Unfortunately, there are two obvious difficulties. Firstly, since $\delta\omega << \omega$ the phase shift is very small – a second-order effect. Secondly, the phase will be distorted considerably by the use of a tuned antenna; not only because of the tuning itself, but also due to the temperature-dependent properties of the antenna's tuning capacitor. The very small phase shift is not, in itself, an insurmountable problem because phase is maintained during demodulation, effectively expanding it in time. However, because of these difficulties I also investigated the possibility of measuring the relative amplitude of the sidebands.

Whereas the phase measurement involves a second-order term, the amplitude measurement is a first-order expression – it is larger in magnitude and does not depend on dispersion. It could therefore be conjectured that, in a practical system, it could be responsive to different geological conditions. In fact, it is known with existing techniques that certain anomalies cause phase discrepancies whereas others cause amplitude discrepancies. Additionally, it would seem to be an easier technique to implement than the phase measurement.

I have described how, by transmitting a suitably designed signal, it can be decoded at the receiver *without* the need for an independent phase reference, to give a parameter which is *assumed* to be related to the conductivity of the ground. This could be a significant advantage in remote sensing methods, especially in the original context of the research, which was coal-seam tomography. In this summary, however, I have glossed over the problem of converting the phase constant into a conductivity measurement, which is difficult, due to the different behaviour of the near and far fields. However I conjecture that it does not really matter if we cannot easily derive the conductivity 'as such'. Even a single electrical resistance measurement does not give us an unambiguous conductivity, since this term is not possible to define in a non-homogenous earth. And in any case, tomographic techniques do not depend on an accurate knowledge of how the signals relate to conductivity. The simpler tomographic algorithms, for example, assume that the fields propagate as rays, which is certainly not the case. The more advanced algorithms allow for the spreading of the field without needing to know the exact process.

What I have described amounts to a new technique, which provides two 'figures of merit' for through-rock propagation – one based on phase and one on amplitude. It does not matter exactly *what* is being measured – they are just two more sets of data that can be collected and, hopefully, usefully interpreted.

A further development of the technique arises because the transmitted signal is a modulated carrier. This suggests that we could consider using an existing broadcast transmission as the source. The technique of prospecting by using a radio receiver on the surface to detect the polarisation of a broadcast transmitter is well known – see, for example, [Phillips and Richards, 1975]. The polarisation is affected by secondary fields, and it changes near to cavities, mineralised areas, fault lines and so on. Detecting the relative phase shift of the sidebands of a broadcast signal may be more practical than detecting a change in polarisation (although the circuitry is more complicated and there are points to be aware of, concerning antenna phase shift, as noted above). The new technique may not detect exactly the same anomalies as earlier techniques but, nevertheless, here are two new parameters to measure, which may give rise to some interesting results when used as passive prospecting tools.

References

Gibson, D, 2014. Using Dispersion to Measure Ground Conductivity. CREGJ(**85**), 7–8,19.

[Available at **doi.bcra.org.uk/j085007**.]

Phillips, W J and Richards, W E, 1975. A Study of the Effectiveness of the VLF Method for the Location of Narrow-Mineralised Fault Zones. *Geoexploration,* Vol.13, 215–226.

Stolarczyk, L G, 2004. Synchronous Radio-Imaging of Underground Structures. United States Patent 6744253.

David Gibson

Leeds, UK.

Abstracts

25th British Cave Research Association Cave Science Symposium

Jointly sponsored by BCRA and GEES

Saturday 25th October 2014

School of Geography, Earth and Environmental Sciences, University of Birmingham, UK

Presented in alphabetical order of speaker's surname (underlined)

Soil Carbon Export characterized using Novel Tracers (SCENT): a programme of research linking soil behaviour and speleothem archives *POSTER*

Clément Bourdin[1], James Baldini[2], Rebecca Bartlett[1], Paula Boomer[1], Ian Fairchild[1], Adam Hartland[3], Nicholas Howden[4], Chaoyong Hu[5], Wolfgang Müller[6], Fred Worrall[2] and Peter Wynn[7]

[1] *School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, B15 2TT, UK.*
Email: C.Bourdin@Bham.ac.uk
[2] *Department of Earth Sciences, Durham University, Science Labs, South Road, Durham, DH1 3LE UK.*
[3] *Environmental Research Institute, School of Science, Faculty of Science and Engineering, University of Waikato, Hamilton, New Zealand.*
[4] *Department of Civil Engineering, University of Bristol, Queen's Building, University Walk, Clifton, Bristol BS8 1TR, UK.*
[5] *State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan, 430074, China.*
[6] *Department of Earth Sciences, Royal Holloway, University of London, Egham Hill, Egham, Surrey, TW20 0EX, UK.*
[7] *Lancaster Environment Centre, University of Lancaster, Lancaster, LA1 4YQ, UK*

Recent work (e.g. Hartland *et al*., 2012, 2014) has focused on the role of natural organic matter as an agent of transport of transition elements and other trace species present in cave dripwaters and speleothems. As a result, attention is focusing on the role of speleothem chemistry as an archive of past delivery of organic matter and hydrological conditions. At the same time, a different community of researchers has been concerned about increasing levels of (nominally) dissolved organic carbon (DOC) in temperate rivers in recent decades and whether this water quality issue arises from temperature rise, recovery from former acidification of catchments, or some other cause. We are now funded by the UK's Natural Environment Research Council for a 3-year project led by one of us (RB) to combine these two research agendas in order to identify the main cause of increased levels of DOC.

We are adopting a combination of experimental and observational approaches, using soils and speleothems from four distinct locations with different environmental histories during the last 200 years. Heshang Cave in central China is in a region that is currently receiving acid atmospheric precipitation, whereas Yok Balum cave in Belize has never done so. Uamh an Tartair in NW Scotland only ever had a weak acidification signal, whereas Browns Folly Mine in SW England has made a recovery from a distinct phase of acid sulphate input. All these sites except Yok Balum have experienced warming in recent decades. Previous experimental studies by RB (Bartlett *et al*., 2005, 2009 and unpublished; Bottrell *et al*., 2009) show that microbial responses to sulphate addition can buffer acidity and might further complicate the soil DOC response to acid loadings under waterlogging conditions (Bartlett *et al.,* 2009; Bottrell *et al.,* 2009; Bartlett *et al*., 2005 and Bartlett *et al*.: unpublished data). Uamh an Tartair's peaty soils are most prone to waterlogging and hence potentially reducing conditions, whereas Heshang and Yok Balum appear to be freely draining. The $\delta^{34}S$ record at Browns Folly Mine implies little role for waterlogging there. Thus there is a clear rationale to connect the soil biogeochemical processes with the speleothem records.

The main work package is to implement a series of laboratory mesocosm soil column experiments to leach the soils with a basal neutralizing layer of carbonate rock, under different conditions of water chemistry and temperature. These experiments will be closely monitored for a variety of inorganic and organic determinands and will run over a year. We will explicitly test for the role of trace metals as proxies for organic matter transport and trace metal ratios as potential indicators of the variable proportion of functional groups on organic moieties released, which in turn may be controlled by environmental variables and soil biogeochemistry.

The results will be compared with multidecadal-scale data on organic carbon content of streams from the UK and laser-ablation ICPMS data on trace metals from speleothems in the study site combined with fluorescence characteristics. The speleothem data will be particularly valuable in enabling us to test the "recovery from acidification" hypothesis for the increase in riverine organic carbon, because the acidification is mainly a product of what has been termed the "great acceleration" of anthropogenic activity since World War II and the speleothems will trace back to an earlier pre- or low-industrial era.

References

Bartlett R *et al.*, 2009. ^{34}S tracer study of pollutant sulfate behavior in a lowland peatland. *Biogeochemistry*, Vol.95, 261–275.

Bottrell, S H *et al.,* 2009. Concentrations, sulfur isotopic compositions and origin of organosulfur compounds in pore waters of a highly polluted raised peatland. *Organic Geochemistry,* Vol.41, 55–62.

Bartlett, R *et al.,* 2005. Behaviour of sulfur during diagenesis of a maritime ombotrophic peat from Yell, Shetland Islands, UK. *Applied Geochemistry,* Vol.20, 1597–1605.

Hartland, A, Fairchild, I J, Lead, J R, Borsato, A, Baker, A, Frisia, S and Baalousha, M, 2012. From soil to cave: transport of trace metals by natural organic matter in karst dripwaters. *Chemical Geology*, Vols 304–305, 68–82.

Hartland, A, Fairchild, I, Müller, W and Domínguez-Villar, D, 2014. Preservation of colloid-metal complexes in a modern hyperalkaline stalagmite: implications for speleothem trace element geochemistry. *Geochimica et Cosmochimica Acta,* Vol.128, 29–43.

Measurement of scallops in a 10m-high vadose canyon in the Pool Sink section of Easegill Caverns, Yorkshire Dales, UK and a hypothetical post-deglacial timescale for the canyon entrenchment

David Checkley[1] and Trevor Faulkner[2]

[1]*Greenhead Barn, Cross Lane, Low Bentham LA2 7ES, UK.*
Email: bcra-chairman@bcra.org.uk
[2]*Limestone Research Group, Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.*
Email: trevor@marblecaves.org.uk

Understanding the vadose entrenchment of cave passages and relating this to the evolution of the external environment and climate has been little studied in the past. This report proposes a new technique to combine measurements of the lengths of wall scallops and their adjacent passage widths to determine the history of palaeo peak water velocity and volumetric flow rate in a vadose canyon. The study site is at an active 10m-high canyon in the Pool Sink section of the Easegill Cave System in the Yorkshire Dales, UK. This exhibits wall scallops continuously from its roof to its floor. The Sauter mean scallop lengths vary from 0.85 to 4.81cm and the canyon widths vary from 35 to 132cm. These enable water velocities at scallop dominant discharge to be calculated as varying from 76 to 548cm/sec. Peak flow rates are estimated to vary from 104 to 3581 litres/sec. Assuming a continuous entrenchment after the local Devensian deglaciation 18,000 years ago, this gives a mean floor lowering rate of 0.55mm per year. This seems reasonable, if both chemical and mechanical erosion applied. Based on this initiation hypothesis and assuming a constant entrenchment rate through time, the peak flow rates can be roughly correlated with known climatic changes during the Lateglacial and the Holocene. Studies of more sites in the Yorkshire Dales are required to ascertain if such estimates of peak recharges could provide reliable proxies for major climatic events.

Full paper:

Checkley, D and Faulkner, T, 2014. Scallop measurement in a 10m-high vadose canyon in Pool Sink, Ease Gill Cave System, Yorkshire Dales, UK and a hypothetical post-deglacial canyon entrenchment timescale. *Cave and Karst Science*, Vol.41(2), 76–83.

The influence of macroporosity on trace element chemistry in speleothems ***POSTER***

Laura Deeprose [1, 2, 3], Peter M Wynn [1], Ian Candy [2], Philip A Barker [1] and Andrew Smith[1]

[1] *Lancaster Environment Centre, University of Lancaster, Lancaster LA1 4YQ, UK*
[2] *Department of Geography, Royal Holloway University of London, Egham, TW20 0EX*
[3] *Email: Laura.Deeprose.2010@live.rhul.ac.uk*

Speleothems are known to frequently possess holes known as macropores. These macropores are larger than 1mm and are located throughout the carbonate fabric[1] .The formation of macropores is dependent upon location in the speleothem and two types of macropores have been identified; axial holes and off-axis holes[1,2]. Axial holes are the result of a slower rate of calcite precipitation and form parallel to the speleothem growth axis while off-axis holes are post-depositional features most likely formed due to drip water penetration through micro-fissures. Due to their modes of formation, the presence of macropores implies a degree of calcite alteration, most likely through dissolution and re-precipitation or potentially as a result of microbial activity[2]. Processes of dissolution and re-precipitation may be considered to influence the chemistry of the speleothem through calcite/water interaction via processes such as prior calcite precipitation (PCP) or incongruent dissolution[3, 4]. However, the effect of the macropores on speleothem chemistry has not previously been investigated. Laser ablation analysis was undertaken on a Late Holocene speleothem from Asiul Cave, northern Spain, possessing several macropores of both axial and off-axial origin. A series of laser ablation transects were taken at varying distances from the macropores to test if they had a significant impact on the trace element chemistry. Preliminary results demonstrate there to be no relationship between the trace element chemistry and the proximity to the macropores. Therefore, although dissolution processes have led to macroporosity within the speleothem sample, any processes of PCP or incongruent dissolution occurring during their formation do not appear to directly influence the trace element chemistry of the calcite within the analytical resolution of the laser ablation analysis. This study lends confidence for the use of these speleothem samples, which may otherwise have been discarded for use in chemical analysis and palaeo-climate reconstruction.

1. Shtober-Zisu, N, Schwarcz, H P, Konyer, N, Chow, T and Noseworthy, M D, 2012. Macroholes in stalagmites and the search for lost water. *Journal of Geophysical Research,* Vol.117, F03020.
2. Shtober-Zisu, N, Schwarcz, H P, Chow, T, Omelon, C R and Southam, G, 2014. Caves in caves: evolution of post-depositional macroholes in stalagmites. *International Journal of Speleology,* Vol.43(3) 323–334.
3. Sinclair, D J, 2011. Two mathematical models of Mg and Sr partitioning into solution during incongruent calcite dissolution: Implications for dripwater and speleothem studies. *Chemical Geology*, Vol.283(3), 119–133.
4. Sinclair, D J, Banner, J L, Taylor, F W, Partin, J, Jenson, J, Mylroie, J, Goddard, E, Quinn, Jocson, J and Miklavič, B, 2012. Magnesium and strontium systematics in tropical speleothems from the Western Pacific. *Chemical Geology,* Vol.294, 1–17.

Birds of a feather buried together: the Late Pleistocene avifauna of the Red Hills Road Cave, Jamaica ***ORAL and POSTER***

Arjan Boot[1] and Stephen K Donovan[2]

[1] *University of Leiden, 2300 RA Leiden, The Netherlands*
[2] *Department of Geology, Naturalis Biodiversity Center, Darwinweg 2, 2333 CR Leiden, The Netherlands.*
Email: steve.donovan@naturalis.nl

The Red Hills Road Cave (RHRC) or fissure, in the parish of St Andrew, Jamaica, is a karstic feature in mid-Tertiary limestones. It was dissected by a road before the late 1980s, since which time it has yielded the most diverse Late Pleistocene cave fauna known from the island. Many or most taxa may have been washed into the RHRC during tropical storms or hurricanes about 30,000 years ago. The fauna includes terrestrial gastropods (62 species), millipedes, isopods, the land crab *Sesarma* Say, rare insect remains, and bones and teeth of mammals (bats and the rodent *Geocapromys*), birds, lizards and amphibians.

The 'Irish Stew' preservation of this deposit has discouraged all but the most determined vertebrate palaeontologists. Although there are some 320 extant bird species known from Jamaica, only about ten have been recorded hitherto from the Late Pleistocene and none from earlier deposits. The RHRC has yielded a moderate diversity of birds, including the extinct flightless ibis *Xenicibis xympithecus* Olson & Steadman, as well as extant *Corvus jamaicensis* Gmelin (Jamaican crow), *Todus todus* Linné (Jamaican tody) and *Eremophila alpestris* Linné (horned lark). Indeterminate bones include members of the families Trochilidae (hummingbirds), Cuculidae (cuckoos) and Scolopacidae (sandpipers), and others belonging to the order Passeriformes (perching or song birds). Overall, at least eight species are represented, but there are probably somewhat more (30+?). The RHRC is therefore the most productive fossil bird site in Jamaica, yet still representing, at best, only about 10% of that alive today.

Testing the contribution of aerosol deposition to pigmented flowstones, Yarrangobilly Caves, NSW, Australia ***POSTER***

Jonathan Dredge[1,2], Rich Boden[3], Ian Fairchild[1,4], Roy Harrison[1], John Hellstrom[2] and Jon Woodhead[2]

[1] *School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham B15 2TT, UK.*
[2] *School of Earth Sciences, The University of Melbourne, Parkville, 3010, VIC, Australia.*
[3] *School of Biological Sciences, University of Plymouth, A421, Portland Square, Drake Circus, Plymouth, Devon, PL4 8AA, UK.*
[4] *Email: i.j.fairchild@bham.ac.uk*

Flowstone offers the potential to develop long-term palaeoenvironmental analyses, but this is typically limited by highly variable growth rates. Aerosol contributions to speleothem chemistry are expected to be maximized during times of slow growth (Dredge *et al*., 2013) and hence flowstone offers opportunities to examine the aerosol record. In dryland environments, fire incidence is of

considerable environmental interest. Here we test the hypothesis that blackened growth layers in flowstones and on modern surfaces at Yarrongobilly Caves relate to smoke or charcoal deposition. The caves are in an upland area of New South Wales (800m altitude) with a mean annual temperature around 12 °C and rainfall around 1000mm. Vegetation is of a sclerophyll type and soils are thin (<30 cm) and loamy to clay-rich, and organic-poor in composition, resting on Silurian limestones. Both Jersey Cave and Harrie Wood cave contain blackened modern horizontal surfaces and the former cave manager Andy Spate reports smoke entering the caves during a forest fire in 1985. Flowstone samples from Jersey cave were dated by U-series and trace element chemistry determined by laser ablation. Aerosol collections were made in both Jersey and Harrie Wood caves using surrogate surfaces for aerosol deposition and studied for their organic and inorganic chemistry and by scanning electron microscopy as were with flowstone residues. Some preliminary biochemical analyses were made in the modern caves.

U-Th dating established confirmed that flowstone growth was slow and intermittent. Sample JD1 grew 10cm during the last 120ka with a pronounced hiatus between 47 and 88ka and faster growth of pale calcite between 88 and 92ka. Black pigmentation is not restricted to narrow surfaces, but characterizes both hiatuses and cm-scale zones of growth. Some intervening zones of slow growth have red pigmentation. Samples JD2 grew at intervals between 400 and 45ka to a total of 7cm. There were insufficient dates to identify specific hiatuses, but a broad zone of black calcite characterizes the interval from 244 to <100ka. and red calcite between 244 and 290ka and beyond about 400ka.

Significant spatial variation was apparent in inorganic components of aerosol collections, but less so for organic components. In the black calcite a smaller range of organic compounds with lower molecular weight are incorporated at concentrations higher by a factor of 2-3 relative to white calcite. Dilute acid residues from flowstone appear primarily to be aluminosilicates with only one carbon-rich grain observed in electron microscopy. Trace element covariations were examined using principal components analysis and different patterns were observed with growth stage, although Fe was consistently highly loaded on the first principal component whereas Sr and Mg were consistently in the second component. P showed variable enrichment in black calcite (JD1) or red calcite (JD2), and Fe (with Th and Ce) in red calcite, and Mn in red calcite and intermittently in black calcite. Abrupt changes in trace element abundances are likely to reflect hiatuses in deposition and hiatus zones already known to exist from U-series chronology are seen to be enriched in various trace elements.

Polyaromatic hydrocarbon (PAH) aerosol supply in the modern environment, in the absence of fires at the time of monitoring, is orders of magnitude greater than that required to result in levels observed in both white and black flowstone concentrations. Modern PAH emission from anthropogenic activity will likely cause much higher atmospheric levels than historically. However, this suggests that forest fire PAH supply is not required to produce the PAH concentrations in black calcite. The absence of identifiable charcoal fragments in speleothem residues confirms that black coloration is not caused by soot. A relative enrichment of low molecular weight organic components may indicate fractionation during transport in dripwater. Aerosol deposition of elements such as Sr, Mg, Al, P and Zn, although spatially variable, is well in excess of that required to account for speleothem deposition at low mean growth rates (1.7µm/year for YD1) and hence, given that significant supply would also be expected from water during growth phases, element incorporation is highly inefficient. Currently oxygen isotope analysis is being carried out to help test the posited links between relative climatic humidity and the growth patterns of the speleothems.

Increased levels of palaeofire proxies in black calcite are predominantly attributed to reduced retention/increased incorporation due to climatic, soil and environmental processes and variable growth rates. Growth of red calcite is likely to occur during periods of oxygenated soils rich in Fe-oxide, with coloration simply being a representation of elemental transport from the overlying soils. Elevated P may mark vegetative die-back events and correlate with the transition to drier more oxic soils with Fe and Mn transport through organic complexing. PCA analysis results present an association between colloidally derived elements and coloration. Additionally, greater supply of bacteria in infiltrating waters may be occurring during periods of increased solution colloidal supply resulting in oxide bioaccumulation processes and coloration.

The modern blackened surfaces remain unexplained by inorganic processes and fire inputs and an alternative bacterial origin can be posited. Denaturing gradient gel electrophoresis analysis of swabs in the cave has identified Actinomycetes on blackened surfaces, and specifically by light microscopy *Hypomicrobium* spp., a bacterial strain found to produce iron and manganese oxides producing coloured deposits on cave surfaces in Guadalupe Caves. Hence coloured calcite could be produced both by diffuse incorporation of soil-derived colloids during relatively wet periods or relatively dry periods when more sharply defined element enrichments develop at hiatuses, with enhancements by bacterial fixation.

Dredge, J, Fairchild, I J, Harrison, R M, Fernandez-Cortes, A, Sánchez-Moral, S, Jurado, J, Gunn, J, Smith, A, Spötl, C, Mattey, D, Wynn, P and Grassineau, N, 2013 Cave aerosols: distribution and contribution to speleothem geochemistry. *Quaternary Science Reviews,* Vol.63, 23–41.

A 'hole' lot of trouble

Andy Farrant

Environmental Science Centre, British Geological Survey, Nicker Hill, Keyworth, Nottingham, NG12 5GG, UK.
Email: arf@bgs.ac.uk

The winter of 2013–14 will be remembered for the incessant rain and flooding, particularly in the Somerset Levels and across southeast England. However, it was not just the flooding that made the headlines. During a three week period in late February and early March, over 25 'sinkholes' opened up across southern Britain, compared to half a dozen or less in a normal year. These were widely reported by the media. Many of these events were not natural features but old chalk mine-workings or deneholes. Whilst sinkholes are not uncommon in the UK, it was unusual to have so many collapses occurring in a relatively short period of time. This presentation explores the background to these events, what causes sinkholes to form, and where they occur.

Hyperalkaline speleothem from Derbyshire: new observations on morphology and growth crystallisation

Lorraine P Field[1,2], Anthony E Milodowski[1], Simon J Kemp[1], Richard P Shaw[1] and Michael Ellis[1]

[1] British Geological Survey, Environmental Science Centre, Keyworth, Nottingham, NG12 5GG, UK.
[2] Email: lorfie@bgs.ac.uk

Unusual speleothem formation, associated with hyperalkaline (pH>12) groundwaters have formed within a shallow abandoned railway tunnel at Peak Dale, Derbyshire. The hyperalkaline groundwaters are produced by the leaching of a thin layer (1–2 m) of old lime kiln wastes that were dumped on the soil-bedrock surface above the tunnel. Rainwater percolating through this lime waste leaches portlandite ($Ca(OH)_2$) formed by the hydration of lime (CaO) and potentially other clinker phases in the limewaste (e.g. calcium silicates and aluminates), giving rise to high pH Ca–OH-type groundwater that is close to portlandite-saturation (approximately pH 12.5), which discharges through fractures in the roof of the tunnel below. This setting causes a different reaction and chemical process to that associated with the formation of traditional calcium carbonate speleothems formed from Ca–HCO_3-type groundwaters normally associated with limestone. At pH 12.5 any carbonate species in solution will be dominated by CO_3^{2-} rather than HCO_3^-. Furthermore, the solubility of $CaCO_3$ in these Ca-OH-type dripwaters is extremely low, and therefore CO_2 is sequestered from the atmosphere resulting in the following reaction:

$$Ca^{2+}_{(aq)} + OH^-_{(aq)} + CO_{2(g)} \leftrightarrow CaCO_{3(s)} + H^+_{(aq)}$$

Stalagmites within this tunnel have an unusual morphology comprising a central sub-horizontally-laminated column of micro- to nano-crystalline calcium carbonate encompassed by an outer sub-vertical ripple-laminated layer. We present the results of a detailed petrological study of the morphology and formation mechanisms of these stalagmites. The stalagmites are composed of calcite, which is shown to be a secondary phase; some pseudomorphs of vaterite are present (<5 µm) but the bulk of the stalagmites comprises larger pseudomorphs (<1 mm) which we believe to be after ikaite (calcium carbonate hexahydrate: $CaCO_3.6H_2O$). Ikaite is often referred to as the 'cold climate calcium carbonate polymorph' (Marland 1975); the first naturally occurring example was identified in Ikka Fjord in Southwest Greenland (Pauly 1963). This polymorph is metastable at ambient pressures and temperatures. However, the tunnel has a constant temperature of 8°C, which is above the potential crystallisation temperatures suggested by experimental work. This indicates precipitation occurs at temperatures close to zero (Bischoff *et al*., 1993). Analysis of a stalagmite actively growing at the time of sampling and preserved immediately following sampling within a dry nitrogen cryogenic vessel, suggests that decomposition to calcite is almost instantaneous following crystallisation of ikaite. Although ikaite has recently been discovered forming during cold weather in superficial tufa deposits associated with high pH springs discharging from lime waste (Milodowski *et al*., 2014), we believe this is the first recorded occurrence of this calcium carbonate polymorph observed within speleothem.

Bischoff, J L *et al.*, 1993. The solubility and stabilization of ikaite ($CaCO_3.6H_2O$) from 0° to 25°C: environmental and palaeoclimatic implications for thinolite tufa. *Journal of Geology,* Vol.101(1), 21–33.

Marland, G, 1975. The stability of $CaCO_3.6H_2O$ (ikaite). *Geochimica et Cosmochimica Acta,* Vol.39(1), 83–91.

Milodowski, A E *et al.,* 2014 in press. The formation of ikaite ($CaCO_3.6H_2O$) in hyperalkaline springs associated with the leaching of lime kiln waste. *Goldschmidt 2014 Abstracts, Mineralogical Magazine,* 1697.

Pauly, H, 1963 "Ikaite", a new mineral from Greenland. *Arctic,* Vol.16, 263–264.

Speleothem and sediment from Water Icicle Close Cavern, Derbyshire, UK

John Gunn[1], Jon Dredge[1], Ian Fairchild[1], David Lowe[2] and Richard Shaw[3]

[1]Limestone Research Group, School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
Email: j.gunn.1@bham.ac.uk
[2]23 Cliff Way, Radcliffe on Trent, Nottingham, NG12 1AQ, UK.
[3]British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK.

Recently discovered cave passages in Derbyshire contain speleothems that give insight into tectonic activity and climate within the last 100 ka and imply that Neogene sediments covered a much larger area than previously known.

The entrance to Water Icicle Close Cavern (WICC) is ~1.6km southsoutheast of Monyash in the 'White Peak' District. The cave is of particular interest as the 32m-deep entrance shaft, which was excavated by miners through solid limestone, gives access to over 500m of large (up to 4m diameter) relict phreatic passage at an elevation of ~ 306m aOD. This is about 110m above the present local base level for drainage, taken to be the lowest of the Holme Grove Risings, which for most of the year form the source of the River Lathkill. Although there are remnant cave passages at high elevation above base level elsewhere in the Peak District, this is the only known laterally extensive cave system and it is also notable for being 5km from the nearest outcrop of the Millstone Grit Group rocks.

In 2009 Orpheus Caving Club members excavated a route through the boulder choke that had been the previous limit of exploration in the Northwest Passage and entered a pristine section of passage that, despite having no sign of previous human visitors, contained a great deal of broken speleothem. The results of TIMS Uranium-series dating, funded by the BCRA, suggest that the breakage occurred during a tectonic event about 86,000 years ago.

The new passage also contains a rounded quartz / quartz feldspar sandstone / ferruginous quartzite pebble assemblage that is unlike any found in other Peak District caves or in the limited surface glacial deposits. Similar pebbles are present in the Neogene Brassington Formation, having previously been part of the "Bunter Pebble Beds" (Sherwood Sandstone Group), and our initial hypothesis is that the pebbles in WICC are most recently derived from the Brassington Formation. At present the nearest Brassington Formation deposits are about 2 km to the south of WICC and their presence in the cave suggests that that the formation once extended over a larger area.

Multi-speleothem records reveal tightly coupled climate between Central Europe and Greenland during MIS 3.

Gina E Moseley[1,5], Christoph Spötl[1], Anders Svensson[2], Hai Cheng[3,4], Susanne Brandstätter[1] and R Lawrence Edwards[3]

[1] Institute of Geology, University of Innsbruck, Innrain 52, 6020 Innsbruck, Austria.
Email: gina.moseley@uibk.ac.at
[2] Centre for Ice and Climate, Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, DK-2100-Copenhagen, Denmark.
[3] Department of Earth Sciences, University of Minnesota, 310 Pillsbury Drive SE, Minneapolis, MN 55455, USA.
[4] Institute of Global Environmental Change, Xi'an Jiaotong University, Xi'an 710049, China.
[5] *Email: gina.moseley@uibk.ac.at*

Marine Isotope Stage 3 (MIS 3, c. 60-29ka BP) was punctuated by abrupt, millennial-scale climate changes that varied not only in character, but also temporally and spatially across the globe. The exact timing and the regional response to those climatic changes are of vital importance for understanding their cause and effects. Here, we present a series of high-resolution stalagmite records from a cave in the Northern Alps covering sections of the period 35–65ka BP. The climatic pattern revealed by the stalagmites temperature-controlled stable isotope ($\delta^{18}O$) profiles strongly resembles that of the Greenland ice cores on not only millennial-scales, but also to the detail of decadal-scale cooling events within interstadials. This demonstrates for the first time a strong climatic similarity/coupling between the two regions during MIS 3. An overall long-term agreement between the stalagmite and ice-core age models suggests an overestimation of the Greenland chronology error estimate in this period.

Full paper:

Gina E Moseley, Christoph Spötl, Anders Svensson, Hai Cheng[4], Susanne Brandstätter, and R Lawrence Edwards. 2014. Multi-speleothem record reveals tightly coupled climate between central Europe and Greenland during Marine Isotope Stage 3. *Geology* doi: 10.1130/G36063.1

Rates of calcite precipitation from the hyperalkaline waters of Poole's Cavern, Derbyshire, UK

Kate Newton

School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
Email: ken155@student.bham.ac.uk

The mechanisms and controls of calcite precipitation from normal pH waters are relatively well researched and understood. However, more recently, hyperalkaline waters (pH > 9.5) have been seen to give rise to calcite deposits forming through a completely different mechanism, with abnormal properties, mostly as a result of anthropogenic activity. Although various theoretical studies have suggested the important role of atmospheric CO_2 in their formation – being taken into solution and used in the reaction – few observational studies have been undertaken to validate this. Poole's Cavern is a large tourist cave in Buxton, Derbyshire, which hosts a variety of speleothems, including some of these unusual calcite deposits, formed as a result of lime waste overlying the cave altering the chemistry of some of the water flowing through the limestone. The fact that these occur within a natural cave system, alongside normal speleothems, makes it an excellent natural laboratory in which they can be studied. Here, calcite samples were collected over various time periods from selected normal pH and hyperalkaline drips within Poole's Cavern, and precipitation rates determined. Dripwater pH and electroconductivity values were measured, as well as temporal variations in drip rates and partial pressure of CO_2 (pCO_2) of cave air from the various areas of the cave. $\delta^{18}O$ and $\delta^{13}C$ values of selected samples were also analysed. Precipitation rates were analysed in relation to varying environment factors on a seasonal and diurnal timescale.

The results demonstrate a clear difference in calcite precipitation rates from normal or high pH waters; the latter being significantly greater, by a factor of 25–30. In addition, isotopic signatures of these fast-growing speleothems show strong depletions in ^{18}O and ^{13}C compared to those formed from normal pH dripwaters, as a result of kinetic fractionation. Variations in calcite precipitation rates in relation to changing cave air pCO_2 levels and drip rates were analysed on a seasonal and diurnal timescale. Changes in cave air pCO_2 are observed to have a clear control where drip rates are stable, on a seasonal timescale. For a hyperalkaline drip, this means greater precipitation rates where cave air pCO_2 is high (generally during summer months): up to c. 35mg day^{-1}, and as low as 10mg day^{-1}. The opposite is true for a normal pH drip, decreasing as pCO_2 increases, ranging between c. 1.7 and <0.1mg day^{-1}. Where drip rate is particularly slow and variable, this is seen to become an important control on precipitation rate, in addition to pCO_2. The rapid growth rate allowed the opportunity for precipitation rates to be analysed on a diurnal timescale for the very first time. However, due to the limited time period in which samples could be collected, a diurnal variation was not identified here. It is apparent, however, when these are compared to samples collected over a longer time period that precipitation rates are lower than expected, likely relating to nucleation effects.

Cave archaeology in Isla de Mona, Puerto Rico

Alice V M Samson[1], Jago Cooper[2] and Rolf Vieten[3]

[1] British Academy Postdoctoral Fellow, McDonald Institute for Archaeological Research, University of Cambridge, CB2 3ER, UK;
Email: avms2@cam.ac.uk
[2] Curator of the Americas, Africa, Oceania and Americas, British Museum, Great Russell Street, London, WC1B 3DG, UK;
Email: jcooper@britishmuseum.org
[3] University of Puerto Rico, Mayagüez
Email: rolf-martin.vieten@upr.edu

This paper presents the first season of archaeological fieldwork in one of the most cavernous locations on Earth, the small (50km^2) limestone/dolomite island of Mona, in the Caribbean. The island's 200+ caves have attracted human activity for over 5000 years, and were possibly the primary motivation in many periods for visiting the island. The archaeology of Mona is being put at increased risk due to the vulnerability of the cave deposits and growing tourist numbers.

Archaeological fieldwork in multiple caves has identified a range of historic and pre-Columbian (pre-AD 1492) activities including historic drawings and inscriptions from as early as the 16th century, to evidence for 19th century guano mining. Fieldwork in June 2014 focussed on the earliest, pre-Columbian subterranean activities, identifying over 20 caves with extensive human modification. This includes the use of pigments and finger fluting on the walls and ceilings, as well as extensive extractive activities of cave wall deposits. These activities, leaving complex designs, many unique in the Caribbean, cover hundreds of square metres of the darkest caverns and tunnels, typically located in hard to access areas with no natural light and associated with sources of water.

One of the principal aims of the 2014 fieldwork was a sampling programme to collect dateable material to build a chronology of the human activity using Uranium–Thorium and Carbon-14 dating techniques. Small samples of flowstone which had formed over anthropogenic modification such as finger fluting, and on top of archaeological floors were collected for application of Uranium-Thorium dating. Where possible, samples of organic materials for radiocarbon dating, such as archaeological charcoal and shell, were collected from the same contexts to allow comparison of dating methods. This paper presents the fieldwork aims, preliminary results and describes the sampling programme.

Millennial scale control of European climate by the North Atlantic Oscillation from 12,500 BP: The Asiul speleothem record

Andrew C Smith[1,4], Philip A Barker[1], Melanie J Leng[2, 3], Stephen R Noble[2], Wlodek Tych[1] and Peter M Wynn[1]

[1] Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, UK.
[2] NERC Isotope Geosciences Facility, British Geological Survey, Nottingham, NG12 5GG, UK.
[3] Centre for Environmental Geochemistry, University of Nottingham, Nottingham, NG7 2RD, UK.
[4] Email: a.smith8@lancaster.ac.uk

Contemporary climate in Europe is strongly influenced by the North Atlantic Oscillation (NAO), the atmospheric pressure dipole between Iceland and the Azores[1]. Under positive NAO conditions winter storm tracks associated with the Atlantic Westerly Jet (AWJ) migrate northwards, leading to wetter and warmer winter conditions in north-western Europe and dry conditions in southern Europe; including the Iberian Peninsula. Under the negative NAO phase, storm tracks weaken and shift southwards reversing the pattern[1]. Existing proxy records of the NAO suggest that this atmospheric process only began to dominate European climate at approximately 8000 years BP, related to the final breakup of the Laurentide ice shelf[2]. However, here we present evidence of precipitation changes from a high-resolution speleothem $\delta^{18}O$ record from northern Iberia, which indicates NAO-like forcing extending throughout the Holocene and into the Younger Dryas (YD) at 12,500 years BP. These variations in precipitation delivery relate to an underlying millennial scale cycle in NAO dynamics. The speleothem $\delta^{18}O$ is strongly correlated to existing records of North Atlantic Ocean ice rafted debris (IRD)[3], indicating an NAO-like connection with oceanic circulation during the Holocene[2]. These large-scale atmospheric processes have dramatically influenced the delivery of precipitation to northern Iberia and may have played a decisive role in environmental and human development in the region, throughout the Holocene.

[1] Hurrell *et al.,* 2001. *Science,* Vol.291, 603–605.
[2] Giraudeau *et al.,* 2010 *Quaternary Science Reviews,* Vol.29, 1276–1287.
[3] Bond *et al.,* 1997. *Science,* Vol.278, 1257–1266.

Multiple U-Th-Pb techniques applied to speleothems: climate and landscape evolution applications

Christopher J M Smith[1,2,6], David A Richards[1,2], Daniel J Condon[3], Matthew S A Horstwood[3], Noah McLean[3], Stephen R Noble[3], Randal R Parrish[3], Jon D Woodhead[4] and Derek C Ford[5]

[1] School of Geographical Sciences, University of Bristol, University Road, Bristol BS8 1SS, UK.
[2] Bristol Isotope Group (BIG), School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol BS8 1RJ, UK.
[3] NERC Isotope Geosciences Laboratory (NIGL), Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG, UK.
[4] School of Earth Sciences, The University of Melbourne, Parkville, VIC 3010, Australia.
[5] School of Geography and Earth Sciences, McMaster University, Hamilton, ON, L8S 4K1, Canada.
[6] Email: chris.smith@bristol.ac.uk

Speleothems are widely recognised as valuable archives of palaeoenvironmental change capable of delivering accurate and precise chronologies for materials up to ~ 500 ka old using the U-Th decay scheme (Richards and Dorale, 2003). For materials at or approaching secular equilibrium the development of U-(Th-)Pb dating techniques has created new opportunities in speleothem research, leading to fresh insights into climate change, landscape development, tectonics, and human and faunal evolution and migration, see review by Woodhead and Pickering (2012). However, widespread adoption of the U-Pb decay scheme for speleothem dating has been hampered by the need to accurately and precisely predict the initial state of U-series disequilibrium (i.e. $(^{234}U/^{238}U)_{initial}$) for materials at or analytically indistinguishable from secular equilibrium, in addition to difficulties associated with identifying samples with a sufficient range of U/Pb ratios to provide high precision isochron age determinations. These challenges are further compounded by the labour intensive nature of current U-Pb dating methods, which employ isotope dilution (ID) and either TIMS or MC-ICP-MS analysis.

Here, we present results demonstrating the potential of U-Pb dating by laser ablation (LA) MC-ICP-MS for a suite of speleothems from Canada, Australia and UK, spanning the Late Pliocene to the Late Pleistocene, exhibiting variable U (1-100μg g^{-1}) and low non-radiogenic Pb (<50ng g^{-1}). To resolve issues of initial disequilibrium, we have adopted a combined U-Th-Pb dating strategy to take full advantage of the sensitivity and spatial resolution of all of the following techniques for individual growth layers: (1) in-situ U-Pb LA MC-ICP-MS (193nm ArF excimer laser) techniques, which enables fast throughput, high spatial resolution and a wide range in U/Pb for individual spots; (2) conventional U-Pb ID TIMS and MC-ICP-MS, for high-precision three-dimensional isochrons at lower spatial lower resolution; (3) U-Th MC-ICP-MS static Faraday methods, to obtain high-precision estimates of initial $^{234}U/^{238}U$ for material ≫500 ka. We discuss the compromises that have to be made between spatial resolution and age precision for speleothems with different growth rates and ages when using the various methods above. In addition, we also highlight a number of challenges specific to U-Pb dating by LA MC-ICP-MS, including U/Pb down-hole fractionation in carbonates.

We illustrate the combination of both LA-MC-ICP-MS and ID-TIMS U-Pb dating alongside U-Th MC-ICP-MS analysis for a specific example of landscape evolution for the 70km-long Ogof Draenen cave system in South Wales, UK, where the timing and extent of Late Quaternary glaciations has influenced local topography and cave development through sediment choking, resulting in repeated changes/switching of underground drainage, creating a hydrological see-saw (Farrant and Simms, 2011).

Farrant, A R and Simms, M J, 2011. Ogof Draenen: speleogenesis of a hydrological see-saw from the karst of South Wales. *Cave and Karst Science,* Vol.38(1) 31–52.
Richards, D A and Dorale, J A, 2003. Uranium-series Chronology and Environmental Applications of Speleothems. *Reviews in Mineralogy and Geochemistry,* Vol.52, 407–460.
Woodhead, J and Pickering, R, 2012. Beyond 500 ka: Progress and prospects in the UPb chronology of speleothems, and their application to studies in palaeoclimate, human evolution, biodiversity and tectonics. *Chemical Geology,* Vol.322–323**,** 290–299.

The lost limestone mines of Dudley ORAL and DISPLAY

John Smith

250, Wolverhampton Road, Dudley, Sedgley, West Midlands, DY3 1RD, UK.
Email: johnsmithdudleycrt@blueyonder.co.uk

The Dudley Limestone Mines history goes back to the first half of the eighteenth century. An example of the way in which the limestone extraction increased from this time can be seen from mine records. In 1724, Richard Bolton, the bailiff for Lord Ward of Dudley, estimated the value of the whole limestone works at £250 per annum free of tax. However, by 1796, they were let for guaranteed royalties of at least £6000 per annum. Some of the local limestone had also been used much earlier, for the building of the Priory in the twelfth century and Dudley Castle in the thirteenth century. Two bands of limestone were mined. These were known as the upper and lower limestone beds, but were more commonly referred to as the Thin and Thick Seams. The Thin Seam was 25 feet thick while the lower Thick Seam was some 30 feet thick. The two seams were separated by 120 feet or so of Nodular Beds. A unique feature in these mines is that the limestone was removed from the Wren's Nest Hill and Castle Hill Mine galleries by means of an underground canal system. The mines under Castle Hill were abandoned around 1850, while the Seven Sisters mine under the Wren's Nest Hill still had five men working underground until September 1924. Following a fatal injury to one of them, mining operations ceased.

In 1961, an entrance into the North end of the Seven Sisters, known as the "Devils Mouth", was collapsed by blowing out five of the supporting roof pillars along the gallery below, using half a ton of explosives. While sealing off this entrance, it created serious problems on the hillside above, resulting in the whole hilltop being fenced off, as it still is today. Next, in 1964, there was a serious Crown-in to the surface of one of the mine galleries located beneath the local football ground. Being next to the Dudley Guest Hospital, this saw the start of major infilling operations by the local authority. By 1970, following a stability survey of the mines on the Wren's Nest Hill, this work accelerated, initially being focused on Wrens Nest and later on Castle Hill, Mon's Hill and sections under Sedgley. The last phase of this infilling programme took place in 2009, when the "East Mines" galleries under the Wren's Nest Hill were infilled. To give an idea of the scale of this infilling, when it began on the Wren's Nest Hill, in the 1970's, one section of the mine received some seventy lorries a day, each carrying twenty tons of sand. By working seven days a week, it took about two years to infill this part of the mine.

Today, it is possible to visit only one of these underground mine galleries, this being on the Castle Hill site. It enters the "Singing Cavern" in the Thin Seam, using the canal system, which is run and operated by the Dudley Canal Trust. Regarding the Wren's Nest Hill and the well-known Seven Sisters mine (formerly known as the Daylight Caverns), all the lower levels have been infilled. The upper daylight gallery has been temporally sealed, but not infilled. Hopefully, it will be opened for visitor access before too long, but this is subject to significant grant aid being available.

Further reading:

Bentley, Joseph, 1840. History, directory and statistics of Worcestershire. Vol.2, Bentley's history and guide to Dudley, Dudley Castle and the castle hill, and alphabetical and classified directory of the borough of Dudley. [Birmingham.]

James, P M, 1832. Lord Dudley's Limestone Quarries. From Aurora Borealis. Dudley Library Archives Reference LD 622.368. Miller, Hugh. 1847. First impressions of England and its people. [London: John Johnstone.] [Chapters 4 and 5].

Speleobiology in the Cantabrian Mountain karst massif of northern Spain

Tom Thomson[1,2] and Fergus McBurney[2]

[1] Department of Entomology (Origins), Natural History Museum, Cromwell Road, London, SW7 5BD, UK.
Email: Tom.thomson@research.darkelement.co.uk
[2] Previously at the University of Plymouth, UK.

The Matienzo karst entomology project is an independent research initiative working within the international caving community that is supported by the BCRA, the Natural History Museum, London, and the University of Plymouth. The aim is to study the fauna of the caves in the Matienzo basin of the central Cantabrian karst, there having been minimal work to date on the invertebrate life within these cave systems. Additionally, no formal scientific work has been carried out to study this specific karst massif or collect enough specimens to create a checklist of species. Only very select data exists for the wider region, and this is only on specific groups. This larger Iberian karst region includes the Picos de Europa and the Spanish Pyrenees. However, whereas both these areas are rich with speleological interest, they differ environmentally from the study area. Personal observations in the course of exploration suggested that the fauna are also significantly different, as supported by the first season of fieldwork. The study is being continued in a variety of environments and karst habitats by voluntary inputs from visiting speleologists throughout the year. This should supplement a first draft checklist of species for each locality. The initial phase of work was focused on testing of trapping methods, distribution linkages and cohabitant relationships between species. More tentatively, the project will study relationships at a higher level between taxon groups and also the distribution of arachnid species in cave entrance zones. This will enable an investigation into the relationship of species distribution and population density under two key sets of variables: (a) cave topography in terms of size, shape and availability of refuges for web building and shelter, and (b) environmental factors of air flow, temperature, humidity and illumination.

"Beware of the Dark Side!" Exploring the cave use strategies in the Neolithic Balkans ***POSTER***

Konstantinos Trimmis

Cardiff University, Department of Archaeology and Conservation. Email: trimmiskp@cardiff.ac.uk

This project, partly funded by BCRA, studies the ways of cave use by humans during the Neolithic period (7th – 4th millennia B.C.) in the Western Balkans. Particularly, the objectives of the project are: 1. To investigate how the cave space was organized according to the distribution of artefacts found in cave deposits 2) To study if the caves had been used for utilitarian purposes (e.g. shelter for herds and herders, storage due to constant temperature, specialized craft activities) and/ or for ritual / ceremonial purposes (e.g. burial ritual and ceremonies, initiation ceremonies) 3) To clarify which were the differences between Neolithic cave deposits and contemporaneous open-air sites 4) To research what was the economy of cave users in those areas, where caves had been close to coastal zones with available marine resources or freshwater resources and how this changed during the Neolithic. Most importantly, this project aims to explore how people used the caves in the complex social structure of the main Neolithic sites, the importance of the caves for the period's societies and how the caves had been associated with the rest of the urban and rural sites of the Neolithic.

I will attempt to achieve these four goals by adapting a pioneering methodology in the field of spatial analysis in the cave environment. I would like to move from a classical geographical interpretation of the spatial data to a geosophical approach, which encapsulates the geographical information in a more phenomenological way of thinking (Gillings, 2011 and 2012; Rennell, 2012). More analytically, I will collect in the field not only the spatial data from the cave artefacts but also the spatial data from the cave micro-environmental characteristics (light zones, humidity and temperature areas, cave decorations, sounds from cave fauna and water-dripping). Through the micro-special analysis and spatial distribution of the above parameters in a particular intra-site area (vertical and horizontal), I will try to outline which areas inside caves share common characteristics. Furthermore, I will try to investigate if the areas with the same characteristics are those areas whose specific clusters of artefacts present the high densities.

During the summer of 2014, I have collected bibliographical data from 72 already-excavated caves in seven different countries (Greece, Albania, Serbia, Croatia, Montenegro, Bosnia, FYROM), which will be available on line soon at www.balkancavearchaeo.org. Moreover, I undertook pilot field research in three caves (Spila Cave, Montenegro, and Koromilia and Sarakinos, Greece), where I gathered spatial data of the micro environmental characteristics of the caves. The goals for next year are to evaluate and present the data from the bibliographical research and to do a more deliberate field research in the rest of the Neolithic caves of the Western Balkans.

Gillings, M, 2011. Chorography, Phenomenology and the Antiquarian Tradition. *Cambridge Archaeological Journal,* Vol.21(01), 53–64.

Gillings, M, 2012. Landscape Phenomenology, GIS and the Role of Affordance. *Journal of Archaeological Method and Theory*, Vol.19(4), 601–611.

Rennell, R, 2012. Landscape, Experience and GIS: Exploring the Potential for Methodological Dialogue. *Journal of Archaeological Method and Theory,* Vol.19(4), 510–525.

Quaternary Climatic Instability in South-East Australia from a Multi-Proxy Speleothem Record ***POSTER***

Megan Webb[1,7], J Dredge[2], P A Barker[1], W Müller[3], C Jex[4], J Desmarchelier[5], J Hellstrom[6] and Peter M Wynn[1]

[1] Lancaster Environment Centre, University of Lancaster, Lancaster LA1 4YQ, UK.
[2] School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
[3] Department of Earth Sciences, Royal Holloway University of London, Egham, UK.
[4] Connected Waters Initiative Research Centre, The University of New South Wales, Manly Vale, NSW, Australia.
[5] 13 Raleigh Street, Spotswood, VIC, Australia.
[6] Earth Sciences, The University of Melbourne, Parkville, VIC, Australia.
[7] Email: m.webb@lancaster.ac.uk

For the past 400–350ka, there has been an overall shift in the climate of Australia towards increasingly arid and variable conditions (1). This shift is largely responsible for the Australian climate experienced today. For the prediction of future environmental change the study of Quaternary Australia is therefore critical, though Australian palaeoenvironmental terrestrial records are rare. The vast majority have been retrieved from fluvial, lake and dune sediments and pollen sequences (e.g.: 2; 3; 4). Although highly useful, these techniques are prone to data loss by erosion or the redistribution of sediments. Speleothems represent an underused alternative archive of environmental change. In particular, no high-resolution speleothem records from Australia have covered the Marine Isotope Stage (MIS) 5–3 period. This is a critical point in the continent's history marking the arrival of humans and loss of the megafauna (1; 5; 6). Flowstone YB-F1, dated to between 99 and 37ka, from Yarrangobilly Caves, represents the first high-resolution, multi-proxy speleothem record from south-east Australia to cover this period. Oxygen isotopes, trace elements and UV fluorescence were obtained for YB-F1 and used to build an environmental interpretation of this critical time. Within central and south-eastern Australia, climatic oscillations throughout the Quaternary were characterised by relatively wet or dry conditions corresponding to interglacial and glacial periods respectively (2). The palaeoenvironmental proxies retrieved from YB-F1 reflected these oscillations. The oxygen isotopic composition of YB-F1 calcite (δ18Ocalcite) was taken to represent rainfall amount and used as an aridity index. Interpretations based on δ18Ocalcite were supported by trace elements and UV fluorescence, allowing periods of relative aridity and moisture excess to be identified. A hiatus of approximately 37ka divides the record into two key growth phases which can be mapped onto MIS 5c–a and 3 respectively. Increasing aridity in the latter half of MIS 5 led to termination of calcite deposition for the duration of MIS 4. Growth recommenced during MIS 3, associated with greater moisture availability, enhanced vegetation and augmented biogeochemical cycling. YB-F1 provides a unique context of terrestrial environmental change highlighting the high degree of climatic instability and intense aridity experienced during this time of irreversible change to the continent's biodiversity.

1. Wroe, S and Field, J, 2006. A review for a human role in the extinction of Australian megafauna and an alternative interpretation. *Quaternary Science Reviews*, Vol.25, 2692–2703.
2. Nanson, G C *et al.,* 1992. Wetting and drying of Australia over the past 300 ka. *Geology*, Vol.20, 791–794.
3. Page, K J and Nanson, G C, 1996. Stratigraphic architecture resulting from Late Quaternary evolution of the Riverine Plain, south-eastern Australia. *Sedimentology*, Vol.43, 927–945.
4. Harle, K J, 1997. Late Quaternary vegetation and climate change in southeastern Australia: palynological evidence from marine core E55-6. *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol.131, 465–483.
5. Miller, G H *et al.,* 2007. Detecting human impacts on the flora, fauna, and summer monsoon of Pleistocene Australia. *Climate of the Past*, Vol.3, 463–473.
6. Prideaux, G J *et al.,* 2007. Mammalian responses to Pleistocene climate change in southeastern Australia. *Geology*, Vol.35, 33–36.