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A U-series date from Canal Cave, Nidderdale, North Yorkshire, UK and its implications for valley incision

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Abstract: The Canal Cave system has been drained as a result of valley incision by the River Nidd. A U-series date obtained from a speleothem sample in Canal Cave show that cave development occurred prior to the end Pleistocene. The presence of detrital thorium in the speleothem samples, probably due to the nature of the catchment, limits dating precision. However, this study confirms that the cave was drained shortly after the area was deglaciated.

Keywords: cave drainage; geomorphology; Late Pleistocene; speleothem; Yoredale Group.

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The caves of the eastern part of the Yorkshire Dales karst in northern England are relatively rarely and superficially studied as compared to those of the classic karst of the Three Peaks area to the west. This is true especially of the most easterly valley of Nidderdale. The valley is surrounded by extensive moorland underlain by sandstone- and mudstone-dominated strata of the Millstone Grit Group. Underlying the Millstone Grit Group beds are strata of the cyclothemic Yoredale Group, which include cavernous limestone-dominated units.

The incision of the Upper Nidderdale valley has partially removed parts of the clastic-rock cover, revealing limestone beds within the Yoredale Group succession in three valley-floor inliers (Fig.1). By far the most extensive cave system is that beneath the main valley, where in normal conditions the River Nidd sinks into the limestone sequence exposed within the Limley Inlier and resurges at Nidd Heads Risings in the Lofthouse Inlier, having traversed passages forming parts of Manchester Hole, Goyden Pot and New Goyden Pot, which together comprise more than 9km of explored passages (Brook *et al*., 1988; Fox 2017). Uranium-series dating has shown that much of this system was developed before early Marine Isotope Stage 3 (Murphy *et al*., 2024).

Southwards from the Limley Inlier, the Lofthouse Inlier hosts the 2.5km-long Eglins Hole/Low Eglins Hole cave system (Fig.1), which trend parallel to the sub-aerial gorge of How Stean Beck. This cave system is unique in the area, because the beck's underground course has been abandoned – now perched above the modern course of the surface stream – in response to the ongoing incision of the gorge by surface streamflow. The gradient of the gorge thalweg is steeper than the local bedding-dip of the limestone (Waltham *et al.*, 1997). At the southern limit of the Lofthouse Inlier, the Blayshaw Gill cave system (Fig.1) gives access to approximately 950m of structurally complex and largely sediment-filled passages.

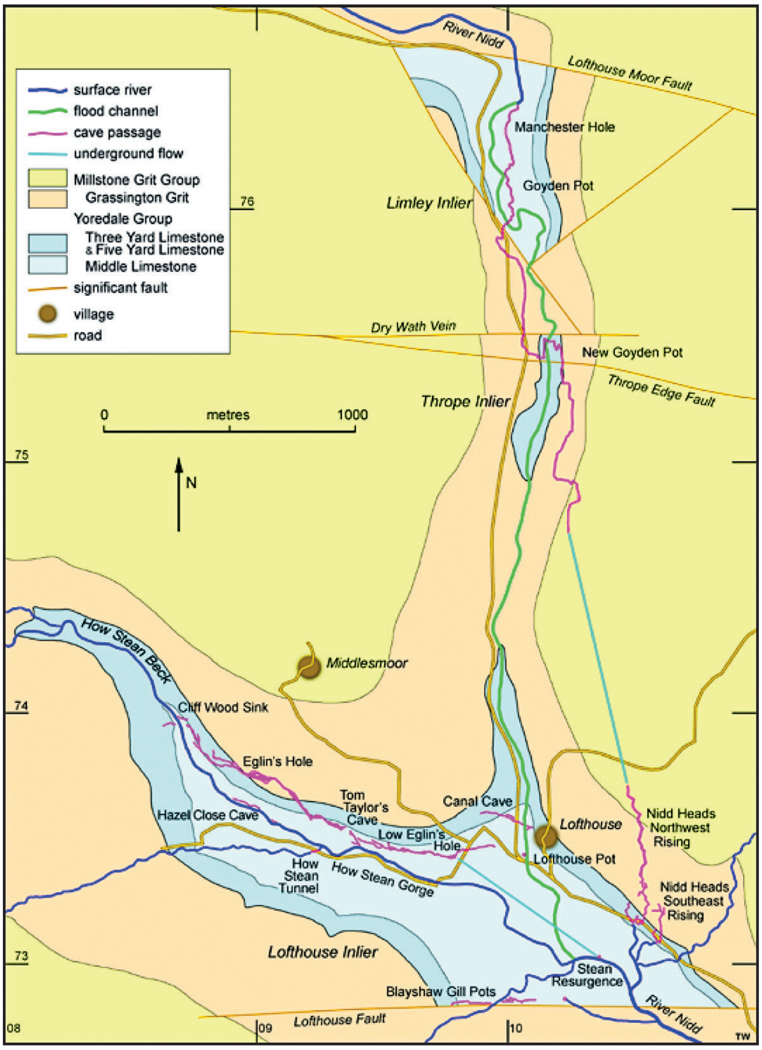

***Figure 1**:*
Outline geology and main known caves in upper Nidderdale. Only the main stream passage of Goyden Pot is marked. [From Waltham and Lowe, 2017, Figure 29.2, compiled by Tony Waltham after surveys by the Cave Diving Group, the Yorkshire Underground Research Team, and the Yorkshire Ramblers' Club.]

Figure 2: *Looking westwards towards the entrance of Canal Cave. The trench crossing the bed of the River Nidd can be clearly seen.*

A fourth series of caves occurs within the Middle Limestone, close to the village of Lofthouse. The 260m-long Canal Cave (British National Grid Reference [NGR] SE1006 7355; Fig.1), which was explored during the 1950s and 1960s (Melvin, 1966; Davies 1970), consists of a narrow west–east- orientated passage containing a 5m-climb, with the cave's upstream (western) end blocked by calcite deposits. Downcutting of the River Nidd has intersected the route of the former passage, which can be traced across the riverbed as a slot (Fig.2) that leads to the passage's downstream (eastward) continuation under the eastern bank. To date this passage, known as Lower Canal Cave, has been explored for 30m.

It has been suggested (Davies, (1974) that the stream in Canal Cave is sourced from a sink approximately 120m from the end of the surveyed cave, but only an unsuccessful dye trace was recorded. Two additional traces have since been attempted from this sink, with no dye detected in Canal Cave, suggesting that the local hydrology might be more complex than initially proposed. A possible water source in the How Stean area was suggested by Melvin (1966). A final destination for the waters entering Lower Canal Cave was suggested by Davies (1974) as being Stean Resurgence/Sandbeds Rising (NGR SE1038 7303; Fig.1), but there was no supporting evidence. Canal Cave/Lower Canal Cave is not the only cave system truncated by the river, with Lofthouse Foss Caves and Perrier Cave being additional examples (see Fox *et al*., 2023 pp.43–46 for details).

In an attempt to constrain the timing of cave development in this intriguing cave system, and thus the date by when the River Nidd had down cut to a level intersecting and draining the cave, a speleothem sample from a ledge above the climb in Canal Cave was selected for uranium-series dating (Table 1). Unfortunately, the sample was contaminated by detrital thorium, resulting in a considerable loss of precision, a disadvantageous factor that had previously been encountered elsewhere in the valley (Murphy *et al*. 2024). Nevertheless, a Late Pleistocene date is indicated for the basal part of the sample (14136 + 11.7 − 11.3 ka BP). This suggests that the cave was drained – and thus that the valley of the River Nidd at Lofthouse had incised close to its present level – close to the end of the Pleistocene, after the area's deglaciation.

In a compilation of U-series dates from the Yorkshire Dales Karst featured as Figure 10.10 in Latham and Ford (2023), the period 10 – 15 ka BP is shown as a period of prolific speleothem growth, with more than 30 dates published. This might be a reflection of the area no longer exhibiting periglacial conditions following the commencement of the Windermere (Late Devensian) Interstadial at 14.7 ka BP (Vincent *et al*., 2010).

^{230}Th dating results. The error is 2σ.

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 (yr) (uncorrected)	**^{230}Th Age (yr) (corrected)**	$\delta^{234}U_{initial}$** (corrected)	**^{230}Th Age (yr BP)*** (corrected)**
Leeds	79.1 ± 0.1	12741 ± 255	18 ± 0	94.0 ± 2.0	0.1710 ± 0.0018	18487 ± 212	**14136 ± 3088**	98 ± 2	**14061 ± 3088**

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 $4.4 \pm 2.2 \times 10^{-6}$.
Those are the values for a material at secular equilibrium, with the bulk earth ^{232}Th/^{238}U value of 3.8. The errors are arbitrarily assumed to be 50%.

*** B.P. stands for "Before Present", where the "Present" is defined as the year 1950 A.D.

Table 1: *U and Th concentrations, isotopic activity ratios and U–Th age.*

Stump Cross Caverns, situated some 10km south of Canal Cave, beneath the Nidderdale–Wharfedale interfluve, is the closest cave site to have been studied in detail. Here, a recent re-study of the site produced no isotopic ages from this interval (Lundberg *et al*., 2020), whereas earlier studies have produced dates of 15 ± 1 ka BP (Atkinson *et al*.,1986) and 11.7 ± 4.7 and 11.3 ± 2.8 ka BP (Baker *et al*., 1996). This indicates that speleothem deposition was taking place close to the study site at a similar time to that of the growth of the Canal Cave sample.

Conclusions

U-series dating of a speleothem from Canal Cave has shown that the incision of the Nidd valley near Lofthouse must have reached the level of the cave by the end of the Pleistocene, draining the active cave passage and thus enabling speleothem growth. As previously recorded in other caves in the valley, a significant detrital thorium content within the sample has imposed a severe limit on the precision of the work. Even allowing for the reduced precision related to this negative factor, it now appears that cave development in Nidderdale was well underway by Marine Isotope Stage 3, pre-dating the Last Glacial Maximum, and that valley incision had reached close to its present level by the close of the Pleistocene. Additionally this work and the dating result supports the assertion of Davies (1974), that the caves of Nidderdale "…*clearly have a varied and complex geomorphic history*

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