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A uranium-series date from Wall End Cave, Silverdale, northwest England: its palaeoclimatic and archaeological significance

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Abstract: Uranium-series dating of a stalagmite floor from a relict cave in the Morecambe Bay karst indicates speleothem deposition occurred between 13,567 to 8539 years BP. Comparison with other cave archaeological sites where a stalagmite floor occurs in a similar stratigraphical position suggests the first human occupation of the region following the Last Glacial Maximum may have occurred in the early part of the Windermere/Late Glacial Interstadial.

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The Morecambe Bay karst area consists of a series of low-lying fault blocks made up of rocks belonging to the Carboniferous (Middle Mississippian) Great Scar Limestone Group (Fig.1). Outstanding examples of limestone pavement and other karst landforms are well-known features in the eastern part of the area (Gale, 2000; Webb, 2013), but there are relatively few explored caves (Holland, 1967; Ashmead, 1974a; Allshorn and Swire, 2017). Limestone escarpments that have formed on the fault blocks lack a capping of impermeable rocks and, thus, drainage is wholly subterranean with little integration of surface flow. Recharge to the limestone aquifers is largely by diffuse flow, but the existence of discrete risings and some restricted active cave development around the bases of the escarpments implies integration of the diffuse-flow inputs within the aquifers (Murphy and Moseley, 2015).

Fragments of hydrologically inactive and largely sediment-choked cave passage survive in places (Walsh, 2010). The bulk of these consist of short, isolated remnants of phreatic passage, with evidence of later vadose activity, if any, obscured beneath sedimentary fill (Gale, 1984a; Murphy and Moseley, 2015).

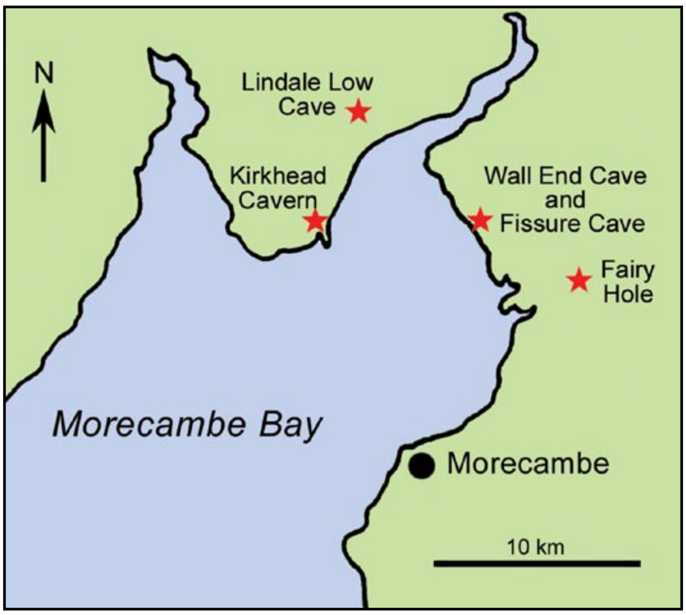

***Figure 1**: Approximate locations of some caves mentioned in the text.*

These cave fragments attracted the attention of antiquarians and bone-hunters during Victorian times (Smith, 2012), followed by archaeological attention mainly confined to the early years of the 20th century (Jackson, 1910) with subsequent bursts of activity in the late 1960s and early 1970s (e.g. Ashmead and Wood, 1974), and the 1980s (Salisbury, 1988, 1992). Much of the archaeological interest has been centred on seeking evidence for early human occupation following the retreat of the Last Glacial Maximum ice sheet from the region.

The known inactive cave fragments show no obvious relationship to the present-day topography or hydrology of the area, and it is also difficult to determine former hydrological relationships between any of them. In an attempt to explain the location of these caves within the modern landscape, Ashmead (1969, 1974a, 1974b) related the altitudes of cave development in the area to a succession of regional water tables controlled by the series of falling Pleistocene eustatic sea-levels proposed by Parry (1960). Gale (1981), however, showed that the distribution of the caves is essentially random, implying the absence of a simple altitudinal control on cave occurrence, and he was also unable to find any morphological or sedimentary evidence of the sea levels postulated by Parry (Murphy and Moseley, 2015).

Measurements of scallop assemblages in three of the Morecambe Bay caves enabled Gale (1984b) to calculate former discharge velocities and, by extrapolation, to estimate the catchment areas of each cave at the time the scallops were formed. In all three examples (Roudsea Wood Cave: SD33358255; Capeshead Cave: SD33337814; and Fairy Cave, Witherslack: SD43408265), the calculated area of the former catchment is far larger than the present-day area, implying, if correct, that the formation of the scallops pre-dates the dissection and reduction of the catchment areas of the limestone fault-blocks in which the caves occur (Gale, 1984, 189–190). However, in the absence of an understanding of the Quaternary and late-Neogene denudational history of the area, Gale was only able to propose a pre-Last Glacial chronology. A uranium-series date from a speleothem sample recovered from a spoil heap resulting from cavers digging activity in Fairy Hole on the southern flank of Warton Crag (Murphy *et al*., 2016) gave an age of 52–62 ka (MIS3) showing that this abandoned phreatic riser was drained prior to this date, confirming the pre-Last Glacial age proposed by Gale.

Tufaceous stalagmite floors are seen in several phreatic cave fragments around Morecambe Bay and have featured in accounts of archaeological excavations. In Kirkhead Cave (Kirkhead Cavern: SD39097566), a well-known archaeological site on the western side of the bay, a soft and porous stalagmite layer found within the cave fill was considered to correlate with cemented scree from deposits around the cave entrance (see the summary in Smith, 2012). Both the deposit in the interior of the cave and the correlated cemented-scree layer outside the cave were found to overlie a cave earth deposit that contained worked flint assemblages considered to be in part of late Upper Palaeolithic (Cresswellian) affinity. In order to try and constrain the date of the flint deposition and thus the stalagmite floor, a portion of deer antler impregnated with calcite reported as being found partially embedded in the stalagmite layer was subjected to radiocarbon-dating at Harwell in 1975. The resulting date was 10,700 years BP ±200 (HAR – 1059 uncorrected). This work was, however, undertaken before the development of modern sample-preparation techniques such as ultrafiltration, when the associated analytical technology and calibration were also relatively primitive.

Later studies (Gale *et al*., 1984, 1985) on the stratigraphy of this site proved rather controversial (Salisbury, 1986; Tipping, 1986; Gale and Hunt, 1990). A major issue was confusion over the position of the antler (mentioned above) that was subjected to carbon dating. The excavation report states it was partially embedded in the stalagmite floor (Wood *et al*., 1969, p.21) though when sent for dating its position was described on the dating certificate as being '*… from beneath a stalagmite level …*'. Another reference gives its position as '*… resting on a tufaceous deposit …*' (Ashmead, 1970). This confusion as to the true location of the dated antler sample has undermined its value in constraining the date of the stalagmite floor and led to debate about the chronostratigraphy of the site. Nevertheless, the dating did show that the cave contains deposits of considerable antiquity. It is presumed that the antler sample was destroyed during the dating process. Lindale Low Cave (SD41708008), referred to as Broca Hill Cave 2 by Allshorn and Swire (2017) and Holland (1967), was excavated during the 1980s (Salisbury, 1988, 1992). This cave produced definitive evidence – from below the level of a tufaceous stalagmite floor – for Late Upper Palaeolithic use of the site.

Sea cliffs around Silverdale on the eastern side of Morecambe Bay contain several cave fragments (Anon, 1969). According to Allshorn and Swire (2017, p.446) the longest of these, Fissure Cave (SD45567557), consists of 15m of passage. The cave is, however, more complex than this simple description might suggest. On entering the cave, a circular, vertical, aven is passed, with scalloping showing water having flowed up the shaft. Scalloping in the cave passage shows water flow was outwards towards the entrance thus the cave appears to be the base of a phreatic loop which has been intersected due to cliff retreat. Beyond this point the roof of the cave passage consists of glacial till containing striated clasts of chloritized lithologies typical of the Lower Palaeozoic strata of the Lake District massif to the north. Because at this point the cave is at least 10m below the surface this suggests the presence of a further vertical shaft that is entirely filled with glacigenic material, supporting the conclusion reached by Walsh (2010) that much cave passage in the area has been filled with glacial sediment. There is a step-up in the cave floor over sedimentary fill above which is a stalagmite floor. Much of the stalagmitic material has a rather spongy, tufaceous, appearance but the top layer, which is more typical of cave speleothem material, is fragmented. The stalagmite floor has been traced throughout the cave, as shown on the accompanying survey (Fig.2). Attempts to date the more crystalline upper layers of this deposit as part of this study were thwarted by the presence of high levels of detrital thorium.

A short cave named Wall End Cave (SD45467569), situated 175m north along the coast from Fissure Cave, consists of 11m of passage. This cave also contains the remains of a tufaceous stalagmite floor. Much of the sediment formerly beneath has been eroded away, leaving the stalagmite floor now at mid-height in the passage. Uranium-series dates obtained for the base and top of a sample from this deposit indicate a period of growth from 13,567±1022 to 8539±2115 (Table 1). Again the presence of detrital thorium significantly affects the precision of the dating, but the result shows that the speleothem floor in Wall End Cave, and by inference the corresponding deposit in Fissure Cave and others across the region, were undergoing active deposition in Late Glacial/Early Holocene times. There must have been significant groundwater movement during this time, indicating a relatively warm and wet climatic regime in the Morecambe Bay area and the high levels of detrital thorium in the samples suggest ongoing weathering of non-carbonate materials. The period indicated by the dates is one of significant climatic instability covering the Windermere Interstadial (Late Glacial Interstadial – Greenland Interstadial 1) and Loch Lomond Stadial (Greenland Stadial 1, Younger Dryas) as well as the early part of the Holocene. The basal date from the sample suggests the early human presence in the area, at the northern limit of Late Glacial human activity in Britain, indicated by archaeological evidence from the Kirkhead Cavern found below the corresponding stalagmite floor, may have been in the early part of the Windermere Interstadial. This fits with findings from Victoria Cave near Settle, 30km to the east, where radiocarbon dates on a reindeer-bone artefact and on a cut-marked wild-horse bone have confirmed human presence during the first part of the Windermere Interstadial (Lord, 2013; Lord and Howard, 2013). Pollen data from a nearby lake site at Hawes Water, two kilometres east of Fissure Cave, indicated a juniper-scrub vegetation at this time, with a transition to birch woodland in the latter half of the interstadial (Marshall *et al*., 2002). There does appear to be some consistency in the stratigraphy found below the stalagmite floor at the various sites discussed. The lowest layer generally comprises very well-rounded gravel clasts including limestone together with chloritized igneous and clastic lithologies. This layer was described as being "river gravels" in reports on the 1970s archaeological excavations at Kirkhead Cave. A similar deposit is seen in the lowest parts of Fissure Cave and preserved as wall remnants in Silverdale Shore Cave. A layer containing many rounded gravel clasts, including

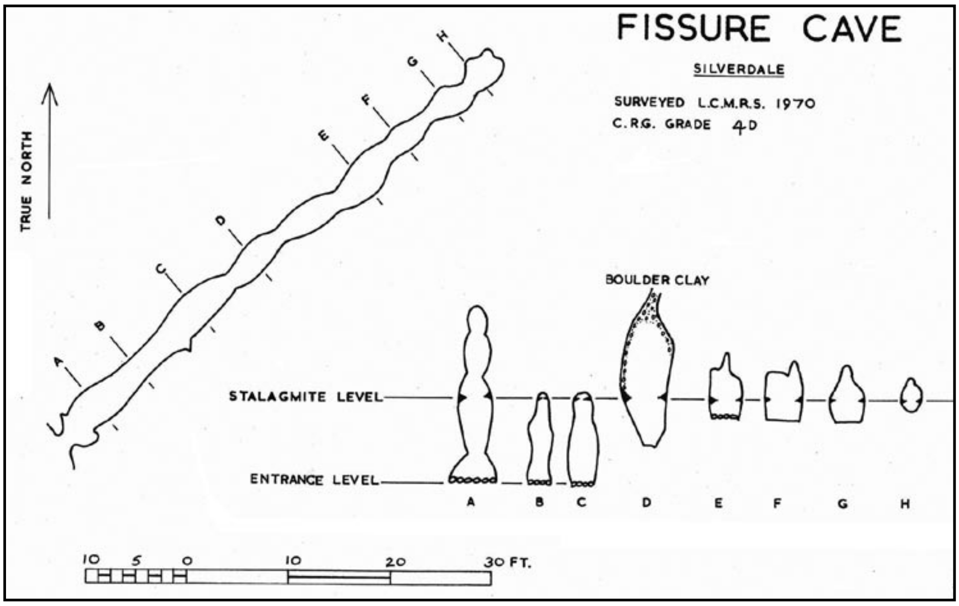

Figure 2: *Survey of Fissure Cave, Silverdale. (Modified from an original in the Ashmead Archive.)*

Sample	Sample Number	^{238}U (ppb)	^{232}Th (ppt)	^{230}Th / ^{232}Th (atomic × 10^{-6})	$\delta^{234}U$* (measured)	^{230}Th / ^{238}U (activity)	^{230}Th age (uncorrected) (yr)	^{230}Th age (corrected) (yr)	$\delta^{234}U_{Initial}$** (corrected)	^{230}Th age (corrected) (yr BP)***
WC-Top	**GM1326**	89 ± 0.1	9717 ± 195	17 ± 0.4	76 ± 3.0	0.1085 ± 0.0016	11,584 ± 178	**8608 ± 2114**	78 ± 3.1	**8539 ± 2114**
WC-Bottom	**GM1330**	241 ± 0.4	13,568 ± 273	43 ± 0.9	142 ± 1.9	0.1479 ± 0.0007	15,075 ± 85	**13,636 ± 1022**	148 ± 2.0	**13,567 ± 1022**

Uncertainties (shown as "±") are 2σ.
U decay constants: $\lambda_{238} = 1.55125 \times 10^{-10}$ (Jaffey *et al.*, 1971) and $\lambda_{234} = 2.82206 \times 10^{-6}$ (Cheng *et al.*, 2013).
Th decay constant: $\lambda_{230} = 9.1705 \times 10^{-6}$ (Cheng *et al.*, 2013).
* $\delta^{234}U = ([^{234}U / ^{238}U]_{activity} - 1) \times 1000$.
** $\delta^{234}U_{initial}$ was calculated based on ^{230}Th age (T), i.e., $\delta^{234}U_{initial} = \delta^{234}U_{measured} \times e^{\lambda_{234} \times T}$.
Corrected ^{230}Th ages assume the initial ^{230}Th / ^{232}Th atomic ratio of $4.4 \pm 2.2 \times 10^{-6}$. The errors are arbitrarily assumed to be 50%.
*** BP stands for "Before Present", where the "Present" is defined as the year 1950 AD.

***Table 1**: U and Th concentrations, isotopic activity ratios and U–Th age for two samples from Wall End Cave, Silverdale.*

typical Lake District lithologies, was reported in a similar stratigraphical position from Lindale Low Cave (Salisbury, 1988). This suggests that the caves of the area were subject to high discharge events, leaving deposits of well-rounded, gravel-size clasts prior to drainage, followed by occasional human occupation in the late Upper Palaeolithic, and then the subsequent episode of tufaceous stalagmite deposition.

Conclusion

The presence of tufaceous stalagmite floors in the phreatic cave fragments that characterize the Morecambe Bay Karst has been recorded in both archaeological and caving literature. Occurrence of such deposits across the area suggests that this is the result of regional climatic control rather than individual cave hydrological conditions. Uranium-series dates on speleothem deposits from Wall End Cave, Silverdale, confirm a late Pleistocene/early Holocene date for the deposition (as had previously been inferred from sparse archaeological evidence), and suggest that human activity in the area started during the early part of the Windermere Interstadial.

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