martin Silver Mine and nearby beaches, no comprehensive studies have been conducted to investigate the controls on mineralisation.

A structural study of the mine and beach exposures revealed high strain deformation from the Variscan orogeny. Pb-Ag-Zn mineralisation forms in syn-orogenic, quartz-carbonate bedding-parallel veins (BPVs) in the upright limb of Variscan nappes. The most extensive accumulations of galena and sphalerite exploit thin vein sections between thicker boudin structures and are proximal to NW–SE faults that cross-cut the bedding.

Observations from optical microscopy and SEM analysis confirmed two generations of mineralisation: an earlier, syn-orogenic, barren phase and a later, undeformed, Pb-Ag-Zn-rich phase. Fluid inclusion microthermometry indicated very low salinities (8-12 wt. % NaCl equv.) for both generations, but higher temperatures (250 °C) and pressures for the earlier quartz-carbonate phase compared to the later ore-bearing phase (130 °C).

It is inferred that regional extension during the Permian re-activated NW–SE Variscan transfer faults which in turn dilated bedding-parallel veins. Upward-migrating metal-bearing fluids percolate through NW–SE faults and mix with downward-migrating sulphur-bearing fluids. Fluid mixing results in the precipitation of Pb-Ag-Zn in dilated bedding-parallel veins in the upright limb.

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Geoheritage comes of age: new advances on a global stage!

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2015 and 2016 have been a very exciting time for geoheritage as a discipline within the Earth Sciences, as it finally gained a truly global profile through recognition at the highest level within global conservation organisations. Firstly, in November 2015, Global Geoparks became a UNESCO programme and hence the first new UNESCO designation since the World Heritage Convention of 1972. This achievement was celebrated in Torbay in September 2016 at the 1st UNESCO Global Geoparks meeting, which attracted nearly 700 delegates from all over the planet, to SW England (*http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/*). Secondly, the globally, highly influential International Union for the Conservation of Nature's, World Conservation Congress in Hawaii in September 2016, adopted a Recommendation on the Conservation of Moveable Geological Heritage, building on the previous Motion CGR4, MOT055 on the Conservation of Geodiversity and Geological Heritage (*https://portals.iucn.org/congress/motion/091*). And finally, in parallel with the IUCN Congress, the International Union of Geological Sciences (IUGS) approved the establishment of an International Commission on Geoheritage at its 35th International Geological Congress in Cape Town, South Africa, also at the beginning of September, building on the success of two pre-existing task groups, on Geoheritage (https://portals.iucn.org/congress/motion/091) and Heritage Stone (www.globalheritagestone.com). With this new global recognition within UNESCO, IUCN and especially IUGS, the principles and practice of Geoheritage and its conservation for future generations has truly come of age!

How long was an ammonite zone? Preliminary results from the Hettangian (Lower Jurassic) of SW England

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The great potential of ammonites for developing reliable correlations was first realised in the mid-18th century, and ammonites still form the background of Jurassic chronostratigraphy, being used to correlate stage stratotypes and their finer and finer subdivisions at the level of 'zone', 'subzone' and 'horizon'. These 'time scales' are all relative, however, and the paucity of radiometrically dated points through the Jurassic has meant that many estimations of Jurassic time have used an averaged duration of ammonite zones, with figures of '1 million years per zone often' being used to construct time scales. Things have moved on, however, and calibration against presumed Milankovitch (i.e., orbital) cycles and strontium isotope curves have facilitated the establishment of more accurate overall time scales for the system. However, at a finer scale, for instance within a specific stage, some finer calibration is still often needed, for instance to provide a time scale for isotope or evolutionary 'events'. However, is averaging the duration of ammonite zones and subzones really meaningful? New analysis of earliest Jurassic, Hettangian, ammonite faunas from SW England indicates that it probably is not. Using a rigorous analysis of Milankovitch cyclicity in the Blue Lias Formation, integrated with high resolution correlations of the successions with ammonite faunas, has confirmed that ammonite zones and their subdivisions – down to the level of biohorizon – can vary significantly in duration. Clearly, averaging zonal durations to create a timescale is not a good idea!

Stellate nodules from the Lower Jurassic of Kilve

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Enigmatic stellate nodules from the Lower Jurassic of Kilve are described. At Kilve beach (ST 1445 4425), limestones and shales are spectacularly exposed in both cliff sections and on the wave-cut platform younging eastwards towards Hinckley Point Power Station. Here, and elsewhere along this part of the Somerset coast, the exposures of the gently dipping Jurassic strata provide an insight into the character of the sedimentology, palaeontology and faulting in the region. The stellate nodules are located in a single bed located within Hettangian strata between the Global Stratotype Section and Point (GSSP) for the base of the Sinemurian at East Quantoxhead and the Quantocks Head Fault. These sediments are characterized by metre-thick shale beds interbedded with limestones. The morphology of the stellate nodules are comparable to 'chrysanthemum stones' or glendonites. The origin and significance of these enigmatic stellate nodules is investigated through geochemical and isotope analyses.

Tectonic and structural controls on the genesis and emplacement of early two-mica (G1) and muscovite (G2) Cornubian granites and their associated W-(Sn) mineralisation

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Variscan thrusting in SW England ceased in the latest Carboniferous (*c.* 305 Ma) (Shail and Leveridge, 2009). It was replaced by a short-lived strike-slip regime, dominated by dextral slip on earlier NW–SE transfer faults, and subsequently a NNW–SSE extensional regime that persisted throughout most of the Early Permian. The latter is represented, in low-grade Variscan-metamorphosed Devonian-Carboniferous successions, by shear zones and detachment faults exhibiting a top-to-the SSE shear sense. Field and seismic data are consistent with Early Permian exhumation and thinning of SW England lower plate crust during the extensional reactivation of the Rhenohercynian-Rheic suture and associated Variscan thrust faults (Shail and Leveridge, 2009).

Granite generation and emplacement in SW England occurred over >20 Ma during the Early Permian (*c.* 293–270 Ma) (Chen *et al.*, 1993). The earliest granites are contemporaneous with mantle-derived melts (lamprophyres and high-K basalts) (Dupuis *et al.*, 2015) and comprise mineralogically, texturally and geochemically distinctive two-mica (G1) granites (Fig. 1) that occur within plutons (>290 Ma) and muscovite (G2) granites that typically occur as smaller stocks (>293–280 Ma) (Simons *et al.*, 2016).

Wolfram mineralisation is strongly correlated with these early granites (G2>G1); in contrast, the later biotite (G3) and tourmaline (G4) granites that have little associated W mineralisation. G1 granites formed by 25% dehydration melting (muscovite + minor biotite) of a greywacke source (731–806°C, >5 kbar), initiated by extensional thinning/exhumation of the lower plate and emplacement of mantle-derived melts into the lower- to mid-crust. Melting of W-bearing source muscovite resulted in magmas that were moderately enriched in W (3.7 ppm) and Sn (10 ppm). Differentiation of G1 magmas, primarily by feldspar-biotite fractionation (Simons *et al.*, 2016), resulted in muscovite (G2) granites further enriched in W (12 ppm) and Sn (18 ppm). Wolfram enrichment of early granite magmas is an important control on prospectivity.

W-(Sn) mineralisation associated with two-mica (G1) granites (Scilly, Carnmenellis and Bodmin Moor plutons) is contemporaneous with the earliest stages of batholith construction. G1 granites exhibit localised solid-state fabrics and ductile shear zones compatible with a top-to-the SSE shear sense and granite–host-rock coupling during the extensional reactivation of thrust faults. W-(Sn) bearing greisen-bordered quartz or quartz-feldspar veins developed in tensile fractures and faults (lodes) during brittle-ductile to brittle deformation of granites and host-rocks during NNW–SSE extension.

W-(Sn) mineralization associated with the muscovite (G2) granites is typically hosted by greisen-bordered sheeted veins and subordinate extensional faults (lodes) in smaller stocks (St Michael's Mount, Cligga Head and Kit Hill granites) emplaced along

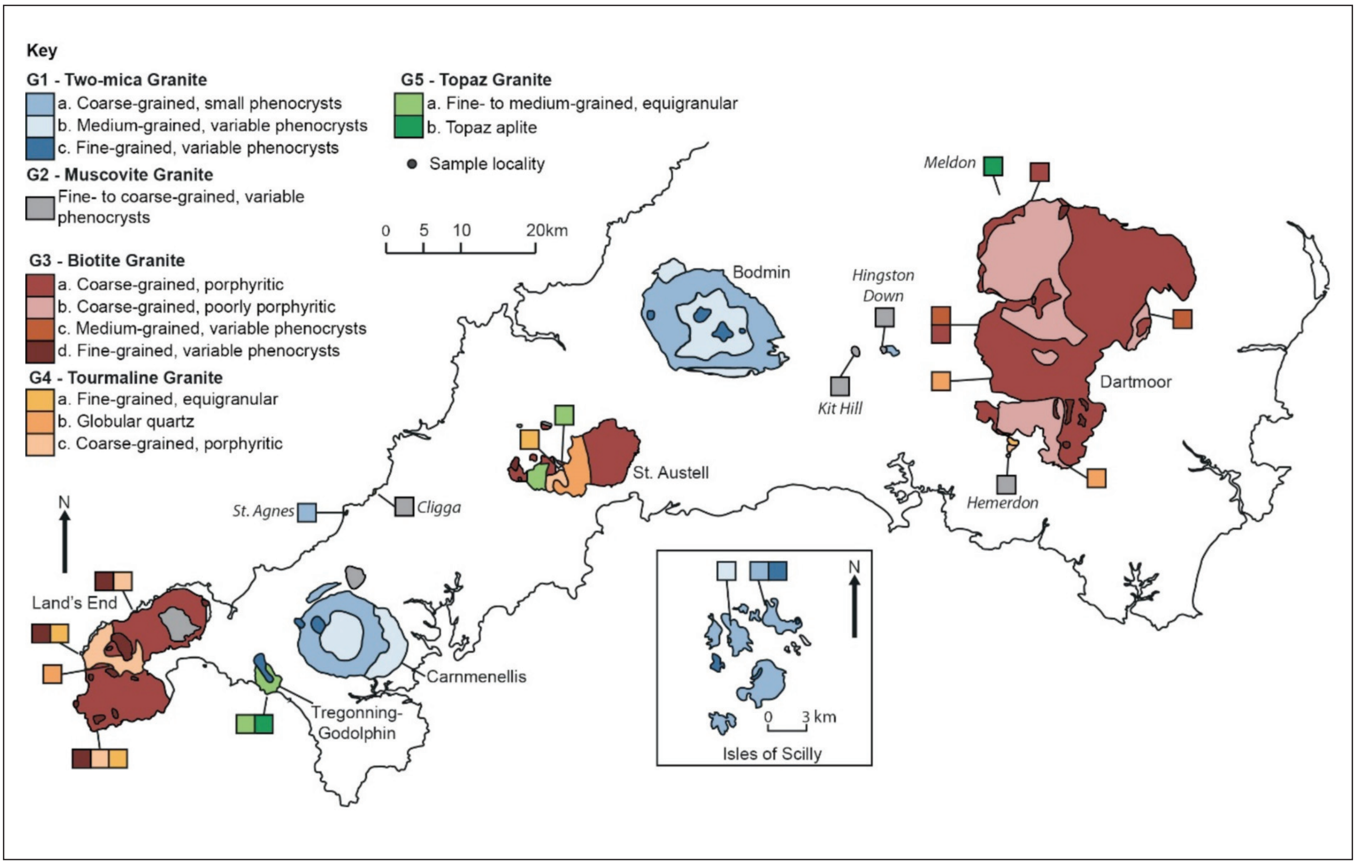

Figure 1. Geological map of SW England showing the principal mineralogical and textural variations in the Cornubian Batholith from Simons et al. *(2016). It combines a mineralogical classification into two-mica (G1), muscovite (G2), biotite (G3), tourmaline (G4) and topaz (G5) granites with a textural scheme based primarily on mean matrix grain-size and the size and abundance of alkali feldspar phenocrysts. Compiled from Ghosh (1927), Dangerfield and Hawkes (1981), Exley and Stone (1982), Manning* et al. *(1996), Selwood* et al. *(1998), Müller* et al. *(2006a) and British Geological Survey data (Geological Map Data © NERC 2016) with additional data from Simons* et al. *(2016).*

NNW–SSE strike-slip faults. The earliest expression of G2-related W-(Sn) mineralisation is hosted by the Hemerdon Granite dyke (>293 Ma), hosted by a NNE-trending pull-apart related to slip on NNW–SSE faults. Early development favoured prospectivity due to tungsten-enriched magmas and higher brittle strain, in both host-rock and granite, controlling the development of effective fault-fracture meshes for fluid migration.

Fault-controlled quartz-tourmaline and polymetallic-sulphide vein systems, related to volatile release from underlying G3/G4 (biotite/tourmaline) and G5 (topaz) granites, commonly overprint the earlier W-(Sn) systems.

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Philip Rashleigh's minerals, from an 18th century private collection to 21st century public view

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Philip Rashleigh (1729–1811) an 18th century gentleman MP with interests in Cornish mines, was able to collect and buy about 4,000 of the best Cornish minerals, kept in his house at Menabilly, near Fowey. He is best known today for his books, Specimens of British Minerals, 1797 & 1802, with over 200 of his mineral samples engraved and water coloured. This was one of the first and best-illustrated books of UK minerals. In 1987 R.F. Symes, with P.G. Embrey's '*Minerals of Cornwall & Devon*' brought many of Rashleigh's minerals to a much wider audience.

Today, much of his collection is on display at the Royal Cornwall Museum, Truro, where the Rashleigh Gallery was opened in 1993 by Dr Robert Symes, formerly of the Natural History Museum, who gave a lecture on Minerals Collection – the Rashleigh Connection. A whole gallery of Rashleigh's minerals was on (free) public view for Truro visitors. Recently RCM and the Open University have 'captured' many of these classic specimens so they can be seen as images on screen, at well above hand lens magnification, and are rotatable. Rashleigh's minerals are now freely available for home study worldwide.

Left high and dry: the importance of stratigraphy in understanding the significance of Pleistocene shoreline deposits

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Late Pleistocene nearshore sandstones at Saunton Sands, north Devon have been well known for decades but their sequence stratigraphic, sedimentological and diagenetic context has been poorly described and interpreted. These marine sandstones are here interpreted to represent the deposits of two separate transgressive-regressive cycles which may correlate to interglacial MIS's 7 and 5e. The lower unit contains a transgressive succession which deepened from foreshore, across a ravinement surface to shoreface (sub-fairweather wave-base) environments. Shallowing through lower and upper foreshore/ backshore suggest that the tidal range may have been less than today. This regressive sequence is capped by a well-defined palaeosol, with rhizocretions. Cements show field, petrographic and isotopic evidence for meteoric phreatic and vadose cementation, including palaeo-groundwater flow. The secession is consistent with deposition during initially rapid and then decelerating rate of rise of relative sea-level, followed by forced regression evidenced by the vadose diagenesis. The subsequent transgression stacked upper foreshore or backshore facies above the palaeosol, indicating renewed generation of accommodation as relative sea-levels rose. This study is just one example of Pleistocene shoreline features where the importance of a rigorous stratigraphic and sedimentological framework is critical to understanding the results of expensive dating techniques.

Integrating geochemistry and geophysics to map subtle variations in composite granites

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The recently acquired airborne geophysics and ground-based geochemistry of the Tellus South West and G-BASE projects provide an excellent dataset for remote sensing mapping in areas of poor exposure. The Cornubian Batholith comprises a series of exposed composite granite plutons. The area is an ideal natural laboratory for testing the ability of Self-Organising Map (SOM) techniques to predict granite type in areas of low exposure.

Data pre-processing involved the creation of stream-sediment catchments from the LiDAR Digital Terrain Model (DTM) and cut to the mapped extent of granite exposure (based on existing BGS maps). Derivatives of the LiDAR DTM were prepared and airborne radiometric data was included as both concentrations and ratios. The data was then cut to the same extent and resolution. Further processing to remove bias and reduce dimensionality of the data included the use of Pearson Correlation Coefficients and the multivariate methods Principal Component Analysis (PCA) and Minimum-Noise Fraction (MNF).

SOM techniques including K-Means (KM), IsoData (ID), Maximum-Likelihood (ML) and Artificial Neural Networks (ANN) include include parametric and non-parametric analyses and trained and un-trained approaches. We present the results from SOM analysis and discuss the best techniques for mapping subtle variations in composite granites.

POSTERS:

THERMAL HISTORY DATA FROM SW ENGLAND - HAEMATITE MINERALISATION, THE STICKLEPATH FAULT AND A FAMILY CONNECTION WITH DEVON'S LAST IRON MINE

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[2] *Geotrack International Pty Ltd, Melbourne, Australia*

Extensive haematite mineralisation occurs in the granite of northeast Dartmoor and in Devonian limestone on the south Devon coast near Brixham. Similar haematite deposits occur over South Wales. Preliminary AFTA results from SW England and South Wales reveal a series of paleaothermal events in the late Carboniferous, Triassic, mid Jurassic, early Cretaceous and Tertiary. Recently published data from South Wales suggest that the mineralisation here was due to hydrothemal circulation through faults during the early Cretaceous. This timing coincides with the early Cretaceous episode recognised in the AFTA.

The haematite mines in Devon are situated near the Sticklepath fault so a similar genesis for the iron is possible here. A key observation from the AFTA however is that the early Cretaceous cooling affected the whole SW England and South Wales region, not just the mineralised zones. Work is ongoing to refine the AFTA interpretation to explain these regional paleothermal episodes and investigate whether mineralisation by hydrothermal fluids during the Cretaceous can be identified in Devon.

Mining of the haematite has been important historically on northeast Dartmoor and the author has recently discovered a family connection to these mines, bringing historical interest to an already fascinating geological story.

FORAMINIFERAL EVIDENCE FOR THE CANDIDATE CALLOVIAN-OXFORDIAN GSSP AT HAM CLIFF, WEYMOUTH

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Ham Cliff, near Weymouth, Dorset, United Kingdom, is recognised as a candidate Global Boundary Stratotype Section and Point for the Callovian–Oxfordian boundary. A detailed analysis of the micropalaeontological assemblage present across the boundary was required following the meeting of the Oxfordian Task Group in June 2014, in order to fulfil more GSSP criteria and increase the candidacy strength. Additional clay samples collected in January 2016 allowed for the construction of a high-resolution data set, demonstrating the changes in abundance of several foraminifera species across the boundary. The possibility of diagenetic altering has been raised following this study, and specimens previously unrecorded at Ham Cliff have been discovered.

The section studied at Ham Cliff [SY 7146 8178] is approximately 300 m north-east along the coastline from Redcliff Point. Access to the site can be gained via the foreshore directly from Bowleaze Cove [SY 7040 8190] or by using the South West Coastal Footpath from Bowleaze Cove and then descending to the foreshore by the westernmost concrete pill-box.

During the meeting of the Oxfordian Task Group in June 2014, clay samples were recovered from the following levels relative to the red nodular marker bed: +3.0 m; +2.5 m; +2 m; +1.5 m; +1 m; +60 cm; +40 cm; +20 cm; ±0 m; -20 cm; -40 cm; -60 cm; -80 cm; -1 m; -1.5 m; -2 m; -2.5 m; -3 m; -3.5 m; -4 m, and -4.5 m. It was unnecessary to collect samples from these levels during the field-trip in January 2016, as sufficient material was already available and ready for processing.

To provide a high-resolution data set, samples were taken during a day-trip in January 2016 at intervals within a metre of the marker bed: i.e., +90 cm, +70 cm, *etc*. The aim of this method was to describe the biotic changes across the boundary with greater certainty and expand on the work undertaken by Malcolm Hart and Gregory Price over the last decade. Approximately 700–800 g of sediment was collected for each sample to ensure that there was sufficient back-up material to repeat the processing if required. The sediment samples were prepared using the Solvent Method, and the most representative of each species were used in SEM photography.

The foramnifera present across the boundary are *Epistomina mosquensis* (Uhlig), *Frondicularia psuedosulcata* (Barnard), *Lenticulina muensteri* (Roemer), *Planularia beierana* (Guembel), *Pseudonosaria* sp. and *Saracenaria oxfordiana* (Tappan). The ostracod *Lophocythere scabrabucki* (Lutze) is also common, along with *Belemnotheuthis* arm hooks, crustacean plate fragments, echinoid spines, crinoid ossicles (possibly *Isocrinus fisheri* (Forbes)), and belemnite rostra. Ichthyoliths (jaw and teeth fragments of teleost fish) and gastropod shells are abundant in every sample.

E. mosquensis is abundant in the strata immediately below the marker horizon, and the originally aragonitic tests are often filled with pyrite. This possibly suggests reducing conditions have affected the sediments from 0–100 cm below the red nodular marker horizon (~55 cm below the stratigraphic boundary). The presence of siderite 80 cm above the horizon possibly is the result of a change to methanic conditions, as siderite requires a sulphate-poor, methane-rich environment in order to form.

Initially, it was expected that the foraminiferal assemblage alone would be sufficient to strengthen Ham Cliffs candidacy as a GSSP for the Callovian–Oxfordian boundary. The data were meant to show trends reflecting the changing environment in relation to sea-level rise that is thought to have occurred over the transition. Unlike the nektonic ammonites, which demonstrate clear faunal changes, the benthic assemblages have been shown to be relatively insensitive to climate variability. However, the study unearthed a highly diverse benthos, previously un-recorded at Ham Cliff. This has opened up a new exciting window on life across the Middle–Upper Jurassic boundary at the locality. The potential for follow-up studies to expand upon this work in greater depth is highly promising.

HILL-SHADED DIGITAL TERRAIN MODEL FROM TELLUSSW

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The LiDAR survey flown as part of the TellusSW survey provides a high (1m) resolution overview of Cornwall and Devon. Delegates are invited to sketch lineaments on a laminated hill-shaded image.

Exceptional preservation of Middle Devonian rugose corals in the Ilfracombe Formation at Hele Bay, North Devon

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While Coasteering along the North Exmoor coast, a little visited bay was reached between Hele Bay and Rillage Point (Figure 1). This is locally called Hagginton Beach and contains decimetre-sized boulders which draw attention to themselves in that each pebble comprises a single coral head. At this point, the Ilfracombe Formation outcrops as steeply dipping sediments with a strong WNW–ESE strike. These Middle to Upper Devonian (Givetian–Frasnian) beds comprise mainly sandstones and mudstones, and are commonly folded and faulted with locally strong cleavage in the mudstones. The Ilfracombe Formation also contains a number of discrete limestone beds, the local one of which is termed the Rillage Limestone.

Figure 1. *Location of Hagginton Beach to the east of Ilfracombe and west of Combe Martin, Exmoor, North Devon.*

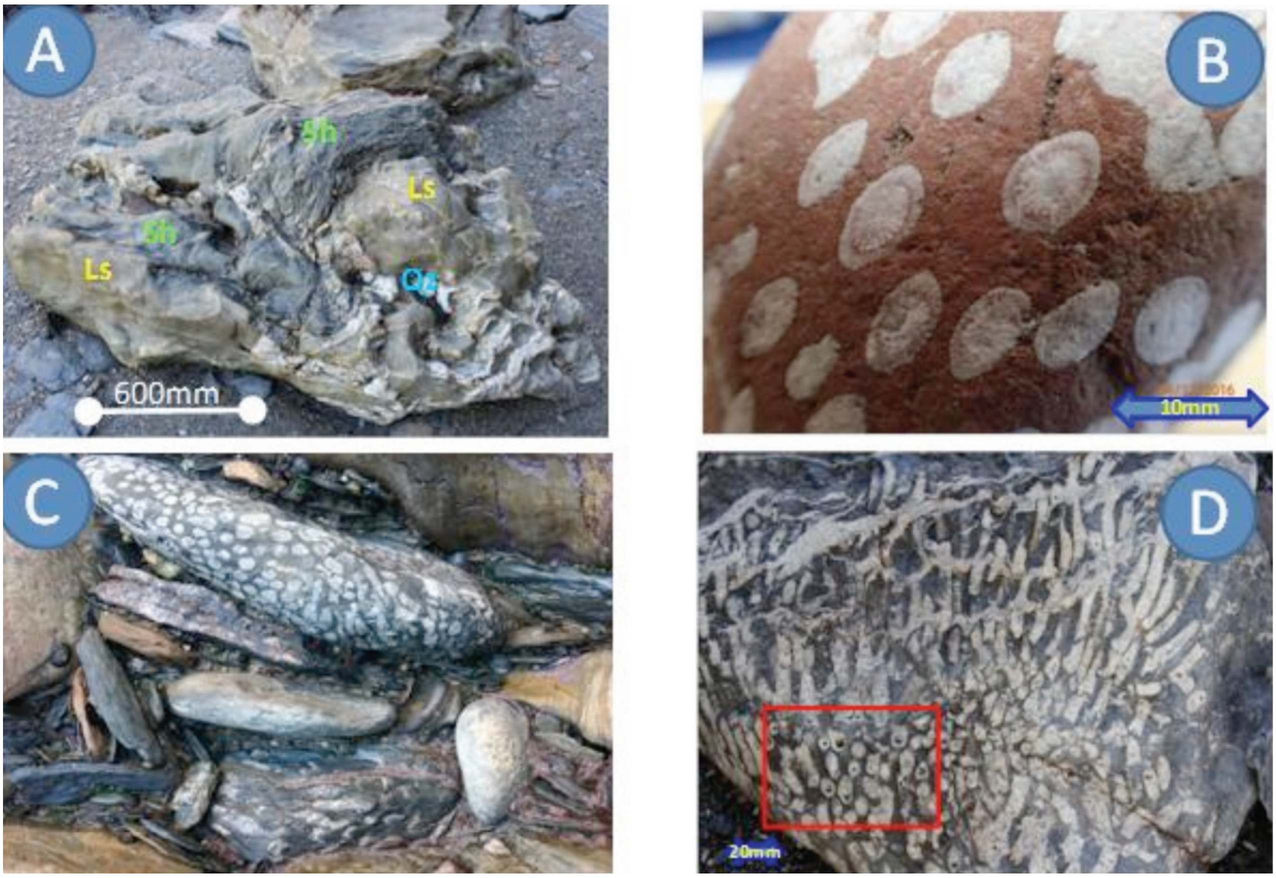

Figure 2. *Examples of mud and limestone melange from slumping in the unnamed limestone (**A**), well preserved corals in a reddened carbonate matrix (**B**), random beach pebbles with corals (**C**) and a single large coral head (**D**).*

Figure 3. *The bioclastic Rillage Limestone outcropping on Rillage Point (top left) and the newly named Hagginton Limestone (bottom right)*

The Rillage Limestone is described by Edmonds *et al.* (1975) as being 15–60cm thick, though the current outcrop appears thicker and to contain a number of beds, some showing evidence of slumping (Fig. 2A). Puzzlingly, the Rillage Limestone is described in detail by Edmunds *et al.* (*op. cit.*) as 'detrital', containing fragments of bryozoa, brachiopods, crinoids, gastropods and algae. Other limestones, such as the younger and thicker Jenny Start and David's Stone limestones are described as containing corals in growth position. Our observations at Hagginton Beach are almost completely the opposite.

Rillage Point is cut by a bed of grey to buff bioclastic limestone (Fig. 3, left) where broken crinoid debris is the main component to the naked eye. This we take to be the Rillage Limestone, which is also seen at the top of the cliff in a quarry just below the Coastguard Cottages.

We conclude that there is an as yet unnamed thicker limestone, outcropping above the Rillage Limestone and that this bed was deposited as a slumped mass flow and contains abundant corals heads. It is this thicker bed, tentatively called the Hagginton Limestone, that provides the coral boulders on Hagginton Beach.

EDMONDS, E.A., MCKEOWN, M.C. and WILLIAMS, M. 1975. *British Regional Geology: Southwest England* (4th Edition). Institute of Geological Sciences, London, HMSO.

Drones for Geographic and Geo-scientific Data Acquisition

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The use of drones for research in Geography and the Geosciences is opening up many exciting possibilities. In rapidly changing natural systems such as recurved spits, dune fields, eroding cliffs, rivers and estuaries, repeated drone missions throughout a year or over several years can provide essential information on processes and pacing, informing future management decisions. Inaccessible landforms such as landslips and geological outcrops on coastal promontories or in quarries can now be surveyed remotely in detail. The rapid acquisition of elevation and spectral data allows ecologists and biogeographers to quickly map seasonal changes in coastal vegetation, plotting the aerial extent of plant communities in grassland and heathland environments. In volcanology, drones equipped with spectrometers have been used to 'sniff' the composition of gases emanating from volcanic craters. Photogrammetry has been used to model calderas, and the addition of an infrared thermal camera can help locate fumaroles and incipient vents. Drones have been used to create 3D models of the Greenland ice sheet where it is calving into the North Atlantic Ocean, to help understand the affects of climate change. Using a drone, potential hazards can be evaluated before committing to a field visit, leading to better risk assessment and safer fieldwork.