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Evidence for Pleistocene frost and ice damage of speleothems in Hallowe'en Rift, Mendip Hills, Somerset, UK

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Abstract: Discoveries in Hallowe'en Rift, Mendip Hills, Somerset, UK during 2018 revealed some interesting morphological features and an abundance of shattered speleothems. It had previously been suggested that this damage might have been caused by earth movements. However, after a close examination of the speleothems, it is apparent that the fracturing and related damage was caused by the actions of frost and/or ice during the Pleistocene. Uranium-series dating of speleothem samples has produced a range of dates relating to Marine Isotope Stages (MIS) 15–13, 7c, 5e and 3.

This paper builds upon a poster presentation that was delivered at the 29th BCRA Cave Science Symposium, held at the University of Bristol in October 2018.

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Introduction

Hallowe'en Rift, NGR ST 5353 4809, altitude 130 metres (m) above Ordnance Datum[1] (aOD), has a current surveyed length of 304m, with a vertical range of 25m. The cave is located in the wooded hillside to the northeast of Wookey Hole Cave (Mendip Hills, Somerset). Excavation of the cave was commenced in 1982, but by the end of the 1980s interest at the site had waned. Then, in the early 1990s, activity in the cave re-commenced and it was during these excavations that a dig on the east side of the entrance was started. Once again interest waned as the participants moved to pastures new. In 2009 the current phase of activity began, and this phase of work concentrated on expanding the cave to the eastern side of the entrance. Exploration and investigation of Hallowe'en Rift is an ongoing project and several potential leads are being pursued actively.

Photo 1*: Detached speleothems piled on the floor of Broken Stal Aven.*

[1] *As defined and used by the Ordnance Survey [of Great Britain], Ordnance Datum (OD) is the* "Mean Sea Level at Newlyn in Cornwall between 1915 and 1921". *For many purposes it can be considered simply as* "Mean Sea Level".

The cave consists mostly of a low bedding-guided passage, partially filled with deposits of sandy silt containing scattered cobbles and boulders of dolomitic conglomerate and common clasts of fragmented speleothems, including broken stalagmite, stalactite and flowstone. In places the low bedding-guided passage has intersected rifts that are generally aligned north–south. Most of the low bedding passages have been excavated. During 2018, progress along the bedding-guided development accelerated and, following several minor breakthroughs, a passage that the explorers named "*An Unexpected Development*" was entered. This c.80m-long passage contains abundant shattered speleothems (see for example Photo 1) and a variety of interesting geomorphological features.

Initial observations and notes

There is a change in the composition of the sediments that form a partial fill in the low bedding sections on the approach to *An Unexpected Development.* Initially the sediments are mostly sandy silt with sporadic cobble- and boulder-size fragments of fractured calcite speleothem. After a drop down into a lower bedding, the fragmented calcite becomes more common and it is the dominant component of the sediment fill. Whereas it has been suggested that the speleothem damage might be related to earth movements, additional research – including detailed examination of the sediments – indicates that the fracturing has been caused by frost and/or ice action.

Among other authors, Gilli (2004) suggests that the global evidence for an absence of stalactites or stalagmites collapsing during earthquakes, the existence of well-ornamented caves in seismic zones, and the results of laboratory testing have demonstrated the robustness of cave formations, proving the point that "caves are very strong". In general, speleothems do not suffer from the effects of earthquakes. The co-seismic origin of massive collapses therefore seems doubtful, and other mechanisms, such as frost and ice freeze/thaw processes, can more readily explain most of the ruptures.

	British Terrestrial Stages	Marine Isotope Stages (MIS)
Holocene	Holocene ***warm***	1
Late Pleistocene 120 – 11.7 ka	Devensian ***cold***	2 – 5d
	Ipswichian ***warm***	5e
Mid Pleistocene 781 – 120 ka	Wolstonian ***cold***	6 – 10
	Hoxnian ***warm***	11
	Anglian ***cold***	12
	Cromerian ***warm***	13 – 20
Early Pleistocene 2.588 Ma – 781 ka	Beestonian ***cold***	21 – 62 (including a 1 Ma hiatus)
	Pastonian ***warm***	63 – 67
	Baventian ***cold***	70 – 68
	Antian/Bramertonian ***warm***	71 – 73
	Thurnian ***cold***	74 – 76
	Ludhamian ***warm***	75 – 80
	Pre-Ludhamian ***cold***	81 – 100

Table 1*: British Terrestrial Stages and approximate equivalence of Marine Isotope Stages (adapted from Figure 17.1, Catt et al., 2006: p.430).*

Most of the passages in Hallowe'en Rift are at shallow, depth, lying close beneath the overlying land surface, with root growth noted to penetrate the passage ceiling in several areas. Snail shells and bat droppings have been observed in parts of *An Unexpected Development*. Present-day conditions in the cave are influenced by the surface climate, an obvious relationship being that during the summer months the cave is generally dry, but under rainy conditions the ground becomes saturated, making the cave wet.

During the Pleistocene Epoch (Table 1), precipitation of calcium carbonate ($CaCO_3$) occurred during the interglacial and some of the warmer interstadial episodes, resulting in the growth of speleothem (including stalagmites, stalactites and flowstone) within the region's caves. Intervening glacials or cold stadial episodes might have resulted in periglacial activity inside the cave, during which some of the calcite layers were fractured (see for example Photo 2) by frost heave and there was some redistribution of the fragmented calcite by solifluction (Lundberg and McFarlane, 2007). It has been suggested that permafrost in caves might have reached depths of ~80–100m, forming an ice plug. However, during subsequent interglacials, thawing might occur to a lesser depth, perhaps ~50m. Effectively the cave would still be 'plugged', causing meltwater outflow (Marc Leutscher, *pers comm*). The passage roof along much of the bedding in Hallowe'en Rift is scoured clean, with scalloping present in several areas. During the build-up of ice and the subsequent thawing, ice could flow and slide, thereby causing stalactites and curtains to be sheared from the roof and stalagmites tipped over or sheared from their bases and displaced (Photo 3). Lumps of calcite enclosed in ice can be deposited on inclined surfaces or be left perched in precarious positions (Photo 4), i.e. at locations where they would not be stable if deposited, for example, by falling during earth movements (Kempe, 2004).

Kempe (2004) describes a wide range of phenomena as evidence for ice-related damage, including:

Photo 2*: Layers of fractured calcite flowstone; the damage to originally continuous flowstone sheets was probably caused by frost heave.*

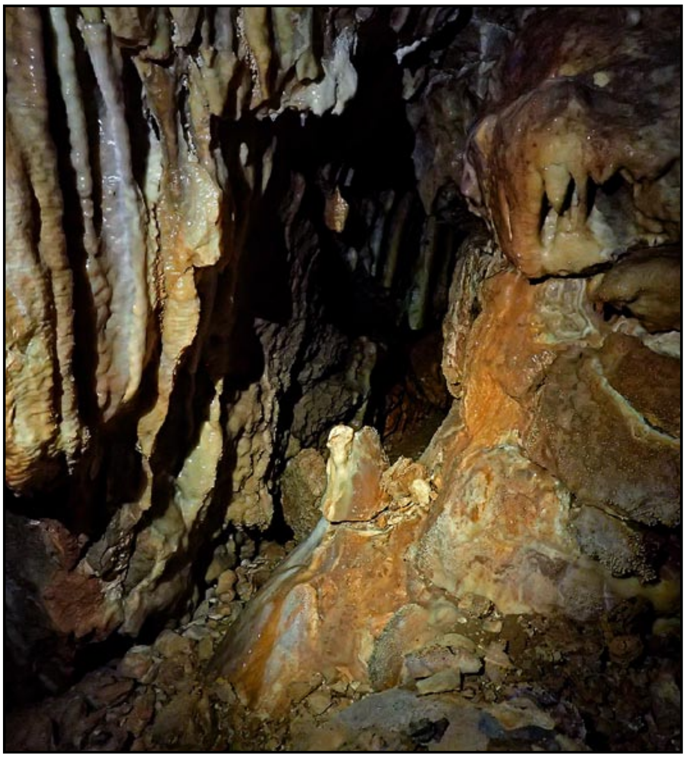

Photo 3*: Shattered speleothems in An Unexpected Development*

- Missing ceiling formations of older generations;
- Sheared-off stalactites and curtains, deposited on top of floor speleothems;
- Broken and redeposited stalagmites;
- Sheared-off stalagmites that have shifted from their base but still stand upright;
- Cracked conical stalagmites;
- Tilted and leaning stalagmites;
- Moraine-like piles of floor flowstone;
- Precariously placed ceiling deposits.

In addition to speleothem damage, Kempe (2004) describes other traces that freezing and cave ice can leave, including:

- Cryoturbation in cave sediments;
- Solifluction deposits;
- Transport of gravel without evidence of flowing water;
- High collagen content of fossil bones;
- Loss of uranium due to 'leaching';
- Scratch marks on cave walls.

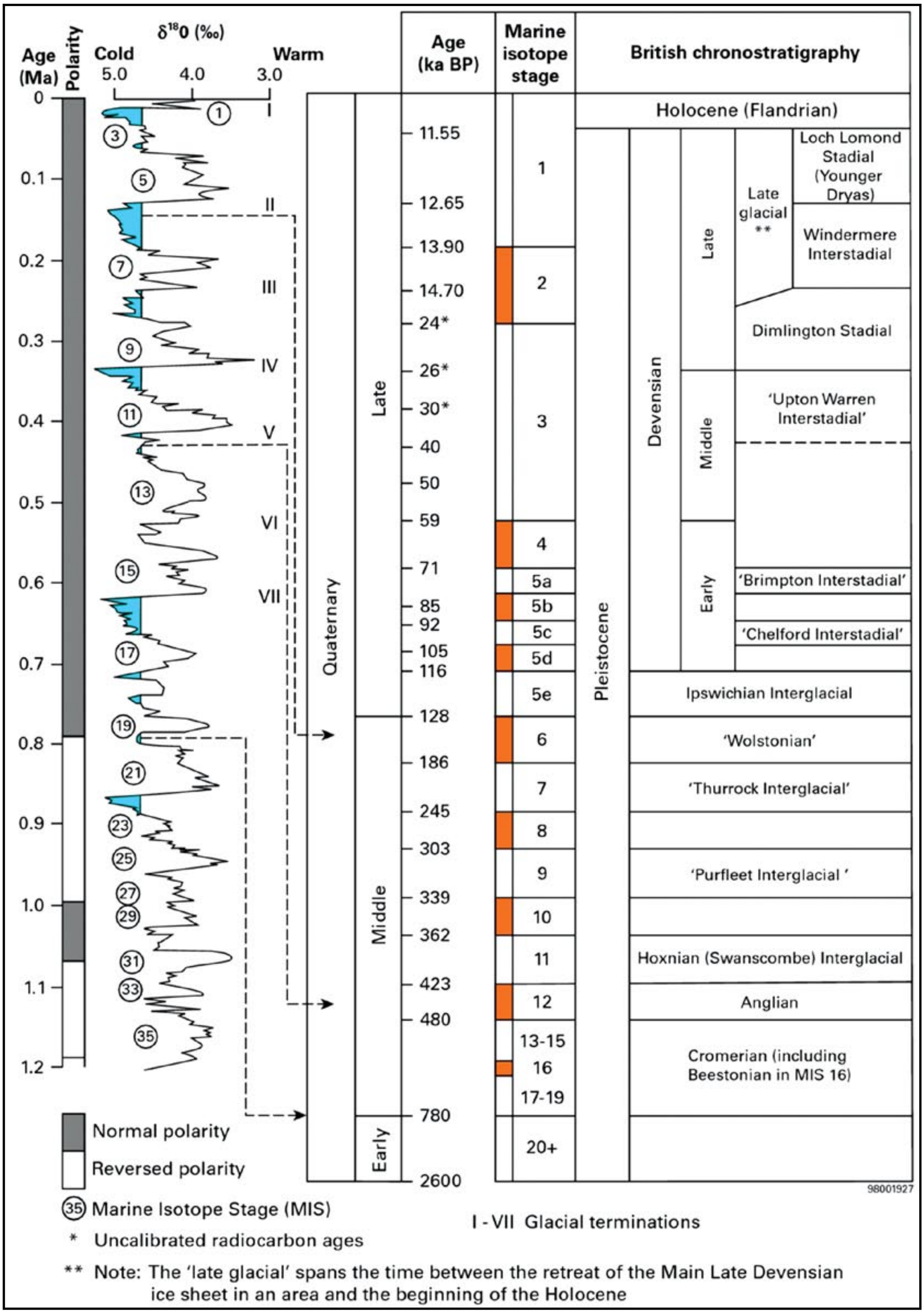

***Figure 1**: British chronostratigraphy terms, geo-magnetic polarity and a representative oxygen isotope record (ODP 677) from the North Atlantic, tuned to orbital timescales. The calendar ages, which are based on historical records, annual layering in ice cores, tree rings, varve counting, etc, are somewhat older than conventional radiocarbon ages, which have been calibrated to take this disparity into account using the radiocarbon calibration program of Stuiver, Reimer, and Reimer (2005) CALIB 5.0. Conventional radiocarbon ages measured on shell material have also been adjusted by subtracting about 405 years, to take into account the 'marine reservoir effect' for British waters. [Figure 64 in Stone,* et al.*, 2010.]*

["CP19/041 BGS © UKRI 2019 BGS Figure P916094 – Description – British chronostratigraphy, geomagnetic polarity and a representative oxygen isotope record (ODP 677) from the North Atlantic tuned to orbital timescales. ***Source:*** *Earthwise a BGS Publication available:* http://earthwise.bgs.ac.uk/index.php?title=File:P916094.jpg&filetimestamp=20160412172228& *"]*

Pleistocene chronology

Details of the geomagnetic polarity, a representative oxygen isotope record, Marine Isotope Stages, British chronostratigraphy and the ages of the sub-divisions of the Quaternary Period, particularly the Pleistocene Epoch, are shown in Figure 1. Due to its mid-latitude position, Britain has experienced strong climatic oscillations throughout the Quaternary and these are reflected in major biological, sedimentological and geomorphological fluctuations (see, for example, Catt *et al*., 2006, p.429). Some of the evidence for these fluctuations has been recorded in clastic cave sediments and speleothems.

By international accord the Bruhnes–Matayuma magnetic reversal, c.780 ka ago, is accepted as marking the start of the Mid Pleistocene. At this time, a change in the Earth's cyclicity, with a decline in the Milankovitch obliquity cycle and an increase in the strength of the 100 ka eccentricity cycle, had a strong effect on climate and led to more extensive glaciations in the northern hemisphere. Within the deep oceanic sequence, the 625 ka of the Mid Pleistocene includes seven major cold stages (MIS 6, 8, 10, 12, 14, 16, 18) and seven interglacial episodes (MIS 7, 9, 11, 13, 15, 17 and the later part of 19) (Catt *et al.,* 2006, p.441).

Again by international agreement, the lower limit of the Late Pleistocene is currently placed at the MIS6–5e boundary, c.120 ka, with the upper limit at the onset of the Holocene placed at c.11.7 ka. This interval includes two Pleistocene terrestrial stages, the Ipswichian (warm) and Devensian (cold), and also MIS 5, 4, 3 and 2 (Catt *et al.,* 2006, p.450). The British terrestrial stages and their approximately equivalent Marine Isotope Stages are shown in Table 1.

Name	Age (ka)	
	uncorrected	corrected
M41 9-59	101 (86–118)	51 (32–71)
M41 9-8a-A	71 (67–76)	45 (41–50)
M41 9-29D	105 (97–115)	86 (76–97)
M41 9-26B	54 (50–59)	51 (45–56)
M41 9-26C	104 (90–120)	——

***Note**: The samples had a very low uranium content and produced low yields of both uranium and thorium, possibly due to organic contamination. In addition, most samples were significantly contaminated by detrital thorium. The ages were corrected for contamination using method 1 (equation 8) of Schwarz (1980).*

***Table 2:** Uranium-series analyses on speleothems from Rhinoceros Hole (adapted from Proctor et al., 1996, p.249).*

Uranium-series dating

In recent years speleothems have become established as one of the most valuable resources for understanding past Earth surface conditions. The common occurrence of continuous episodes of growth, perhaps thousands of years in duration, and the preservation of information – speleothems contain several proxy parameters – can represent timescales from days to millions of years. Individual caves may continue to accrete speleothems over intervals in the order of 10^4 – 10^7 years. Excellent chronologies can be obtained from speleothems using uranium-series dating (e.g. Fairchild and Baker, 2012). In addition, recent advances in resolution have made U–Pb dating a viable option, potentially extending the measurable age range across all of Earth time.

Uranium-series dating, also called uranium–thorium dating, is a radiometric technique, established during the 1960s, that has been used since the 1970s to determine the age of calcium carbonate materials such as speleothems and corals. It provides an age based upon the degree to which secular equilibrium has been restored between the radioactive isotope thorium–230 and its radioactive parent uranium–234 within a sample. The method has an upper limit of circa 500 ka.

Speleothems from Hallowe'en Rift were sampled in 2013 and uranium-series dates obtained by Christopher Smith, University of Bristol. The oldest date, 563 +170 −74 ka, is at the upper limit of the method, but likely relates to Marine Isotope Stage (MIS) 15–13, the Cromerian Complex. Deposits found in the Mendip area attributed to the Cromerian Complex are found at Westbury-sub-Mendip Quarry, comprising cave deposits with numerous mammal bones and, there are deposits of glacio-fluvial gravels of the Kenn Formation found at Bleadon Hill (ST 350573) (e.g. Catt, *et al.,* 2006, p 441). Other cave deposits in southwest England include basal breccias at Kent's Cavern, Torquay, Devon (Lundberg and MacFarlane, 2007).

A younger date, 51.26 +0.31 −0.32 ka, has some similarity to dates obtained on speleothems sampled from Rhinoceros Hole (Table 2), a cave located in the Wookey Hole ravine near to Hallowe'en Rift (Proctor *et al*., 1996); these dates relate to MIS 3, Mid Devensian.

Middle Devensian sediments in England are mainly represented by fluvial and cave deposits. In northwest and southwest England cave sequences indicate slightly warmer conditions in the later part of the Middle Devensian. During this time production of soil CO_2 was sufficient to allow limestone dissolution and support the growth of speleothems. In the earlier part of the Devensian almost no speleothems were formed and during the later Devensian, c.30–14 ka ^{14}C BP, permafrost inhibited micro-biological oxidation of soil matter and so restricted speleothem formation (Catt *et al*., 2006).

	^{230}Th age (yr BP) uncorrected	^{230}Th age (yr BP) corrected
HR1-T	215,642 ± 2471	215,221 ± 2576
HR1-B	220,954 ± 2209	219,378 ± 2429 correlates to MIS7
HR2-T	127,174 ± 902	125,341 ± 1532
HR2-B	129,903 ± 569	126,834 ± 2197 correlates to MIS5e

***Note**: Corrected 230Th ages assume the initial 230Th/232Th atomic ratio of 4.4±2.2 x 10^{-6}. Those are the values for a material at secular equilibrium, with the bulk earth 232Th/238U value of 3.8. The errors are arbitrarily assumed to be 50%.*
BP stands for "Before Present" where the "Present" is defined as the year 1950 AD. T and B indicate Tops and Bottoms of samples.

***Table 3**: U-series dates for speleothems sampled from solifluction deposits in October 2018. See also Figure 2 and Photo 6.*

***Photo 4**: Frost/ice damaged stalagmite at the top of the rift in An Unexpected Development. It is unlikely that precariously balanced pieces would remain in-situ if they are the result of earth movements.*

Climatically, MIS3 stands out from other 'warm' episodes (e.g. MIS5), in being relatively cold and highly unstable. A series of rapid climatic changes, the Dansgaard–Oeschger (D–O) oscillations, between ~60 ka BP and ~25 ka BP, each lasting ~500–2000 years, consisted of abrupt warming of ~5–8°C within 10–50 years, followed by slower cooling. Thus, MIS3 was neither an interglacial nor a glacial, but a series of alternating warm and cold events occurring over millennial timescales (e.g. Pettitt and White, 2012).

The Stage 3 Project (van Andel and Davies, 2003) divided the climatic fluctuations into three broad sub-phases:

1. An early mild phase ~59–43 ka BP;
2. A period of climatic deteriorations, ~42–37 ka BP, showing more tightly spaced clusters of cold D–O oscillations;
3. A cold phase commencing ~37 ka BP during which conditions were similar to those of the last glacial maximum (MIS2).

Additional uranium-series dating of speleothems recovered from solifluction deposits, carried out by Dr Gina Moseley, University of Innsbruck, in 2019 (Table 3), obtained dates of: 219.4 ± 2.4 ka to 215.2 ± 2.5. These relate to MIS7c, the 'Aveley' Interglacial, a period of maximum insolation (the solar radiation that reaches the earth's surface and affects temperature) for a warm stage within MIS7 (after Scott and Ashton, 2010, *in* Pettitt and White, 2012, p.212). A second date, 126.8 ± 1.5 to 125.3 ± 2.2, MIS5e, relates to the Ipswichian Interglacial (Table 3). The range of the dates obtained is presented in Figure 2; the wide range for MIS13–15 reflects the result being at the upper limit of the U-series dating method.

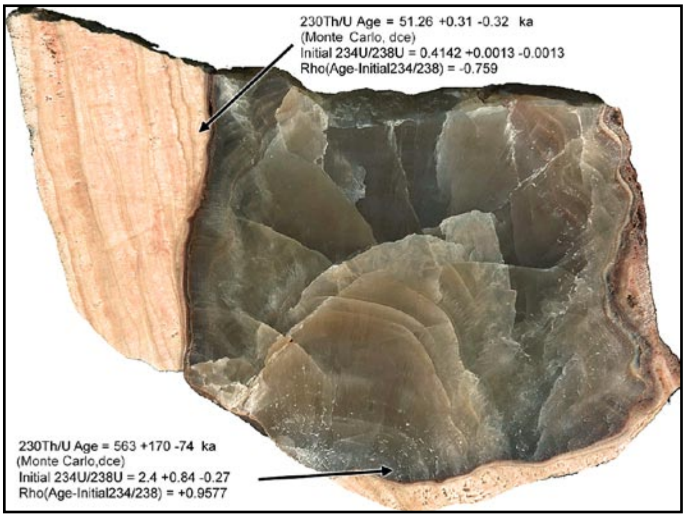

***Photo 5**: Image and details of Uranium-series dating by Christopher Smith, University of Bristol (2013). See also Figure 2.*

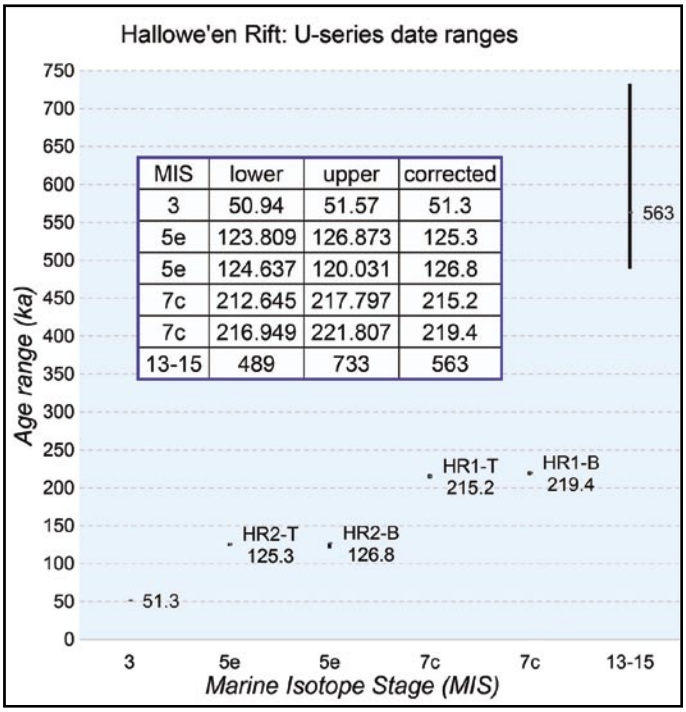

***Figure 2**: Chart showing U-series date ranges obtained from speleothems sampled in Hallowe'en Rift. "T" and "B" indicate sample Tops and Bottoms respectively.*
See also Table 3 and photos 5 and 6.

*The **inset table** shows the data represented by the chart.*

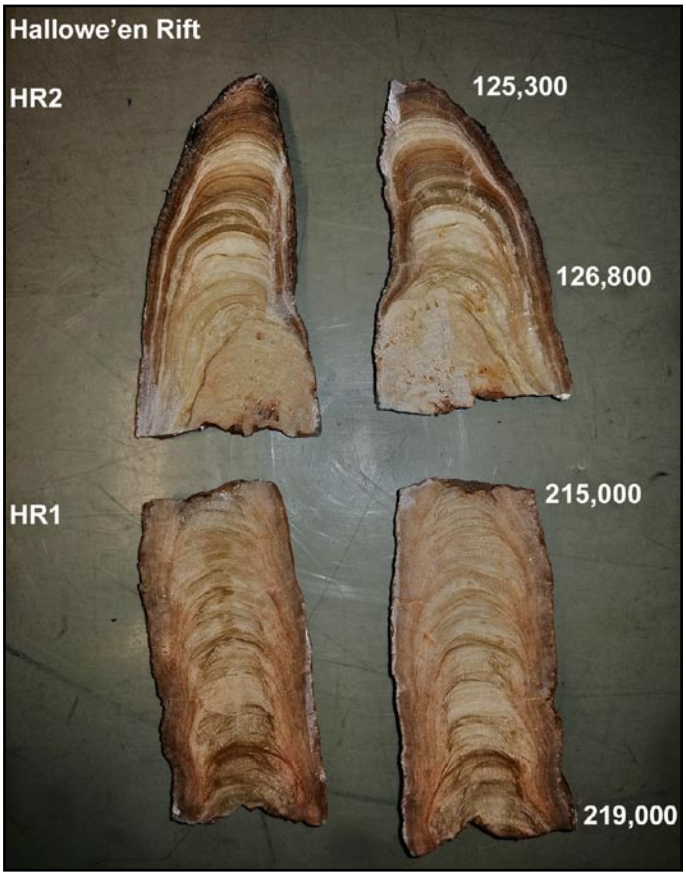

***Photo 6**: Image and details of Uranium-series dating by Dr Gina Moseley, University of Innsbruck (2019).*
See also Figure 2 and Table 3.

The Ipswichian interglacial, MIS5e, was one of the warmest episodes of the last 500 ka, with palaeoenvironmental evidence indicating mean July temperatures some 4°C above those in southern England at present. Winters were mild, with mean January temperatures perhaps only dropping to 1–2°C (Pettitt and White, 2012, p.291). The temperatures for July in southern England for the period 1971–2000 averaged a high of ~21°C and low ~12°C, with January temperatures averaging 5.4°C to 9.2°C.

The preceding MIS6 appears to have seen some 50 ka of sustained cold and was one of the most severe glaciations of the past 500 ka, with mean July temperatures c.10°C and January temperatures c.−21°C. The Early Devensian glaciation, MIS4, and cold sub-stages of MIS5d and MIS5b show similar conditions. The faunal record is characterized by a suite of Arctic-adapted mammals, formally assigned to the Banwell Bone Cave Mammalian Assemblage Zone (MAZ) (Pettitt and White, 2012, p.287).

Comments

Investigation of Hallowe'en Rift is an ongoing project and it is evident that, to enable a better understanding of the chronology of the events that took place in the cave, additional dating of speleothems is required.

Further research is planned, with the intention of trying to establish details of the phasing of the fine sediment (clay, silt and sand) deposition within the cave passages.

It is highly likely that similar frost/ice-related speleothem damage has occurred in other Mendip caves, particularly shallow caves, and a re-evaluation of these sites should be considered.

Acknowledgements

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Photographs are by the author unless stated otherwise.

References

Catt, J A, Gibbard, P L, Lowe, J J, McCarroll, D, Scourse, J D, Walker, M J C and Wymer, J J, 2006. Quaternary: ice sheets and their legacy. 429–469 *in* Brenchley, P J and Rawson, P F (eds), *The Geology of England and Wales*. [London: The Geological Society.]

Fairchild, I J and Baker, A, 2012. *Speleothem Science: from Past Processes to Past Environments*. Blackwell Quaternary Geoscience Series. [Wiley-Blackwell.]

Gilli, E, 2004. Glacial causes of damage and difficulties to use speleothems as palaeoseismic indicators. *Geodinamica Acta*, Vol.17(3), 229–240.

Kempe, S, 2004. Natural speleothem damage in Postojnska jama (Slovenia), caused by glacial cave ice? A first assessment. *Acta Carsologica*, Vol.33/1, 18, 265–289.

Lundberg, J and McFarlane, D A, 2007. Pleistocene depositional history in a periglacial terrane: A 500 k.y. record from Kent's Cavern, Devon, United Kingdom. *Geosphere*, August 2007, 199–219.

Pettitt, P and White, M, 2012. *The British Palaeolithic: human societies at the edge of the Pleistocene world*. Routledge Archaeology of Northern Europe. [London and New York: Routledge.]

Proctor, C J, Collcutt, S N, Currant, A P, Hawkes, C J, Roe, D A and Smart, P L, 1996. A report on the excavations at Rhinoceros Hole, Wookey. *Proceedings of the University of Bristol Spelaeological Society*, Vol.30(3), 237–262.

Stone, P, Millward, D, Young, B, Merritt, J W, Clarke, S M, McCormac, M and Lawrence, D J D. 2010. *British Regional Geology: Northern England*. Fifth Edition. [Keyworth, Nottingham: British Geological Survey.]

van Andel, T and Davies, S W G, 2003. *Neanderthals and Modern Humans in the European Landscape during the Last Glaciation: Archaeological Results of the Stage 3 Project*. [Cambridge: McDonald Institute.]