

Forum

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ABSTRACTS OF THE 17TH BCRA CAVE SCIENCE SYMPOSIUM SCHOOL OF GEOGRAPHICAL SCIENCES UNIVERSITY OF BRISTOL 4 MARCH 2006

Rapid karstic by-pass flow in the unsaturated zone of the Chalk and implications for contaminant transport.

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Tracer tests have been performed on the unsaturated zone of the East Yorkshire Chalk aquifer, UK. Rapid tracer travel times through significant thicknesses of unsaturated Chalk (15 to 38m) indicate that by-pass flow must occur through fractures. Transport processes in the unsaturated zone of the Chalk aquifer thus have similarities to those in the vadose zone of karstic limestone aquifers. Modelling of tracer breakthrough curves indicates that by-pass flow is sufficiently rapid to significantly inhibit diffusional loss of tracer into the porous matrix of the Chalk. The presence of rapid karstic by-pass flow in the unsaturated zone of the Chalk will limit the potential for attenuation of groundwater contaminants in this zone.

Climatic and land use changes identified from lipid biomarker records preserved in stalagmites

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Lipid biomarkers (biologically derived fatty molecules that are indicative of different groups of vegetation, bacteria etc.) are widely recognised as useful proxies for environmental change, and are frequently used in studies of soil, peat and sediment cores. This work continues the development of novel biomarker time series by investigating the lipid signals present in stalagmites at an unprecedented level of detail.

The work presented here demonstrates how the small concentrations of lipids extractable from stalagmites can be used to reconstruct terrestrial ecological change driven by both climatic and anthropogenic controls. A streamlined method for the routine analysis of lipids with minimal contamination is presented, together with results from contrasting stalagmites from northwest Scotland and southeast Ethiopia.

The lipid records recovered show clear and statistically robust variations relating to changes in the overlying vegetation and soil ecosystems. These reflect both changes in the turnover and

transportation of soil organic matter and variations in the dominant vegetation type of the catchment area. In the Scottish sample, all these changes relate to climatic events over the past two millennia; in particular a dramatic change in input and vegetation type is seen at a period provisionally identified as the Little Ice Age.

Meanwhile, the Ethiopian stalagmite, which forms a high-resolution record of the last 100 years, shows clear variations in input driven by major continental drought cycles, as well as more detailed variations in overlying plant type, which reflect local land-use change with the expansion of agriculture in the region.

Together these samples unequivocally demonstrate that lipid biomarkers preserved in stalagmites record both ecological changes and the anthropogenic and climatic controls that act on them. Thus the technique can substantially add to our understanding of environmental changes both past and present.

Tracing the impact of mine drainage pollution in a karst aquifer, Xingwen, China.

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Groundwaters of the karst aquifer in Xingwen, China are affected by pollution derived from the mining, processing and smelting of pyrite ores. All of these lead to high concentrations of sulphate in groundwater. However, many of the sinking streams feeding the aquifer are from shale catchments and have naturally high sulphate concentrations. Is it possible to estimate the proportions of sulphate that are due to natural and different pollutant sources?

Sulphate is composed of sulphur and oxygen atoms, both of which have isotopic compositions that vary as a result of natural processes. These two isotopic compositions can thus be used as a "fingerprint" for different sulphate sources. In the Xingwen study, sulphate oxygen isotope composition is highly effective at distinguishing sulphate from atmospheric "acid rain" sources due to smelting from sulphate produced by aqueous pyrite oxidation (natural or acid mine drainage). The ranges of sulphur isotope composition in sulphate from natural weathering, mine drainage and processing effluent are sufficiently different to distinguish these sources. A combination of sulphur and oxygen isotopic measurements is thus highly effective at discriminating between all the sulphate sources to the karst aquifer. This indigenous tracer thus provides a powerful tool for assessing the impact of acid mine drainage on karst groundwater.

Karstic systems and the preservation of palaeoenvironmental signals by speleothems.

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Speleothems are primarily studied in order to generate archives of climatic change, but the way in which the weather, the seasons and longer-term climatic fluctuations become encoded is dependent on environmental filters, which can be modelled formally using time

series statistics. It is useful to distinguish five sources of variation: atmospheric, vegetation/soil, karstic aquifer, primary speleothem crystal growth and secondary alteration. The direct role of climate diminishes progressively through these five factors.

In this poster, particular attention is paid to high-resolution geochemical variation, including a comparison of conventional, laser-ablation and ion microprobe isotope analysis, and the light that they shed of different potential causes of decadal-scale isotopic variation.

A variety of trace element patterns occur, with a strong seasonality reflecting variation in cave ventilation and/or dryness. A particularly robust and simple trace element pattern from the Clamouse Cave in southern France marks the expression of an arid phase 1200–1100 B.P. that may have had a widespread distribution.

Swildons Hole: a centenary reappraisal.

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It has now been over 100 years since the discovery of Swildon's Hole. The system, one of the best sporting caves in the country, has a special place in the history of cave geomorphology. It is one of the best examples of cave development in dipping limestones in Britain, and contains many classic geomorphological features. It was intensively studied in the late 1950s and early 1960s by the 'High Priests' of Swildon's Hole, Derek Ford and William Stanton, and others. During this time, theories to explain the various stages in the development of the cave were put forward. The study of this and other caves on Mendip led Derek Ford to develop his 'Four State Model' for cave formation which was published as a series of academic papers in the late 1960s and early 1970s. The Swildon's Hole-Wookey Hole system is an outstanding example of a State 3 cave with a mixture of water-table passages and deep phreatic loops down to depths in excess of 90m.

Discoveries in the cave since the 1960s have enabled many of Ford's predictions and observations to be tested. The publication of a new book on Swildon's Hole celebrating the centenary of the cave's discovery has led to a reappraisal of the geomorphology of Swildons Hole, and its place in the surrounding landscape. An additional palaeo-water table level has been identified, and a refined model of cave evolution put forward.

Relationships between cave dimensions and local catchment areas.

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The caves formed in the Caledonide metalimestones of central Scandinavia are identified as occurring in one of three cave hydrological classes that are randomly intermingled with each other both geographically and altitudinally: relict (31%), mainly vadose (28%) and combination caves (41%). The morphology of the relict caves in this region shows that they were commonly enlarged phreatically. Their dimensions of length, vertical range, cross-section and volume are unrelated to their local catchment area, whose mean size is only 2.6km². Indeed, large relict caves may be found near ridge tops, and their mean cross-section (XS) to catchment area (CA) ratio is as high as 20.3m²km⁻². Mainly vadose (MV) caves contain active stream passages and sumps without significant phreatic upper levels or passages. Although there is no simple relationship between their *mean* dimensions and their local catchment area, which has a mean size of 4.7 km², their mean XS/CA ratio is only 2.8m²km⁻². However, their *maximum* lengths, cross-sectional areas and volumes were found to be constrained by the logarithm of catchment area. The combination caves contain relict phreatic (and, more rarely, relict vadose) passages that lie above an active streamway. Their mean dimensions are significantly larger than those of both relict and MV caves. Their mean CA is 4.6km² (close to that of the other active cave class) and their mean XS/CA

ratio is 11.6m²km⁻², which is intermediate between relict caves and MV caves. These observations support other evidence that the active mainly vadose passages developed during the present conditions of the Holocene, with dimensions related to the flow-rates of present allogenic discharge, whereas the relict phreatic passages enlarged when the caves were submerged by flowing glacial meltwater that was less related to present catchment area, during a previous deglaciation phase. It is further suggested that most relict caves and the whole set of mainly vadose caves have each separately experienced only one phase of cave enlargement after inception, whereas the larger dimensions of the combination caves indicate that they are more representative of the full range of enlargement opportunities that were available to the caves during the glacial evolution of their local topography.

The Roosky Turloughs, County Fermanagh, Northern Ireland.

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The 'Fardrum and Roosky Turloughs Area of Special Scientific Interest' is located near Ely in County Fermanagh. The approximate central point of the 43.1 ha site is at Irish Grid Reference H 180502. The site comprises a group of three turloughs with Roosky Lough in the south, Green Lough to the north, and Fardrum Lough between the two. These are the only turloughs in Northern Ireland and are amongst the most northerly occurrence of these lake types in Ireland. The site is also a candidate Special Area of Conservation (SAC) under the European Union Habitats Directive as one of only two turlough sites in the United Kingdom, the other being Pant y Llyn in South Wales.

Roosky Quarry is situated between Fardrum and Roosky turloughs and has two parts, the "old" and "new" quarries. The old quarry is thought to have been first worked about 70 years ago and to have been dormant for about 30 years. The new quarry is thought to have been first worked around 50 years ago and to have been dormant until 2002 when blasting and stone extraction recommenced under an existing planning permission that dated back to 1978. One of the conditions attached to this permission is that: *"The maximum depth of excavation shall not exceed the lowest part of the existing quarry floor and shall not penetrate the water table"*.

The paper will outline research commissioned by the Environment and Heritage Service to clarify the hydrogeology of the area and the extent of quarrying impacts on the turloughs. The question of what constitutes a 'water table' in a karstified aquifer will also be examined.

A shot in the dark: Identification of a fatal projectile injury in the skeletal remains of a young woman excavated from Feizor Nick Cave, North Yorkshire, UK.

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The skeletal remains of a young woman were discovered in Feizor Nick Cave during an early 20th Century archaeological excavation. Reanalysis of her remains identified a possible unhealed wound in her spine from a sharp-edged weapon. A small cut was noted in the anterior surface of the 12th thoracic vertebral body, the front of the spinal column just under the rib cage. This cut mark was not commented upon in the earlier anthropological report as it was thought to be caused by excavation tools. A sample of her skeleton was submitted for radiocarbon dating and generated an Early Bronze Age date (3720 ± 30 BP; 2210 – 2030 BC).

Whilst finds of embedded projectile points in human and animal bone are not uncommon in the archaeological record, identification of such wounds in the absence of embedded points are rare. Previous experimentation involving archaic projectiles has not examined the

effects of stone-tipped arrows and spears on bone. Current experimental research involves impacting animal bone with flint-tipped arrows, shooting arrows at bone targets and impacting bones with flint points using a charpy impact tester. Preliminary results indicate that positive identification can be made, both grossly and microscopically, of bony trauma caused by flint projectiles and compare well with this archaeological example of a suspected arrow wound. The arrow would have passed through her body under the ribcage and glanced off her spinal column, causing much visceral damage and internal haemorrhage. The skeletal evidence suggests that this young woman died of injuries sustained in a fatal assault from a flint projectile fired from a bow; her body was then placed in a shallow grave within the cave.

In sickness and in health: Earlier Neolithic human mortuary activities in Yorkshire caves and rock shelters.

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Most of the human remains from caves in the Yorkshire region were considered to be Late Neolithic or Bronze Age articulated burials. A reanalysis by the author of skeletal material from more than twenty subterranean sites has highlighted the complexity and significance of these sites and their relationship with other features in the landscape. A radiocarbon dating programme has identified a group of Earlier Neolithic cave sites near Settle, North Yorkshire; these dates represent the earliest evidence for human deposition in this upland region.

Research focused on two main questions – who were these people and why were they placed in these liminal locations? Taphonomic and anthropological analysis has identified unusual post mortem treatment of some of these remains and this will be discussed with regard to an individual's age and manner of death, physical disfigurement and evidence of disability in the skeletal record. There would seem to be an association between tufa formation and the deposition of human remains at these sites, deceased infants appear to have been placed directly into the tufa, encasing their bones. During the Romano-British period, tufa was thought to symbolise rebirth and was incorporated into temple sites as a building material. Can we see the origins of this ideology in the caves and rock shelters of North Yorkshire?

Interpretation of isotope proxies and variability in a mid-latitude savanna: the Cold Air Cave stalagmites, Makapans Valley, South Africa.

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The Cold Air Cave project consisted of monitoring the conditions in a relatively small but enclosed dolomitic cave system in the Makapans Valley, and analysis of at least 2 continuous speleothem records, one a 6.5 Ka aragonitic (T7) and the other a 24 Ka part-calcite/part-aragonite stalagmite (T8). The results have been published; here I will discuss some of the implications the oxygen and carbon isotope data and the scale and frequency of variability. The scale of variability in the $\delta^{18}\text{O}$ series was immediately observed to be high, and the relationship to temperature direct rather than inverse, in direct contrast to the sole existing southern African speleothem record at that time, the Congo Cave stalagmite. However, the isotopic records for the two stalagmites agree well where overlap occurs, imparting confidence that the climate records are robust, and the results of our monitoring exercise and comparison with regional records all point towards an interpretation of the $\delta^{18}\text{O}$ series as reflecting primarily $\delta^{18}\text{O}$ of precipitation. The $\delta^{13}\text{C}$ reflects the relative proportions of C_3 and C_4 vegetation in the catchment, but the shifts and trends in vegetation are only intermittently concordant with those in $\delta^{18}\text{O}$. The main trends for both the $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ records of T8 in the late Pleistocene are low

frequency quasi-periodic shifts. The glacial to interglacial shift is marked by a sharp change in mineralogy from calcite to aragonite followed by a hiatus, and isotope differences are mostly explained by this shift. In the Holocene the $\delta^{18}\text{O}$ trend is from more positive to more negative values culminating at AD 1700. Trends for $\delta^{13}\text{C}$ differ, from lower values in the early Holocene to higher values at 2–2.5 Ka. Wavelet transform analyses on T8 show that greatest strength in $\delta^{18}\text{O}$ variability occurred in the 4 and 0.75–1 Ka ranges, along with frequency and amplitude modulation. The higher frequency end of the spectrum is very noisy and there is little indication of the presence of an 18–20 year cycle expected by climatologists. Surprisingly, the ~4 Ka oscillation is more consistent and prominent in the $\delta^{13}\text{C}$ series, as is a band centred within 0.5–1 Ka. These observations may suggest that controls on vegetation and rainfall cycles in these middle latitude zones are influenced more strongly by sub-precessional (and precessional) scale variability than by large-scale glacial-interglacial shifts.

Quaternary sea level and palaeoclimate from submerged speleothems.

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Sea level records provide important information on land, sea and ice distribution interactions and palaeoclimate. Previous sea level data has been derived from a number of sources. Raised coral reef terraces provide an important radiometric ($^{230}\text{Th}/^{234}\text{U}$) source of sea level data. The record is however predominantly for high sea stands, with only very few records of low stands derived from corals sampled in boreholes. The most complete coral terrace record has been obtained from the Huon Peninsula, Papua New Guinea though issues regarding the accuracy of the elevation are caused by uncertainty in the rate of tectonic uplift. $\delta^{18}\text{O}$ from benthic foraminifera provides a useful proxy for ice volume and thus sea level change though care has to be taken to avoid samples affected by diagenesis and post mortem re-working. Beyond the limits of ^{14}C , the dating of ocean cores is however only by correlation. Diagenesis also limits the accuracy with which sea level data derived from marine molluscs and ooids in raised beach deposits can be dated, though good results can be obtained in arid areas. Marine notches and palyforms can also be used to constrain the elevation of former sea levels, however more recent reoccupation may modify and destroy older records, and dating may be problematical. Submerged terrestrial deposits and particularly forests have also been used as accurate sea level indicators. Records of ice-rafted debris are potentially useful for glacial times but are sparse and due to chronological uncertainties the analysis is restricted to the broader glacial-interglacial timescales only.

This project aims to establish ages and elevations of Quaternary sea levels via analysis of speleothems from submerged caves. Speleothems form in karst regions as secondary calcite deposits due to the degassing of CO_2 from percolating ground waters. The resultant calcite structure is frequently dense and macro-crystalline, which impedes chemical migration of isotopes and inhibits recrystallisation allowing for ^{238}U -, ^{234}U -, ^{230}Th dating to high precision and accuracy. Speleothems only form in subaerial conditions and often contain continuous growth periods constraining low sea stand ages. Coastal locations provide an opportunity to sample submerged speleothems that ceased growth during flooding in response to rising sea levels. Other means for dating changes in relative sea level can be obtained from subaqueous speleothems. Phreatic crystalline deposits and marine encrustations of serpulid worms form high sea stand overgrowths. The early colonizing boring mussel *Lithophaga lithophaga* can also provide data for the initiation of submergence.

This project aims to address the lack of current low sea stand data. Employment of the highly precise multiple collector inductively coupled plasma mass spectrometric (MC-ICP-MS) ^{238}U -, ^{234}U -, ^{230}Th dating technique allows for dating of top and basal ages to obtain timing of initiation and cessation of sample growth. The samples presently being analysed are from nine cenotes located in

the tectonically stable Yucatan Peninsula, Mexico. The samples are from a depth of up to 24.5m below present sea level and potentially provide a 400 ka sea level record. Further sampling is to be undertaken in Bermuda and the Bahamas, where there are comparative coral reef sea level records. Submerged speleothems from Bermuda provide the project with a marine isotope stage (MIS) 5 record allowing for the limited research on the lower stages to be expanded. Glacial sea levels for MIS 4 and 6 may also be constrained from the deeper cave system of the Guardian Blue Hole, Bahamas.

Cave development on the Caribbean coast of the Yucatan Peninsula, Quintana Roo, Mexico.

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Extensive flooded cave systems are developed in a zone 8 to 12km inland of the east coast of the Yucatan Peninsula, Quintana Roo, Mexico. In plan, the systems comprise cross-linked anastomosing networks, composed of horizontal elliptical tubes (which are actively developing where associated with the present fresh/saline water mixing zone), and canyon-shaped passages. Both forms are heavily modified by sediment and speleothem infill, and extensive collapse. The pattern of Quintana Roo caves differs both from the mixing chamber form of flank margin eogenetic caves, and also the dendritic and rectilinear maze patterns of epigenetic continental (telogenetic) caves. Unlike the latter, Quintana Roo caves are formed by coastal zone fresh/saline water mixing processes. Whilst mixing dissolution is also responsible for development of flank margin cave development, these may be typical of small islands and arid areas with limited coastal discharge, whereas Quintana Roo type caves are formed when coastal discharge is greater.

In the Quintana Roo caves, multiple phases of cave development are associated with glacio-eustatic changes in sea level. Two critical bifurcations control cave development following low stands; first whether the passage remains occupied by the mixing zone and connected to underlying deep cave systems, and second for passages above the mixing zone, whether active fresh water flow is maintained by tributaries. In the first case, inflow of saline water drives mixing dissolution, enabling removal of the low-stand carbonate fill, and continued passage enlargement. In the second, despite limited dissolution in the fresh water, continued removal of uncemented sediments can maintain the cave void. Where neither of these conditions is met, enlargement will cease and the cave void will become occluded by collapse and sediment infill.

The diet of the Cave Spider *Meta menardi* (Latreille 1804), (Araneae-Tetragnathidae).

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This study investigated the range and number of prey consumed by a population of *Meta menardi* in an abandoned mine drainage adit at Mary Tavy, on the edge of Dartmoor (Devon, UK). The adit was visited each month from October 1997 to November 1998 and any spider found feeding was interrupted and its prey removed and preserved in alcohol. Over the 13 months a total of 69 prey were recovered representing 18 taxa. While a number of flying insects used the adit as a refuge in which to over winter they formed a small percentage of the total prey consumed. Most of the prey were members of the soil or litter fauna that were observed walking over the surface of the adit walls.



THESIS ABSTRACT

Inception and development of conduits in the Cuilcagh Karst, Ireland.

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PhD thesis, November 2005

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This thesis explores speleogenesis within the Dartry Limestone Formation of Cuilcagh Mountain by considering the hydrogeology of the aquifer in the modern setting but also by considering its evolution since it was deposited during Asbian (Dinantian) times. Due to a regional synclinal structure, which plunges gently northwestwards, the aquifer remains buried beneath the upland and is not exposed to the south. However, the formation crops out along its northern and eastern upland margins where resurgences drain the aquifer via an extensive cave system network that includes Marble Arch Cave. In the west, the aquifer lies near surface but a significant artesian resurgence, Shannon Pot Rising, emerges from the aquifer via c.20m of overlying sandstones and shales. Water tracing experiments undertaken during this research project have added significant clarity to the hydrological regime that operates within this karst aquifer. These tests have shown that whereas extensive conduit systems are present at the eastern and northern margins of the uplands, Shannon Pot Rising in the west is the outlet for a regional conduit system that operates beneath Cuilcagh Mountain where the aquifer remains buried and in places confined. Water tracing has also identified that the boundary between the regional and marginal systems correlates to an igneous intrusion, the Cuilcagh Dyke. Hydrochemical data from Shannon Pot Rising indicate that the regional system has both shallow and deep flow components. This and hydrogeological evidence indicate that Shannon Pot developed as an overflow and that its conduits formed at depth and unrelated to surface processes. Study of the cave systems at the eastern and northern margins have identified a number of lithological discontinuities within the sequence that have guided conduit inception within the aquifer. These early systems were later modified when the aquifer became unconfined and surface karst landforms developed.



A Geophysical Investigation into imaging large cavities within karst limestone environments

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MSc thesis, Submitted for the MSc Exploration Geophysics, 2005-2006

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Large caverns are a relatively uncommon feature within the subsurface of a karst limestone environment and are often the subject for geological, biological, engineering and speleological studies, as well as having a large appeal to cavers and potholers.

A geophysical field survey was undertaken over the cave system of Lamb Leer in the Mendip Hills in North Somerset during July, 2006, in order to ascertain the existence of, and determine the location of Palmer's Chamber, a large phreatic cavern within karst limestone.

Four standard electrode arrays, using an Iris Syscal 72 channel resistivity static system, were tested across the Main Chamber, a