Article:

Murphy, PJ and Everett, S (2013) The "gulfs" of Greenhow Hill, North Yorkshire, UK. Cave and Karst Science, 40 (2). 87 - 91. ISSN 1356-191X

ISSN 1356-191X

The "gulfs" of Greenhow Hill, North Yorkshire, UK.

Phillip J MURPHY [1] and **Shirley EVERETT** [2]

[1] School of Earth and Environment, University of Leeds, LS2 9JT, UK.

[2] 12 Sawley Close, Embsay, North Yorkshire, BD23 6QY, UK.

Abstract: Sediment-filled karstic cavities known locally as 'gulfs' or 'gulphs' were encountered my miners working the mineral veins of the Greenhow Hill mining field in the Yorkshire Dales, UK. Based upon study of limited historical records of the mine workings, subsequent publications, and examination of the few gulfs still accessible, it appears that the main phase of gulf development post-dates late Permian mineral emplacement but some might, at least in part, pre-date mineral emplacement. Available evidence suggests that clastic sediments, which include re-worked epigenetic mineral material and occupy all reported and accessible gulf cavities, might have been emplaced during an interglacial warm phase older than the Last Glacial Maximum.

Received: 25 February 2013; Accepted 01 May 2013.

The Greenhow Hill mining field, positioned on the interfluve between Wharfedale and Nidderdale in the southeastern corner of the Yorkshire Dales (Fig.1), differs from other mineralized areas of the English Pennines in that the mineralized carbonate strata are folded into a complex, broadly antiformal, structure that forms the eastern limit of the Ribblesdale Fold Belt (Arthurton, 1984; Kirby *et al.,* 2000). Three domes (Coldstones, Greenhow Hill and Nussey Knot) are identified within the main antiformal crest, and these are separated by the Green Grooves and Craven Cross basins (Fig.2). This fold structure is further complicated by its coincidence with the Craven Fault Zone, a major regional structure that forms the southern limit of mineralized ground in the Coldstones and Greenhow Hill area.

Broadly the stratigraphy consists of limestone strata, equivalent to the upper part of the Carboniferous Great Scar Limestone Group; older beds are not exposed in the area. Overlying rocks of the Yoredale Group were thought to be absent in the Greenhow district by Dunham and Stubblefield (1945) but a borehole sunk by Bewerley Mines in 1971 proved a 68m-thick sequence of sandstones and shales, including the Dirt Pot Grit, which was faulted out of the sequence recorded in Gillfield and Cockhill levels (Dunham and Wilson, 1985). Above the Dirt Pot Grit the Toft Gate Limestone, a highly crinoidal unit, correlates with the Simonstone Limestone and immediately higher beds within the Yoredale Group. An erosion surface that cuts across the Yoredale Group equivalents and underlying beds of the Great Scar Limestone is overlain unconformably by the sandstones and shales of the Millstone Grit Group (Waters and Lowe, 2013, Figure 2.9).

A mix of relatively complex structure and stratigraphy has provided a more diverse environment for epigenetic mineralization than is usual within the Pennine ore fields. Details of the stratigraphy and structure are given by Dunham and Stubblefield (1945) and an account of the mineralization is provided by Dunham and Wilson (1985). Historical information about the mining field is given by Gill (1998).

Figure 1: Location of the study area; pale blue and darker blue shading show the approximate surface extents of the Great Scar Limestone Group and of the Main (Great) Limestone within the Yoredale Group respectively. (Map base kindly provided by T Waltham.)

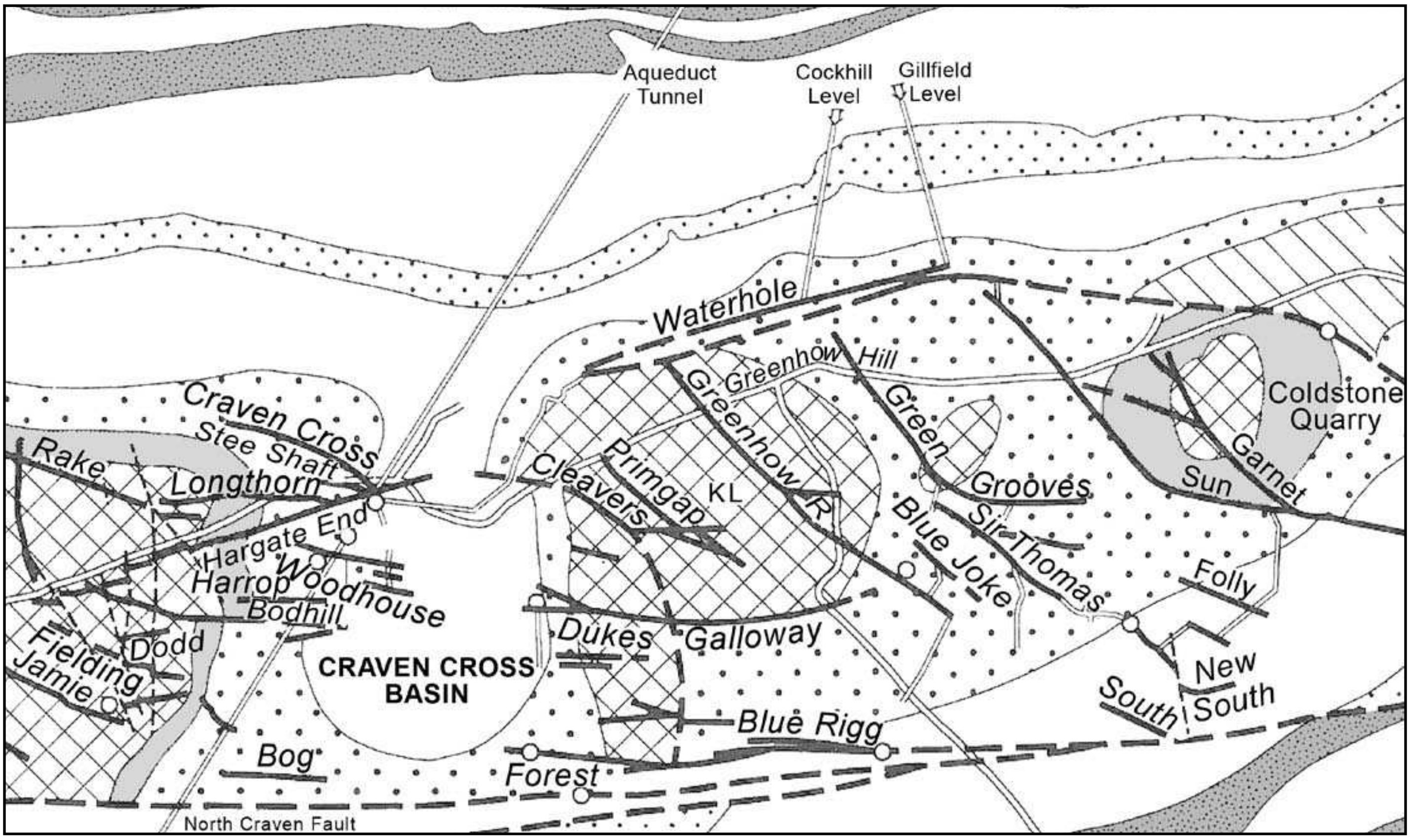

Figure 2: *Simplified geological map of the Greenhow area. Hatched areas are carbonate strata; the hatched area west of Coldstone[s] Quarry marks the core of the Coldstones Dome. Reproduced from Dunham and Wilson, 1985.*

Figure 3: *Looking into a gulf on Waterhole Vein. The fill has slumped in the foreground revealing the dissolutionally sculpted gulf wall.*

Gulfs

Sediment–filled, near-vertical dissolution cavities, known locally as 'gulfs' or 'gulphs', cutting across productive mineral veins in the Greenhow mining area, were recorded by Varvill (1927, pp.503–504) and Dunham and Stubblefield (1945). These cavities, which are described as either swallow holes or caverns, developed either along or across the productive veins, have walls that appear water worn, either smooth or fluted. Some gulfs occur where veins are cut by cross veins, but others are unrelated to cross veins. Most of the recorded gulfs are within the rocks forming the Coldstones Dome (Fig.2), but one possible example was encountered in the Lanshaw Level, some 8km to the west in Hebden Gill. Gulfs are distinct from the essentially horizontal passages that were met in the Stump Cross/Mongo Gill cave system, which developed beneath the western end of Greenhow Hill (Fig.2) (see Waltham *et al*., 1997, pp.117–119; Craven, 2011).

Dunham and Stubblefield (1945) show a number of gulfs on their figured sections of Sir Thomas Vein and Blue Joke Vein. This figure, which is based on a mine section (dated 1818) produced by Nathan Newbold, is also reproduced by Dunham (1974, p.305). The largest of the features shown has a width of 60m (190 ft) where crossed by the main level, and might exceed 107m (350 ft) vertically.

Gulfs are also recorded by Dunham and Wilson (1985) as being intersected on a westward drive 122m from the level head in the Gillfield Level (Fig.2), in ground on the northeastern margin of the Craven Cross Basin. A gulf up to 26m (80 feet) across, developed where the vein intersects a cross-course, was encountered on the Galloway Vein (Dunham, 1952, p.77). According to local tradition, an area on the eastern side of the Craven Cross Basin, where Cleavers Vein, Primgap Vein and a group of smaller veins occur (Fig.2), was very 'gulfy' (Dunham, 1952, p.77).

The intersection of several gulfs by Coldstones Quarry and the reopening to visitors of Gillfield Level have enabled re-examination of these features. Gillfield Level (Fig.2) intersects Waterhole Vein, which exposes a number of gulfs of various dimensions. The intersection of these features must have presented problems for the miners, as they replace vein materials and the fill requires supporting. Wooden supports have been recovered from a gulf that was uncovered in Coldstones Quarry, and Colling (1844) reports the use of stone arching for support. The gulfs currently seen on the Waterhole Vein are vertical pipe-shaped features, and phreatic scalloping preserved on their walls shows clearly that they are of dissolutional origin (Fig.3).

Dunham and Stubblefied (1945) describe the fill within the gulfs as consisting of limestone, clay and sand derived from rotted Millstone Grit. They record the fill on Galloway Vein as comprising residual clay containing water worn boulders. The fill also contained large inclusions of high-grade fluorspar and lumps of galena with cerrusite coatings. A gulf on Galloway Vein was being mined in 1942 and produced significant tonnages of fluorspar. Dunham and Wilson (1985, p.110) speculate that residual deposits with very high levels of ore and spar might occur at the bottom of the gulfs due to natural, possibly karstic, concentration processes; such sites were suggested as possible exploration targets (Dunham and Wilson, 1985, p.233). A cavity filled with fine sand, which took *"... many thousands of wagons"* to remove before it could be tunnelled through, was reported by Colling (1844). Sand from this site, which is no longer accessible, is still washed though Cockhill Level (Fig.2).

X-ray diffraction analysis of the clay- and silt-grade fraction from the two gulfs accessible on Waterhole Vein shows that the fill contains kaolinite and illite, both of which are weathering products of feldspar minerals (Fig.4). Quartz and calcite can be accounted for from a local source and the presence of fluorite fits with the information from mining activity in the fill. However, the presence of clinochlore, the magnesium end-member of the chlorite group of phyllosilicates, is more difficult to explain. Chlorite minerals are ubiquitous in low-and medium-temperature metamorphic rocks. They are diagnostic mineral species of the zeolite and lower greenschist metamorphic facies. Chlorite can occur in some hydrothermal ore deposits but it was not recorded by Dunham and Wilson (1985) in their detailed survey of mineralization across the Askrigg Block.

The closest occurrence of chloritized strata to the study area is within the outcrops of Lower Palaeozoic rocks of the Howgill Fells and southeastern Lake District of Cumbria or in the Southern Uplands of Scotland. Analyses of clay-grade material from cave deposits believed to be of Last Glacial Maximum age from Victoria Cave (Murphy and Lord, 2003), Joint Hole (Murphy, 1999) and Illusion Pot, Kingsdale (Murphy *et al*., 2001) did not detect the presence of chlorite. This is consistent with an origin associated with the Last Glacial Maximum ice cap, which developed locally over the Askrigg Block and prevented incursion of ice from outside the area (Mitchell and Hughes, 2012). Analyses of loess from areas of limestone outcrop to the south of the Lake District, which were overrun by ice streams sourced within the Lake District Massif, do indicate the presence of chlorite (Vincent and Lee, 1981).

Thus, the presence of chlorite-group minerals within the Greenhow gulf fill deposits suggests that the ultimate source of at least part of the clastic sediment component was an area or areas lying beyond the Askrigg Block, underlain by outcrops of low-grade metamorphic rocks. As transportation of clastic material from the source area(s) was almost inevitably by glacial ice, its initial emplacement in the Greenhow area must pre-date the Last Glacial Maximum, because only locally sourced ice was present in the southern Askrigg Block at this time.

An example of a sub-horizontal cavern associated with mineralization has also been recorded from the limestones within the Coldstones dome structure. This cavern was referred to as Pendleton Pipe by Anon (1960) and Brook *et al*. (1988), and erroneously re-named Mackwell's Cavern by Dickinson (1959, 1960). It was crossed by the Garnet Vein (Fig.2). Fill within the Pendleton Pipe cavern has been mined extensively, but sections of natural roof and speleothem deposits are reported by Dickinson (1959). This intriguing site has since been quarried away.

Other sub-horizontal caverns containing mineralization at Nussey Knot are described as 'flatting beds' by Varvil (1920, 1927). Here the caverns contained galena with barite and fluorspar. The cavern deposits were thickest where intersected by vertical fissures and were richest where they were intersected by vertical veins.

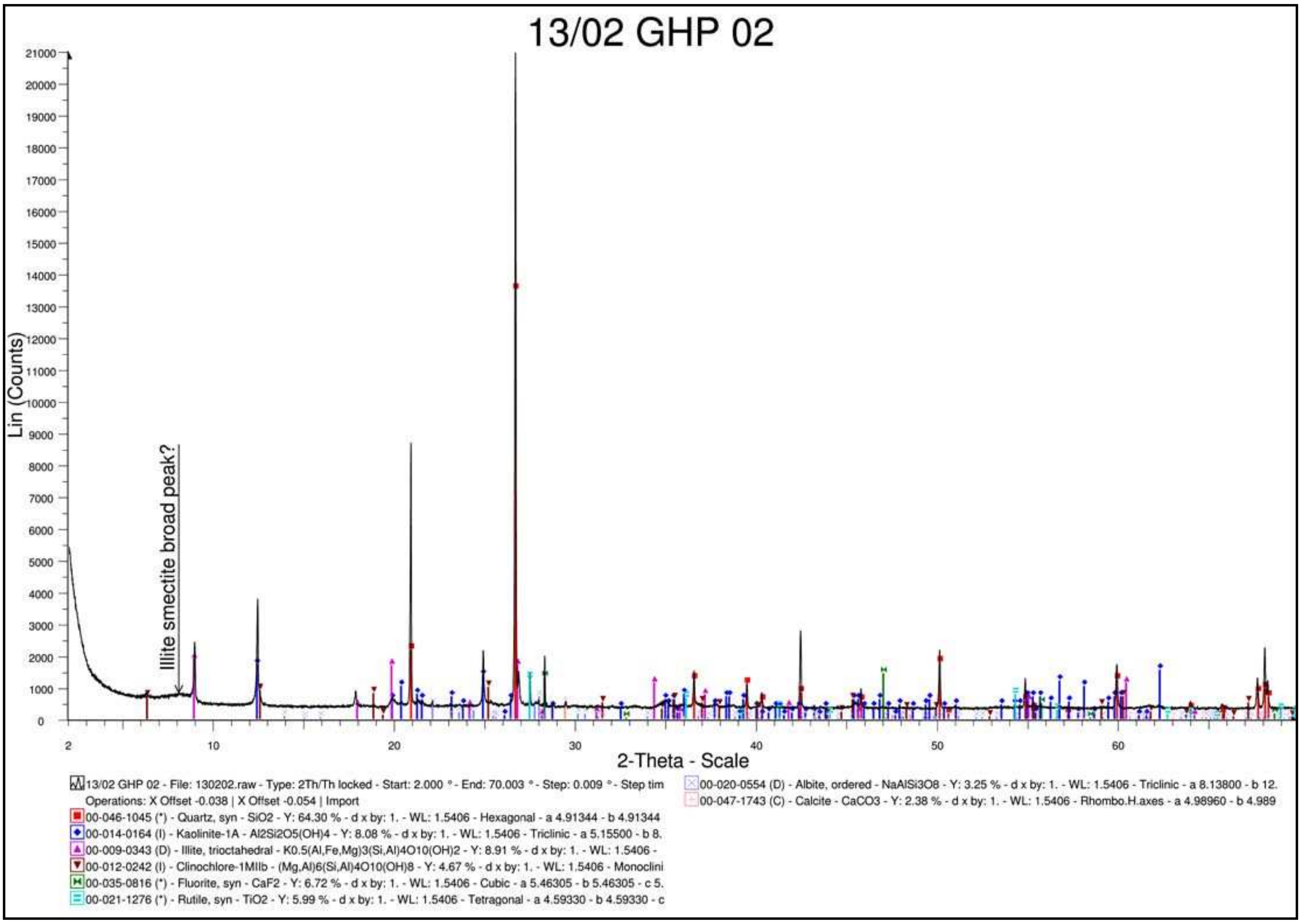

Figure 4: *X-ray diffraction analysis of the fill from the gulf on Waterhole Vein pictured in Figure 3.*

Age of the gulfs

The major development of the gulf cavities themselves must post-date the folding of the sequence – hence post-dating mid-Carboniferous (Dinantian to early Namurian) tectonic uplift (Arthurton, 1984). The fill within the cavities includes derived vein material, so the deposition of the fill must post-date the primary mineral emplacement. Dunham and Wilson (1985) suggested that the main surge of mineralization probably occurred between the Stephanian (late Carboniferous) and Thuringian (latest Permian), so there is a possibility that the cavities, or at least their smaller ancestral dissolutional voids, pre-dated the mineral emplacement. Caverns that hosted the 'flatting beds' at Nussey Knot and Pendleton Pipe on Greenhow Hill clearly pre-dated the mineralization and so might be older than the main enlargement of the gulf cavities and are certainly far older than the deposition of the gulf fill material.

Limited speculation on the ages of the gulfs was recorded by Dunham (1974): *"The veins are transected by karst features such as the 'gulfs' at Greenhow or the caverns at Lunehead, related to the present, or perhaps in part to the Tertiary vadose regime."* However, as the gulf cavities are clearly of phreatic origin and show no evidence of post-drainage vadose alteration they cannot relate to any present or past vadose regime.

The presence of chlorite-group minerals within the clastic fill of the gulfs on Waterhole Vein suggests that at least some of the sedimentary material deposited within the gulfs was sourced outside the Askrigg Block area. Because the most likely transporting agent is glacial ice, the sediment transport and deposition must relate to the ice that advanced and decayed prior to the Last Glacial Maximum, considering that the fine-grained material deposited from the ice of this latter advance contains no minerals sourced outside the immediate area. Perhaps the gulf fill is a product of the "Wolstonian" or Anglian ice advances, which would suggest that the gulfs were being filled with reworked material derived from glacial deposits at least as long ago as the warm episode of the Ipswichian interglacial (Marine Isotope Stage 5e). The presence of kaolinite, a weathering product most typically associated with warm climates, lends some circumstantial support to an assumption of a possible Ipswichian age.

Other occurrences

Large karstic cavities that might be of a similar type to the gulfs of Greenhow are known from a number of regions within the UK:

Derbyshire vein cavities

Large, commonly apparently isolated, phreatic cavities have been described from the cave systems around Castleton in the Derbyshire Peak District (Ford, 2000; Cordingley, 2000). These are associated with mineral veins and fractures, and are referred to as vein cavities. They are generally sub-vertical, irregular in profile and cross-section, commonly have vertical extents greater than 100m and show typical phreatic dissolution morphologies on their walls. Clearly some have developed along mineral veins and some on fractures with little or no mineralization. The geological setting of the vein cavities shows a number of similarities with that of the gulfs: they are developed in limestone that is overlain by rocks of the Millstone Grit Group; they are found in a heavily mineralized area, and they are morphologically very alike. The vein cavities were attributed by Ford (2000) to an early phase in the development of the karst, possibly associated with the unroofing of the limestone by erosion in the Mesozoic.

Furness sops

In the south Cumbria iron-ore field a significant proportion of the ore was found in dissolutionally eroded hollows, known as sops, within the limestone (Rose and Dunham, 1977; Gale, 2000). These are circular to oval features in plan view, which narrow downwards to form an overall bowl shape. The ore in the sops consists of a mass of broken fragments underlain by brecciated limestone and overlain by similarly brecciated St Bees Sandstone. The most likely explanation for the formation of these sops is that they were pre-existing voids formed by dissolution beneath an ore body that then collapsed into the void. The shape of the sops differs significantly from that of the gulfs, and is much more suggestive of an origin as dissolutional hollows than as conduits. Infilled dolines are also recorded in the Brassington area of Derbyshire (Pound *et al.,* 2012) and in North Wales (Appleton, 1989) but are not directly associated with epigenetic mineralization.

Craven Fault Zone potholes

Many large potholes are developed on faults/joints associated with the Craven Fault Zone in the Ribblesdale/Ingleborough/ Gragareth region of the Yorkshire Dales. These features are very similar in appearance to the gulfs and at least one example (Hull Pot, Ribblesdale) is developed along a mineralized fracture zone (Gemmell 1952 p.19, Gill and Burt, 2003, p.219; Waters and Lowe, 2013, p.25). The Gaping Gill system on Ingleborough contains several vertical phreatic cavities including Bar Pot, which has been interpreted as a phreatic riser (Murphy, 2007; Glover, 1974) and the iconic Main Shaft leading into the fault-aligned Main Chamber (Murphy *et al.,* 2005). Newby Moss, the southwestern corner of Ingleborough, contains over twenty caves characterized by deep vertical shafts developed on faults, including Long Kin West, which has been explored to a depth of 168m (Nunwick and Yeadon, 2000; Waltham *et al*., 1997, p.63).

The morphology and scale of these features are very similar to those of the gulfs and they occur in close association to the Craven Fault Zone. They are however situated away from the main areas of mineralization and are in an area of only very gently dipping strata.

Forest of Dean

The iron ore deposits of the Forest of Dean are largely contained in dissolutional voids (Lowe, 1993). Fragments of unmineralized conduits (both active and relict) have been encountered. They are guided by bedding-aligned lithological contrasts and only locally show major sub-vertical development comparable with that seen in the gulfs.

North Wales

Several large caverns have been found associated with mineral veins within Carboniferous limestone successions in northeastern Wales (Appleton, 1989). Major drainage levels driven by mining companies in the late 19th and early 20th centuries encountered some very large water flows, suggesting both that large phreatic cavities were being de-watered and that the apparently isolated caverns formed part of an extensive integrated karst drainage system. The largest cavern found, Powell's Lode Cavern, occurs on the intersection of two mineral veins, Barclays Lode and Powell's Lode. It has a total vertical range of at least 110m, 60m of this being the plumbed depth of a lake whose bottom depth has not been confirmed (Ebbs, 1999).

Conclusions

The gulfs of Greenhow Hill are a series of sub-vertical phreatic dissolution cavities associated with vein mineralization. They are one example of fault/vein-associated, near-vertical phreatic cavities, examples of which are also known from other areas of the UK including north Derbyshire, Ingleborough/Craven Fault Zone and North Wales. Analyses of fill deposits within the gulfs show that they post-date the epigenetic mineralization and probably pre-date the last interglacial. The essentially dissolutional gulf cavities themselves are significantly older, being enlarged later than local mid-Carboniferous uplift and folding, and probably being at least partially formed prior to mineralization during Permian times.

Acknowledgements

The Greenhow Local History Society kindly arranged access to the Gillfield Level and Waterhole Vein.

References:

Anon, 1960. Garnet Vein Flats – Pendleton Pipe. *BSA Cave Science,* Vol.4, No.30, 279.

Appleton, P. 1989. *Limestones and Caves of North Wales*. 217–254 *in* Ford, T D (Ed.), *Limestones and Caves of Wales*. [Cambridge University Press.]

Arthurton, R S, 1984. *The Ribblesdale Fold Belt, NW England – a Dinantian/early Namurian dextral shear zone*. 131–138 *in* Hutton D H W and Sanderson D J (eds), *Variscan tectonics of the North Atlantic Region*. Special Publication of the Geological Society of London, No.14.

Brook, D, Davies, G M, Long, M H and Ryder, P F, 1988. *Northern Caves, Volume 1, Wharfedale and the north-east*. [Skipton: Dalesman.]

Colling, M, 1844. Report on the state of the principal levels in the Greenhow Mines with remarks on some of the veins and workings. Private report to royalty holders.

Cordingley, J N, 2000. Vein cavities in Castleton caves; further information. *Cave and Karst Science,* Vol.27(2), 85–88.

Craven, S, 2011. The lost caverns of Greenhow Hill. *Craven Pothole Club Record,* 103, 12–13.

Dickinson, J M, 1959 Mackwell's Cavern. *Journal of the Craven Pothole Club,* Vol.2(5), 270.

Dickinson, J M, 1960. Mackwell's Cavern – Pendleton Pipe. *Journal of the Craven Pothole Club*, Vol.2(6), 342.

Dunham, K C, 1974. *Epigenetic minerals*. 293–308 *in* Rayner, D H and Hemingway, J E (eds), *Geology and Mineral Resources of Yorkshire*. [Yorkshire Geological Society.]

Dunham, K C, 1952. Fluorspar (fourth edition). Memoirs of the Geological Survey Special Report on the Mineral Resources of Great Britain, Vol.IV. [London: HMSO.]

Dunham, K C and Stubblefield, C J, 1945. The stratigraphy, structure and mineralisation of the Greenhow mining area, Yorkshire. *Quarterly Journal of the Geological Society of London*. Vol.100, 209–268.

Dunham, K C and Wilson, A A, 1985. *Geology of the Northern Pennine Orefield, Vol.2, Stainmore to Craven*. Economic Memoir of the British Geological Survey.

Ebbs, C, 1999. In search of lost caverns. *Descent,* 149, 20–23.

Ford, T D, 2000. Vein cavities: an early stage in the evolution of the Castleton Caves, Derbyshire, UK. *Cave and Karst Science,* Vol.27(1), 5–14.

Gale, S J, 2000. *Classic Landforms of Morecambe Bay*. [Geographical Association.]

Gemmel, A, 1952. *Damming and diving at Hull Pot*. 18–28 *in* Gemmell, A and Myers, J O. *Underground Adventure*. [Clapham: Dalesman.]

Gill, M C, 1998.*The Greenhow Mines*. *British Mining*, No.60. [Northern Mine Research Society.]

Gill, M C and Burt, R, 2003. *The Mines of Yorkshire. British Mining,* No.72. [Northern Mine Research Society.]

Glover, R R, 1974. *Cave development in the Gaping Gill system*. 343–384 *in* Waltham, A C (Ed.), *Limestones and Caves of North-West England*. [Newton Abbot: David and Charles.]

Kirby, G A, Bailey, H E, Chadwick, R A, Evans, D J, Holliday, D W, Holloway, S, Hulbert, A G, Pharaoh, T C, Smith, N J P, Aitkenhead, N and Birch, B, 2000. *The structure and evolution of the Craven Basin and adjacent areas*. Subsurface Memoir of the British Geological Survey.

Lowe, D J, 1993. The Forest of Dean caves and karst: inception horizons and iron-ore deposits. *Cave Science*, Vol.20(2), 31–43.

Mitchell, W and Hughes, A L C, 2012. *The Late Devensian glaciation in the Yorkshire Dales*. 34–45 *in* O'Regan, H J, Faulkner, T and Smith, I R (eds), *Cave Archaeology and Karst geomorphology of North West England*. [London: Quaternary Research Association.]

Murphy, P J, 2007. Cave Development in the Yorkshire Dales. *Teaching Earth Sciences,* 32. 23–26.

Murphy, P J, 1999. Sediment studies in Joint Hole, Chapel-le-Dale, North Yorkshire, United Kingdom. *Cave and Karst Science,* Vol.26(2), 87–90.

Murphy, P J and Lord, T, 2003. Victoria Cave: new thoughts on an old site. *Cave and Karst Science,* Vol.30(2). 83–88.

Murphy, P J, Smallshire, R and Midgley, C, 2001. The sediments of Illusion Pot, Kingsdale, North Yorkshire, UK: evidence for sub-glacial utilisation of a karst conduit in the Yorkshire Dales. *Cave and Karst Science,* Vol.28(1), 29–34.

Nunwick, M and Yeadon, G, 2000. The health farm on Newby Moss. *Descent,* 156, 28–30.

Pound, M J, Riding, J B, Donders, T H and Daskova, J, 2012. The palynostratigraphy of the Brassington Formation (Upper Miocene) of the southern Pennines, central England. *Palynology,* Vol.36(1), 26–37.

Rose, W C C and Dunham, K C, 1977. *Geology and Haematite deposits of South Cumbria*. Economic Memoir of the Geological Survey of Great Britain.

Varvil, W W, 1927. A study of the shapes and distribution of the lead deposits in the Pennine Limestones in relation to economic mining. *Transactions of the Institute of Mining and Metallurgy,* Vol.XLVI, 463–509.

Varvil, W W, 1920. Greenhow Hill Lead Mines. *The Mining Magazine,* May 1920, 275–282.

Vincent, P J and Lee, M P, 1981. Some observations on the loess around Morecambe Bay, North-West England*. Proceedings of the Yorkshire Geological Society,* Vol.43(3), 281–294.

Waltham, A C, Simms, M J, Farrant, A R and Goldie, H S, 1997. *Karst and Caves of Great Britain*. [Joint Nature Conservation Committee.]

Waters, C and Lowe, D, 2013. *Geology of the limestones*. 11–28 *in* Waltham, T and Lowe, D (eds), *Caves and Limestones of the Yorkshire Dales*. [Buxton: British Cave Research Association.]