TRAVELS BENEATH THE EARTH
CELEBRATING THE UBSS CENTENARY

In 2019, The University of Bristol Spelaeological Society (UBSS), one of the oldest caving clubs in the country, celebrates 100 years of cave and archaeological exploration and research. On the 9th/10th November, to mark the occasion, the society is hosting a weekend of presentations and fieldtrips celebrating its past, present and future.

TIME	ORAL PRESENTATIONS – PROVISIONAL TITLES	PRESENTER
08.30	Doors open, registration, coffee	
09.15	Take seats	
09.20	Welcome and housekeeping	
SESSION 1: HISTORY AND ARCHAEOLOGY		**Chair:**
09.30	Memories of Journeys Beneath the Earth: oral histories of UBSS cavers	Andy Flack
09.50	Living on the Edge: Humans and Neanderthals in South-west Britain	Rhiannon Stevens
10.10	The Writing on the Wall, historic graffiti in caves and mines	Linda Wilson
10.30	***Coffee Break***	
SESSION 2: EXPLORATION		**Chair:**
11.00	Recent exploration and surveying by UBSS students in and around County Clare	Ashley Gregg
11.20	Untangling the mysteries of Austria's second-longest cave system	Elaine Oliver
11.40	Dark Horizons Under Trees	Dick Willis
12.00	***Lunch Break***	
13.00	Return from lunch, take seats	
SESSION 3: SPELEOGENESIS & PALAEOCLIMATE		**Chair:**
13.10	From GB to Gibraltar: speleothems, caves and climate"	Tim Atkinson
13.30	Some aspects of karst, caves and hydrogeology in lowland western Ireland	Dave Drew
13.50	Speleogenesis: the art of reading a cave.	Andrew Farrant
14.10	Picken's Hole: Chronostratigraphy and Sedimentology of a Last Interglacial to Holocene Collapsed Cave, Western Mendip Hills.	Pete Smart
15.00	***Coffee Break***	
SESSION 4: UBSS NOW AND THE FUTURE INCL. KEYNOTE		
15.00	What lies beneath: a butchered human bone assemblage from Charterhouse Warren	Rick Schulting
15.45	Presidential Address- One hundred years of the UBSS	Elaine Oliver
16.00	Close of talks	
16.10	Posters, drinks and nibbles & Irish Guidebook Launch	
17.30	Close of Symposium. On to meal at 18.30 – 19.00?	

MEMORIES OF JOURNEYS BENEATH THE EARTH: ORAL HISTORIES OF UBSS CAVERS

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'Memories of Journeys Beneath the Earth: oral histories of UBSS cavers.'
Established in its current form in 1919, the University of Bristol Speleological Society is an historic organisation with an institutional memory that stretches back many decades. Its library and museum holds written records that document many aspects of the Society's activities – and the wider cultures of caving more in the UK and beyond – but such documents are fundamentally limited in their ability to capture what it was really like to wander/crawl/climb the dark caverns and crevices beneath the earth. Over the course of the Society's centenary year, we have conducted around twenty oral history interviews with significant members of UBSS's caving community. In so doing, we have captured memories that do not appear in any written record.

This paper engages with aspects of our oral histories that deal directly with what it was like to be underground, relating diverse attitudes – from delight to dread – towards the darkness itself, and uncovering the ways in which UBSS alumni related the rich sensory experiences of their lives underground. Many of these experiences were about the adaptation of their bodies to the new spaces that surrounded them that reveal a deep symbiosis between the body of the caver and the physical world. Others were about changing technologies, including changes in climbing equipment that allowed for easier access to the underground, clothing that kept cavers increasingly warm and dry, and lighting that enhanced the scale and scope of perception in the darkness. Transformations across these categories compelled cavers to interact with the cave environment in changing ways. In short, this paper will illustrate that relationships between UBSS cavers and their underworlds were rich, unstable, and changing across time, space and according to individual experience.

LIVING ON THE EDGE: HUMANS AND NEANDERTHALS IN SOUTH-WEST BRITAIN

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Britain constituted Europe's most northwestern peninsula during the late Pleistocene. For most of the Palaeolithic, Britain formed the edge of the hominin geographical range. Novel scientific methodologies are allowing us to test whether the ebb and flow of Neanderthals and different modern human groups into and out of Europe's northwestern peninsula was a response to oscillating climates. Using stable isotopes, radiocarbon dating and ZooMS analysis we are working to reconstruct the chronology of the human presence in the region and the environment in which the people lived. This project is only possible as the UBSS curators have had the foresight to keep parts of the collections that in the past may have been thought of as useless. Scientific analyses of "Old collections" are providing key breakthroughs in archaeology and will continue to do so for many years to come.

THE WRITING ON THE WALL, HISTORIC GRAFFITI IN CAVES AND MINES

Linda Wilson
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Visitors to caves have been leaving marks on walls from the time of the Neanderthals to present day. Caves such as Chauvet and Lascaux need little introduction and in 2003 prehistoric cave art was discovered at Creswell Crags in Nottinghamshire. In Church Hole and other nearby caves many people also have left behind their names and initials as a record of their visit and this has been a common practice amongst cave tourists throughout the world for several hundred years.

Cave conservation codes are relatively recent, with the first formal code in the UK being published in 1995, although neither this nor the most recent BCA guidelines mention graffiti, but despite that omission, it is commonly accepted by cavers and mine explorers that graffiti should not be left in caves and mines. The challenge in this context is to record and evaluate any graffiti before a decision is taken whether to remediate modern graffiti or not and care should be taken in projecting today's values back in time when leaving behind a record of your visit was an accepted part of cave and mine 'tourism'.

Graffiti is part of the narrative of each site and can form an important and irreplaceable historic record. Examples of undeniably historic graffiti include the 18th century inscription known as the Miners' Toast in Speedwell Cavern and the names left behind on the Signature Stone in Poulnagollum in Co Clare, Ireland. The latter provides our only record of early descents of the cave on 7th and 8th October 1880.

The landscape of cave/mine graffiti was complicated in 2012 by the discovery of protective marks in Goatchurch Cavern and Wookey Hole in Somerset of the type found in both vernacular and religious buildings. Distinguishing such marks from simple initials is not easy and here context is an invaluable aid to interpretation. Unless the significance of the graffiti is readily ascertainable, wherever feasible, all markings in caves and mines should be recorded to an equal level of detail. This will enable further investigation and research to be carried out on the whole collection, which may well throw light on to the significance of either individual graffiti or the collection. The recording and evaluation phases of any research should remain separate and during a survey, all graffiti present should be recorded, without any value judgements being made.

This paper seeks to demonstrate the historic value of graffiti in cave and mine contexts and will present two different recording methods: a survey using information sheets and photographs to the use of photogrammetry to obtain a 3D model, in this case of the Signature Stone in Poulnagollum.

RECENT EXPLORATION AND SURVEYING BY UBSS STUDENTS IN AND AROUND COUNTY CLARE

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The UBSS have been conducting caving expeditions to Ireland for many years, gathering lots of data, culminating in the publishing of a series of guide books, the latest being Caves of Mid-West Ireland (2019). From 2012 – 2016 the focus of expeditions was the Cong isthmus in Co. Mayo and the neighbouring part of Co. Galway. In the even more recent years students have been involved in the updating and re-surveying of several cave systems in County Clare, including the Coolagh River Cave. The use of modern surveying techniques has allowed more detailed and complete surveys to be produced alongside up to date descriptions. There is still much to be done and further student expeditions are definitely justified in the near future.

UNTANGLING THE MYSTERIES OF AUSTRIA'S SECOND-LONGEST CAVE SYSTEM

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1976 saw the first Cambridge University Caving Club expedition to Austria's Dead Mountains (Totes Gebirge); the University of Bristol Spelaeological Society was invited along five years later, and members continue to attend to this day. A far cry from the generally horizontal and often constricted nature of Mendip caving, this region has offered many an UBBS caver their first real taste of Alpine adventure. From humble beginnings by the shepherds' huts just a short walk from the roadhead to a massive system over 140 km in length, this is a look back at what UBSS members old and new have been getting down to in the land of schnapps and chamois.

DARK HORIZONS UNDER TREES

Dick Willis
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Lives turn on small moments.

For Dick Willis this was a Saturday morning in 1972 when UBSS member Chris Smart came into his room in Hiatt Baker Hall and asked, 'what's wrong with you?' The grumpy response was that Dick had completed his BSAC pool training, made a wetsuit and had been due to go on his first open water dive that weekend. Unfortunately, having pulled a muscle playing squash, the University Doctor (UBSS member Peter Standing, ironically) refused to certify him as fit, so his training cohort had gone without him. "Well, you've got a wetsuit, why don't you come caving with us this afternoon?" asked Chris and in that moment Dick's life changed direction completely.

Some years later, in 1980, having caved throughout the UK, in Ireland, Greece, France, Spain and New Guinea, often with other UBSS members, Dick found himself in a longboat going upriver to the Mulu National Park in Sarawak, Borneo. The caves of Gunung Mulu had been first explored and surveyed in 1978 during the joint Malaysian/Royal Geographical Society's 15-month multi-disciplinary expedition to study the Park and produce its management plan. A small group of 6 cavers, including Phil Chapman from UBSS, were included in the team because the RGS had noted a rudimentary survey of a large cave in a 1961 report about Mulu from G E Wilford of the Malaysian Geological Survey. Deer Cave turned out to be the largest in the world and the team came back to the UK having explored and surveyed some 50km of passages elsewhere in the Park, most of a scale never seen before.

In the ensuing years, 36 British expeditions, often with participants from other countries, have returned to Mulu to work with the Sarawak Forestry Department and local people to explore and survey Mulu's stupendous underground systems. Although caves of similar size have been found elsewhere, particularly in Vietnam, Laos and China, few places have such a tight concentration of consistently massive caves. So far, the Park contains over 510km of surveyed cave, including Sarawak Chamber, which for many years was considered the largest natural underground chamber on Earth, as well as the vast Clearwater System which is over 220km long and is, almost certainly, the largest cave by volume in the world.

Dick has participated as a team member or leader in 11 of these expeditions, most recently in 2018. In this talk he reflects on his experiences, the exploration and scientific work by his colleagues, including 10 other UBSS members, the relationship of what is now known as the Mulu Caves Project with the Sarawak Government and his hopes and fears for the Park's future.

FROM GB TO GIBRALTAR: SPELEOTHEMS, CAVES AND CLIMATE"

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In 1964 Derek Ford published a definitive account of the geomorphology of GB Cave in Proceedings. With the advent of U-series dating in the 1970s (also developed by Derek Ford with Henry Schwarcz at McMaster University in Canada) Peter Smart and I undertook to date the cave development that Derek had described, thinking that the cave was "young" and might have formed during the Last Interglacial. Russ Harmon did the initial dating. To our surprise the majority of speleothems sampled were out of range, i.e. older than 400,000 years - not "young" at all! This talk will commence with a summary of the dating results in GB Cave, as an example of the use of spelothem dating in geomorphology, and then move on to show the use of stalagmites as archives of palaeoclimate, with recently studied examples from Gibraltar, including a detailed archive of temperature and the isotopic composition of rainfall during the Last Glacial.

SOME ASPECTS OF KARST, CAVES AND HYDROGEOLOGY IN LOWLAND WESTERN IRELAND

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Unlike the UK and most limestone areas elsewhere in Europe, the great majority of Ireland's karst terrain is lowland, rarely above 100m in altitude and, to the casual visitor, has little in common with the spectacular plateau karsts of Sligo, Leitrim and the Burren. However, the central lowland of Ireland extending almost from Dublin in the east to Galway in the west is almost all underlain by Carboniferous limestone and therefore karstified to some extent. East of the River Shannon the limestone is commonly blanketed with considerable thicknesses of glacial and post-glacial deposits that obscure many of the karst landforms. West of the Shannon the limestone it at or close to the surface and the karst is more evident. These western lowlands extend over more than 9,500km2 of counties Clare, Galway, Roscommon, Mayo and a small part of Co. Sligo. Distinctive examples of typical karst hydrological features and associated caves from North Co. Mayo, South Co, Clare and eastern Co. Galway are presented in order to convey an impression of one of Europe's most remarkable, but least visited, karsts.

SPELEOGENESIS: THE ART OF READING A CAVE.

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Caves are great for recreation and sport. They are also amazing time capsules of data on landscape, hydrological and climatic change over the past 1-2 million years. The clues to deciphering these data repositories are held within the passages themselves - their morphology and geometry, and in the sediments and speleothems they contain. By studying caves and cave deposits, it is possible to deduce how they form and subsequently develop over time in response to changing landscapes and climates. Often caves reveal clues about the past that have long since been erased from surface environments. Moreover, new discoveries provide opportunities for improving our understanding of the subterranean world. Over the past 30 years, over 150 km of new cave passage has been discovered in South Wales and the Mendips; 150 km of cave passage that provide new insights into cave development, landscape evolution, hydrology and climatic change in the region. This talk will give an overview of how caves form, how to read the clues they contain, and provide some local case studies.

PICKEN'S HOLE: CHRONOSTRATIGRAPHY AND SEDIMENTOLOGY OF A LAST INTERGLACIAL TO HOLOCENE COLLAPSED CAVE, WESTERN MENDIP HILLS.

Peter Smart
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Picken's Hole is a collapsed cave infilled by surface and sub-surface sediments situated on the spur leading to Crook Peak, Western Mendips. It is named from MJ Picken who in 1961 recognised that badger hole debris included the remains of prehistoric animals. UBSS excavations commenced in 1961 and extended to 1967, with preliminary reports by Tratman in 1964 and ApSimon in 1986. I visited the site with ApSimon in 1983 and collected sediment samples from re-exposed surfaces of the DEF downslope face, and also obtained details of sediment samples previously analysed by D Findlay of the Soil Survey.

The basal unit (6) is a complex partially cemented breccia in places infilled with clastic sediments. The breccia appears to be the same as that recognised in the adjacent Denny's Hole cave, and is an early hypogene cave fill with exotic calcite cementation. U series dating of flowstone overlying this unit in Picken's Hole provides a basal date of 200±11 ka for the later deposits. Two other chronological controls are provided by 14C ages of 49,933-38,313 cal BP for bones from the hyena den fauna of Unit 3, and by mammalian faunal zone equivalence for the underlying wolf den fauna from Unit 5 (Marine Isotope Stage 5a). This also raises the possibility that fauna from Unit 4 is equivalent to the Brean Down mammalian faunal zone which is dated at 64.9±4.3 - 60.7 ±5.5 ka. The sediment sequence extends to the present surface, and includes possible out of sequence ages of 12,460 ± 60 cal BP and12,400 ± 1500 cal BP. equivalent to the Goughs cave mammalian faunal zone, and also an early to middle Neolithic age on a human molar (3,695-3380 cal BP). The deposits therefore appear to span the termination of the last interglacial through the last glacial to the Holocene.

The main bulk of the deposits comprise matrix and clast supported breccias with less clast rich intervals. Clast orientation data suggest that Unit 4 was derived by block fall onto a cave floor, whilst later units had a distinctive slope orientation and could be associated with solifluction processes into the exposed cave void following progressive roof failure. Matrix material has a significant acid insoluble component of silt size. Heavy mineral composition indicates derivation is not from Carboniferous Limestone acid insoluble residues, but is similar to Mendip soils which are thought to be derived from aeolian transport from the west. Some of this material may predate the accumulation of the sediments and be derived from previous interglacial soils, but some may also have been accumulated contemporaneous with deposition during the last glacial. There is a complex pattern of breccia clast weathering with depth and sediment units which indicates active pedogenesis of the surface exposed deposits during the last glacial. Almost certainly the record as currently recorded is insufficient to record the high frequency climatic oscillations which occurred in Marine Isotope Stage 3. A remarkable sample from Unit 3 also appears to be almost wholly composed of earthworm granules.

A major feature of the sequence is the erosional unconformity which separates Unit 1 (the surface soil and associated sediment sequence) and the underlying units. This slope parallel surface truncates previous near horizontal unit boundaries, but lacks chronological control. It may be associated with the Holocene 8.2 ka event which has been suggested to explain erosion of loessic deposits in North-west England or with Mesolithic (or more likely Neolithic) agricultural clearance and intensification, but these do not readily explain the angular difference between prior and later sediments. A possible explanation is that the cave retained a downslope wall buttressing the in-cave deposits, but that this wall failed with the melting of permafrost in the immediate postglacial, as observed in present-day alpine areas experiencing melting of permafrost .

With advice from English Heritage, the National Trust have cleared the areas adjacent to Picken's Hole of trees. Inadvertently this has allowed ready public access to the Picken's Hole Cave, the easy route unfortunately being down the extant DEF face of the excavation. Unlike the cave itself which is robust,

the critical reference face is being significantly degraded. Fortunately it appears that there may be further deposits remaining in situ in the continuing buried cave to the north east. Conservation of these deposits and the DEF reference face is critical. Further and more detailed work at this site using modern methods is warranted.

WHAT LIES BENEATH: A BUTCHERED HUMAN BONE ASSEMBLAGE FROM CHARTERHOUSE WARREN

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Steven Pinker's 2011 book 'The Better Angels of Our Nature' reflects on the decline in violence over the course of human history. The site of Charterhouse Warren in Somerset reveals the darker side of our nature. Excavated in the 1970s, and dating to the Early Bronze Age, ca. 2200 BC, the scattered remains of at least 40 men, women and children were found in a 20m-deep pit. This largely unknown assemblage is striking for the sheer number of cutmarks indicating dismemberment, alongside perimortem fracturing of long bones and injuries to skulls. While evidence for violence is not unknown in British prehistory, nothing on this scale has been found, and the site joins a small number of Continental Neolithic and Bronze Age sites showing extreme violence and postmortem processing of human remains. This presentation provides an overview of the new research being undertaken on the assemblage, documenting and characterising the extent of the injuries, investigating who these victims were, and understanding the site's place in the wider context of the European Early Bronze Age.

ONE HUNDRED YEARS OF THE UBSS

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Rather a lot can change in a hundred years: from practitioners of a nascent sport decked out in tweeds and carbide lamps, pushing the sumps of Swildon's with questionable homemade diving equipment, to shining thousands of lumens on some of Earth's most remote places and surveying them with the latest laser technology. Yet some things never change: we continue to push the boundaries of the known world, we enjoy a(nother!) pint as much as our predecessors did, and of course the Hut remains the heart of the Society, as it has done from the very start. So where next for the UBSS?

POSTER PRESENTATIONS

DIETARY ECOLOGY OF THE FISSURE-INFILL FOSSIL FAUNA OF THE BRISTOL T-J ARCHIPELAGO

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In the early Mesozoic, the southwest of the UK was partially submerged, forming a series of palaeo-islands. The limestones present within the islands formed a karst surface and small animals were washed into caverns and fissures. These "fissure faunas" provide a unique opportunity to explore the ancient ecosystems. Clevosaurus is a common lizard-like reptile from the fissures, the skulls of two species of which are reconstructed here to discern their dietary ecology through tooth and jaw analysis.

MAKING A RECORD OF CAVES, HISTORIC GRAFFITI AND OTHER MARKINGS

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The use of a standardised cave recording methodology will make it easier to construct a database for information collected. Individual recorders using standard forms will collect the same/similar data wherever they are.

The purpose of the guidelines is to describe the process of making an initial record of cave sites and associated features, in an appropriate manner using the relevant conventions.

It would also be useful to record the current state of the cave sites and/or resources, especially if they are scheduled. The data collected can then be used to produce a current condition survey for the sites.

A PREVIOUSLY UNKNOWN MAJOR PALEOKARST WITHIN A MODERN CAVE IN NE INDIA; THE PIELKHLIENG POUK-KREM SAKWA SYSTEM, MEGHALAYA

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The Late Paleocene to Middle Eocene sedimentary sequence in Meghalaya comprises interlayered coaly sandstones and limestones hitherto considered as conformable. Major cave systems totalling over 500km occur in the Lakadong and Prang Limestone Members in the Jantia and Khasi Hills. One such cave in the Lakadong Limestone is the 20km long PP-KS system. Exploration over the last decade has found a wide variety of paleokarst features through many parts of this cave. These include a pinnacle epikarst on the top surface of the limestone with up to around 15m relief seen in the walls and roof of the cave with sandstone and coals infilling around the pinnacle towers. Also within the upper part of the limestone large ball shaped sandstone bodies occur which are interpreted as pit and cavern infills. Paleokarsts infilled by sandstone are relatively rare and this one is especially well developed with spectacular underground exposures. The findings call into question the conventional belief that this Late Paleocene stratigraphical sequence is conformable, showing instead a significant unconformity during which the Lakadong Limestone was exposed and karstified during a period of relative of sea level fall prior to sandstone deposition.

IF THE DEAD COULD TALK: A TAPHONOMIC APPROACH TO NEOLITHIC MORTUARY TREATMENT IN THE CAVES OF SOUTHWEST BRITAIN

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There are a range of burial practices in the Neolithic. This research examines burials in caves in southwest Britain, focusing on 19 caves sites in Wales and 2 sites in southwest England. This project employs an integrated taphonomic approach, combining macroscopic analysis of bone surface preservation and microscopic analysis of bone microstructure (histology). By undertaking traditional and novel osteological analysis this research will examine pre- and post-depositional treatment of the deceased and the means by which bones became disarticulated.

Current research has progressed our understanding of burial practices in subterranean environments (e.g. Schulting *et al.* 2010; 2012; Leach 2015; Peterson 2019), however, a substantial corpus of funerary remains of prehistoric date, with many dating to the Neolithic, have not been subject to holistic study. Thus, more work is needed to reconstruct mortuary practices and address regional, chronological and demographic variation in practices, aspects that to date have been approached mostly on a theoretical level.

Macroscopic taphonomic analysis (visual osteological examination of surface modifications of human remains) provides information on the degree and duration of exposure of the remains, the nature of manipulation and/or disturbance of the bones and the agents of these modifications impacted on the bone. In addition, microscopic analysis (thin section microscopy under transmitted light microscopy to assess the degree and nature of microstructural bioerosion) provides insight into early post-mortem processes and reveals the rate and nature of soft tissue decay.

This poster illustrates examples of initial findings for the taphonomic analysis (signs of weathering, disarticulation and fracturing, abrasion, gnawing and discoloration of the bone) on sites across Wales. Burial patterns and practices revealed from analysis of disarticulated remains will be presented, including some unusual case studies, and future plans for analysis described.

BACK TO BACKWELL – A HISTOLOGICAL EXAMINATION OF HUMAN REMAINS FROM BACKWELL CAVE, NORTH SOMERSET

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It has been 82 years since excavations by the University of Bristol Spelaeological Society, led by Tratman (1938), revealed a large comingled corpus of prehistoric human remains buried mysteriously within Backwell Cave. The cave itself is small in size, making the interment of at least 18 individuals all the more puzzling. Adding to the confusion is the distribution of demography: both males and females are represented, with ages spanning from children to mature adults. Clearly, this was a significant site specially selected as an arena for human burial, but that's where our current understanding ends. The fragmentary and disarticulated nature of the deposit, along with the tangled chronological sequence of use of the cave from the Neolithic to Iron Age, limits modern interpretation.

This poster describes the ongoing and upcoming research on human remains from Backwell cave. The primary focus of this research is to identify early post-mortem treatments afforded to individuals deposited within the cave. This will be done through histological analysis of bacterial bioerosion present, or lacking, in the bone microstructure. Through this analysis, it can be determined whether the individuals were inhumed within the cave—as suggested by Tratman (1983)—or defleshed prior to deposition. The assemblage is highly fragmented, so the distal end of five adult right humeri were selected to ensure that no individuals were duplicated. In addition to histological analysis, stable isotope analysis and radiocarbon dating will greatly enhance our understanding of the lives and deaths of people buried there. This forms a case study for PhD research investigating Iron Age mortuary practice in southwest Britain.

RECONSTRUCTING THE PLEISTOCENE MAMMALIAN ASSEMBLAGES OF BADGER HOLE AND RHINOCEROS HOLE CAVES AT WOOKEY HOLE, SOMERSET, UK.

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Badger Hole and Rhinoceros Hole, two neighbouring caves in Somerset, were found by this study to contain mammalian assemblages typical of Marine Isotope Stage 3 (MIS 3), 29-57 kyr cal BP, closely resembling that of the nearby Hyaena Den.

Badger Hole was excavated between 1938 and 1958 be H.E. Balch, the material from this excavation has remained at Wells and Mendip Museum since that date, much of the material remained unidentified. Rhinoceros Hole was excavated in the 1970s by E.K. Tratman from UBSS, the material from this excavation remaining at UBSS Museum. Both collections were examined in detail and found to be comparable with known Late Pleistocene mammalian assemblages including that found in Hyaena Den, a neighbouring cave already subject to considerable study. These assemblages show a close match with the Pin Hole Mammalian Assemblage Zone (MAZ), a benchmark indicative of Mid-Devensian (Marine Isotope Stage 3) age, within the range of 29 to 57 kyr cal BP. This was within the last glacial period but subject to a series of rapid climatic oscillations including relatively temperate episodes.

Both caves contain evidence of Hyaenas denning within the caves and of their large herbivore prey including Mammoth, Woolly Rhinoceros, Bison and Horse. Other predator remains were found in lower numbers including Brown Bear, Red and Arctic Fox, Cave Lion and Wolf.

Biostratigraphies were constructed for each assemblage in order to identify any appropriate palaeological and palaeoclimatic inferences. Rhinoceros Hole was found to contain evidence of climate change through the sequence, showing a dominance of temperate/woodland taxa in the lower layers moving to a colder Mammoth-Steppe fauna in the upper strata of the cave deposit. Badger Hole did not show significant change, with a predominance of cold-adapted mammals found throughout the sequence. Within the material from both Badger Hole and Rhinoceros Hole there are a small number of stone tools, indicative of Neanderthal technology and similar to those found at other UK sites dated to 42-43 and 44-46 kyr cal BP. It is likely the sites were used as summer hunting camps by Neanderthals rather than permanent dwellings.

PIPE AND SPONGE: SEASONAL VENTILATION OF CAVES FROM THE POINT OF VIEW OF GROUND AIR CIRCULATION IN THE ROCK AROUND THEM

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The concepts of conduit and diffuse flow of water in limestone aquifers are familiar to karst hydrologists. The same concepts can be applied to air movement in the unsaturated zone, as air is a fluid capable of movement through a porous medium under a gradient of potential energy. Within a defined region of unsaturated rock with homogeneous permeability to an incompressible gas, the steady-state pattern of diffuse flow depends solely on the values of potential energy per unit weight of gas (a.k.a. *potential*, or *head*) at the boundary of the region. If either the values themselves or their local normal gradients are specified for the whole boundary, then the internal flow lines can be found by obtaining a solution of Laplace's equation appropriate to these boundary conditions. Many analytical solutions of Laplace's equation are known for specific geometries, but for practical problems it is often easier to use a numerical technique known as the Boundary Integral Equation Method (BIEM) to obtain values of potential for points within the region of interest and to find the gradients of these to obtain a graphical representation of flow lines.

For ground air movement in an unsaturated aquifer with no caves, the region of interest is bounded by the ground surface and underground by the water table. The driving force for movement is the difference in density between ground air and external air. This is primarily due to differences in temperature, though the contents of water vapour and CO_2 also affect density. Because of the large amount of heat stored in bedrock, underground air is essentially isothermal with a temperature close to the mean annual temperature on the surface. It can therefore be regarded as possessing constant density, as the effects of pressure on density can be neglected for height differences of a few hundred metres. If we now consider a region with topography – e.g. a hill rising from a flat plain – then at a point on the hillside at height h above the plain the atmosphere exerts a pressure on the ground surface of $P_o - \rho_e gh$ where ρ_e denotes the density of external air and g is gravitational acceleration. However, for an *underground* point adjacent to the surface at the same level the density is ρ_g and therefore the pressure potential per unit weight of ground air on the boundary is $-\rho_e h/\rho_g$ relative to atmospheric pressure at the level of the plain. The elevation potential for unit weight of ground air at the same point is h, so the total energy per unit weight of ground air (or hydraulic head) is $h(\rho_g - \rho_e)/\rho_g$. Clearly the hydraulic head at the boundary of the region of interest changes with altitude at a rate that depends on the relative difference in density between external air and ground air. This drives the steady-state motion of the ground air. As the external air will generally be colder and denser than ground air in winter, the hydraulic head decreases with altitude and the ground air flow within the hill will be upwards. Cold, relatively dense external air will enter the ground through the lower part of the hillsides, rapidly acquiring heat from the bedrock and reaching the normal temperature and density of ground air as it does so. It will then flow within the bedrock along rising paths, and will exit again through the surface in the upper parts of the hillsides. This flux will depend on the density contrast and the permeability, but the precise pattern of flow paths will also depend on the shapes of the boundaries, i.e. the height and shape of the hill and the shape of the water table. In principle, this type of flow is universal in permeable topography, the flow direction reversing if the density contrast reverses in sign, as would occur in summer in the extra-tropical latitudes. Thus, ground air exchanges with atmospheric air on a seasonal basis in these latitudes. Within the tropics, however, the daily temperature range may be larger than the seasonal range. A steady-state model has severe limitations under such circumstances, as the flows will be transient, but nevertheless predicts that in the tropics the direction of flow would tend to reverse diurnally. Diurnal reversals can also be expected in extra-tropical regions during periods in autumn and spring.

Though very simple, this model can be adapted to take account of the presence of caves. Compared with the gas permeability of fractured bedrock, caves have almost infinite permeability for flows along their length. They are like zero-resistance pipes embedded in a somewhat permeable sponge. The walls of the cave can be treated as an internal boundary to the region of interest. The air in single entrance caves can therefore be treated as having a hydraulic head equal to the head on the hillside at their entrance elevation. Caves with two entrances at different levels will have classical chimney-effect winds along their length, and to a first approximation the head at intermediate points along the passage length can be linearly interpolated between the entrance values. (We note that this does not constitute a proper coupling between the diffuse and conduit flows of air, but maintain that it is a useful approximation for insights into the effect of the cave on ground air flows. We note also that other causes of air flow in caves are not represented at all in this approach.)

We have examined the effect of a cave using the BIEM method for a variety of simple 2-D geometries, allowing us to deduce the season in which the cave acts as an outward-flowing discharge conduit for ground air. As ground air is enriched in CO_2, this should be the season in which the CO_2 levels of cave air are highest. In contrast, if the cave acts as a conduit by which external air enters the diffuse flow, it will have low CO_2 levels. The relevance of this for palaeoclimatology is that speleothem $\delta^{13}C$ and $\delta^{18}O$ will be raised by the rapid degassing that occurs when cave air CO_2 is low, whereas $\delta^{18}O$ should be nearer to isotopic equilibrium with drip water when CO_2 is high and degassing is slower.

Single entrance caves beneath flat, horizontal plateaux experience little density-driven air movement because of the lack of topographic relief in the surface. Caves entered at the bottoms of dolines have highest CO_2 in summer, lowest in winter. The same applies to caves with single entrances in valley floors or in the lower parts of hillsides. Caves with single entrances in the upper parts of hillsides, or on

hilltops, or on culminations of knolls on otherwise extensive plateaux, should have higher CO_2 in winter. Those with entrances close to the mid-height of the local topography (for example, half way up the side slope of a gorge incised into a level plateau) may experience relatively little seasonal contrast in CO_2, because they will act as outlets for ground air flowing from below in winter, and from above in summer.

Caves with multiple entrances are generally well-ventilated by virtue of the chimney-effect winds that flow along them, so will tend to have low CO_2 levels. These will be augmented in summer by the entry of high-CO_2 ground air if both entrances lie below the average elevation of the local topography, and in winter if both lie in the upper half of the topography.

CAVE MONITORING OF THE STABLE ISOTOPE SIGNALS TRANSMITTED TO SPELEOTHEMS IN GIBRALTAR

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An eight-year cave monitoring effort in Gibraltar had the ultimate aim of reconstructing $\delta^{18}O$ in past precipitation from well-dated speleothems. We measured stable isotopes in cave waters from nine sites 40 to 170 m deep in New St Michael's (NSM) and Ragged Staff (RS) caves, comparing them with monthly GNIP values for Gibraltar rain. Additionally we conducted artificial tracer tests that tracked two dyes from distinct points on the surface to multiple drip sites in NSM.

Seepage waters have a very narrow compositional range and little difference between sites when compared with the fluctuations of $\delta^{18}O$ and $\delta^{2}H$ in monthly rainfall ($\delta^{18}O$ range 12.5 ‰). $\delta^{18}O$ varies seasonally by only tenths per mille whereas inter-annual ranges are up to 1 ‰. The restricted ranges and compressed seasonal variations indicate temporal mixing of rains that entered the sub-surface at different times. Comparison of exceptional variations in rainfall with subsequent seepage samples reveals a component of seepage that has been stored for at least one year.

The artificial tracers indicated marked spatial mixing as water flowed from the surface to the caves. Tracers from single points on the surface above MSN formed overlapping plumes of dyed water that could be detected across 200 m horizontally. The tracer results confirm the temporal mixing and indicate residence times that are less than the three month monitoring period but exceed the initial breakthrough times of days to weeks after injection. Combined with the one-year storage time indicated by stable isotopes, the tracer results imply that the full residence time distribution for water in the unsaturated zone must range from a few days to over one year.

This temporally and spatially dispersive behaviour arises from the geometric properties of the fracture network that the cave seepages have passed through, so will have been broadly invariant in the past. The water isotope signal that Gibraltar speleothems capture is averaged over a period of around one year and very short events will not be recorded.

The stable isotope data also show the influence of other processes than simple mixing. Seepage waters have lower values than the amount-weighted averages for rainfall, suggesting a bias towards isotopically lighter rains. Plots of $\delta^{2}H$ versus $\delta^{18}O$ show no consistent signs of modification by evaporation, despite Gibraltar's hot dry summers, so the isotopically heavier rains are completely lost to evapo-transpiration. A less easily explained feature is that the deuterium excess of seepage is higher than that of average

rainfall, although lying within its overall range. This may be caused by addition of condensation water to the shallow epikarst.

In the cooler climates of the Last Glacial evaporation would have been less than today and the isotopic composition of seepage may have been closer to the annual average of rainfall. Samples from speleothems often span several years even in highly-resolved records, with the implication that in cool climates the calcite $\delta^{18}O$ will reflect the average for rainfall over this time interval. In climates resembling the present it may be displaced slightly towards lighter values.