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PEN PARK HOLE, BRISTOL
A REASSESSMENT

by

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NGR ST 58527920
Altitude 78 m AOD
Length 112 m
Depth 61 m

ABSTRACT

Pen Park Hole was reopened in February 1992. This allowed new studies to be made of its geomorphology, and in addition further researches into its history were conducted. It is concluded that the cave was first discovered in 1669 and first explored in that year. It has never been commercially mined, although several investigations have been made by miners. The cave is considered to be of hydrothermal origin and to be much older than the nearby Mendip caves, probably being active in late Triassic, early Jurassic times.

INTRODUCTION

Pen Park Hole, in Bristol, was closed by Bristol City Council in 1961. In 1992, they kindly allowed it to be reopened, as part of their landscaping of the area around the entrance. This has enabled a fresh study to be made of this cave, of its geology and geomorphology and for exploration of previously unentered passage to be completed. At the same time, the early records relating to the site have been reassessed and re-interpreted, in the light of the findings from within the cave.

HISTORY OF DISCOVERY AND EXPLORATION

Discovery and Early Exploration

Previous accounts of Pen Park Hole (Rudder, 1779, Tratman, 1963) state that the site was first discovered by lead miners, probably in the early seventeenth century and worked by them at some time before its re-discovery in 1669 and the first recorded descent, on 2nd July of that year, by Captain Samuel Sturmy, a retired mariner, and teacher of navigation from Easton in Gordano. Indeed it was Sturmy himself who first described it as "an old Lead Oare Pit" (Hooke, 1678) and it is largely on his word that this presumption has been accepted since. Sturmy's description has been published numerous times (Catcott, G.S. 1792, Hooke, 1678, Lowthorp, 1705, Southwell, 1683) and is the main source for pre-twentieth century descriptions of the cave.

There is only one known record that relates to the cave before the 2nd July

1669, a letter written by a Mr Thomas Henshaw to Sir Robert Paston, Bart. and dated 21st August, 1669 alludes to its opening a short time before that date (C.T.D., 1887). This is given here:

"On Sunday I heard the Duke |of Monmouth|, after he had related to us the story of Candie, sent by Madame, his sister, that a workman in a quarry of stone in Glostershire, not far from the Severn, going to raise a great stone (he had loosened) on one end, it sunk away downward from him, and had almost carried the fellow along with it, leaving a great hole, which, they trying to fathom, found it 60 fathom ere the plummet reached the bottom; the news of this being sent to the King, one here at London undertook to go down and give an account of it. When he was below he found great vast caverns and a great river 20 fathoms over and eight deep into a lesser cavity where he judged there might be some rake of a mine ; he sent in a miner with a light who was not gone far, but he cried that they were all made, for he had found what they sought for ; but when he had gone a little farther he come thundring back again ready to break his neck, saying he had met with a spirit that so frighted him, he would not venture in again for the world."

This clearly refers to Sturmy's descent, but says, also, that the discovery, probably the original discovery, was through quarrying for stone, not mining and that it was of sufficient interest for the King to be informed. Sturmy, in a paragraph only given in the relatively rare first publication of his account, (Hooke, 1678) says:

"In pursuance of His Majesties Commands to me at the presenting of my Mariners Magazine, I have with much diligence, some charge and peril endeavoured to discover that great Concavity in the earth in Gloucestershire, four miles from Kingrode, where his Majesties great Ships ride in the Severn. And I find by experience that what has been reported of that place is fabulous, whilst I thus describe it"

The remainder of this account is virtually identical with the more well known version published later by the Royal Society (Southwell, 1683) and is as follows:

"Upon the second of July 1669. I descended by Ropes affixt at the top of an old Lead Oare Pit, four Fathoms almost perpendicular, and from thence three Fathoms more obliquely, between two great Rocks, where I found the mouth of this spacious place, from which a Mine-man and my self lowered our selves by Ropes twentyfive Fathoms perpendicular, into a very large place indeed, resembling to us the form of a Horse-shoo; for we stuck lighted Candles all the way we went, to discover what we could find remarkable; at length we came to a River or great Water which I found to be twenty fathoms broad and eight fathoms deep. The Mine-man would have perswaded me, that the water Ebbed and Flowed, for that some ten fathoms above the place we now were in we found the water had (sometime) been, but I proved the contrary by staying there from three hours Floud to two hours Ebb, in which time we found no alteration of this River; besides its waters were fresh, sweet and cool, and the Surface of this water as it is now at eight fathoms deep, lies lower than the bottom of any part of the Severn Sea near us, so that it can have no community with it, and consequently neither flux nor reflux, but in Winter and Summer, as all Stagna's Lakes and Loughs (which I take this to be) has. As we were walking by this River thirty two fathoms underground, we discovered a great hollownes in a Rock some thirty foot above us, so that I got a Ladder down to us, and the Mine-man went up the Ladder to that place, and walk'd into it about three score and ten paces, till he just lost sight of me, and from thence chearfully call'd to me, and told me, he had found what he look'd for (a rich Mine;) but his joy was presently changed into amazement, and he returned affrighted by the sight of an evil Spirit, which we cannot perswade him but he saw, and for that reason will go thither no more.

Here are abundance of strange places, the flooring being a kind of white stone, Enameled

Figure 1. *Engraving of Captain Samuel Sturmy, taken from his* Mariners Magazine.

with Lead Oare, and the Pendant Rocks were glazed with Salt-Peter which distilled upon them from above, and time had petrified.

After some hours stay there, we ascended without much hurt, other than by scratching our selves in divers places by climing the sharp Rocks, but four days together after my return from thence I was troubled with an unusual and violent Headach, which I impute to my being in that Vault. This is a true account of that place so much talk'd of described by me.''

Thus it would seem that the discovery was of sufficient interest not only for the King to be informed, but for him to command its exploration. There are two possible explanations of this. The first is economic, in that a potential new mine would be an important source of revenue. The second, probably the most likely, in that a mariner, and an inquisitive type, rather than a mine captain was chosen to explore and report on it, is that Charles II, the first patron of the Royal Society, was ''a monarch fascinated by novelty and prodigy — tropical birds, exotic fruit, scientific experiment and the academic discovery of the Avebury stone circles all equally delighted him.'' (R. Hutton, *pers. comm.*, see also Hutton, 1989 pp. 448-50 for a more detailed description of the King's character and intellect.) Either way it is unlikely that the discovery would have caused much interest at court had it been mined in the relatively recent past, as suggested by Rudder (1779) and Tratman (1963).

It is easy to see why Sturmy himself was appointed to this task; he was then at court, having just presented his book, the ''Mariner's Magazine'', to the King. This work had shown him as a diligent and reliable observer and he probably knew the area, having been born in Gloucestershire and having lived for most of his life in and around Bristol, where he was a Burgess and a prominent member of the Society of Merchant Venturers (Manwaring, 1924). Captain Sturmy's account is written in the first person, but, in fact was written for him, by a Mr. Thomas Alcock (Hooke, 1678). Four days after his descent, Sturmy suffered a severe headache, which he attributed to his being in the cave. This turned into a fever from which he died, which apparently deterred anyone from repeating his exploration for some years (Southwell, 1683). He was buried on the 21st September, at St George's Church, Easton in Gordano. There is a memorial plaque to his name in the church, near where he lived and to whom he had recently presented a copy of his book. In 1970, the local bell ringers recommenced the tradition of ringing a peal on the bells on his birthday, 5th November.

Sturmy's descent of the Hole and his subsequent death, as well as having been properly recorded, seem to have entered into local folklore, for in 1911 a newspaper article was able to quote part of a rhyming account of his adventure, including his meeting with ''the Goblin of the Hole'' (H.V., 1911). Unfortunately only a brief extract of verse was printed and it has not been possible to trace the full text of the poem. The following quotation gives its flavour:

On, and still on this path they follow
Through many a chasm and gorge and hollow;
Until from a passage narrow and small
They enter what looks like a monster hall;

And then as a sudden turn they take
They see before them a spacious lake-
There are knackers, and gnomes, and frightful shapes
From which no trespasser ever escapes.

This article goes on to describe Sturmy's meeting with the Goblin, and says that this creature predicted his early death and that of the miner, here named Dick, who accompanied him.

The conclusion is that Pen Park Hole was first discovered by quarry workers and was first descended, by Captain Sturmy, on 2nd July 1669. Sturmy's own description of the cave as an old mine therefore needs to be explained. This can be done by comparing the site with other underground sites then known. The well-known caves of any size were all horizontal stream caves, such as Wookey Hole, or Peak Cavern. The cave most similar, quite close to Pen Park Hole and incidentally, actually discovered by lead miners, is Lamb Leer in Somerset. This, however, is not known to have been descended any earlier than 1676 (Shaw, 1962) and was not therefore available as a comparison. Numerous mines of anything up to 30 fathoms (180 feet) in depth were known, however, so the comparison was obvious.

By 1682, the assumption that the cave had been discovered by miners was already being made. Sir Robert Southwell (1683) wrote, in his preamble to the publication of Sturmy's account in Philosophical Transactions, "where some Miners for lead discovering a large Hole in the Earth". That miners worked in the cave is undeniable, but at a much later date. The evidence for and dating of this will be given below.

The second known exploration was that by Captain Greenville Collins, commander of the Survey Yacht Merlin, on the 18th and 19th September 1682. Collins produced the first survey of the cave, which was published the following year, along with both his and Sturmy's descriptions (Southwell, 1683). According to Shaw (1979), this was the first survey of a natural cave to be published, although an earlier unpublished one is known, of a cave at Cheddar (Boycott, 1992).

The Eighteenth Century

It is likely that other adventurous people descended the cave at times over the following years, but they have left no record. The next significant exploration took place on 3rd May 1760 when the cave was descended by three colliers from Kingswood. They were accompanied by Alexander Catcott, at whose instigation this exploration took place. He went down the first few feet, and recorded the colliers' findings in his Fossil Journal, now in the Bristol Reference Library (Catcott, A. 1757-[1767?]). These are not known to have been published previously, and are therefore quoted here in full:

May 3rd 1760

John Rathbone, Abraham Stout, William Bryant, three coalminers from Kingswood, descended Pen Park Hole;- about 10 fathom below the surface they came to a cavity the entrance of which was about 20ft wide and about 7 feet high, the inside about 20ft wide

and 10 feet high towards the mouth of the entrance for some way; in other parts lower and narrower and in some places so narrow and low as hardly room left to crawl in at, the whole summing in about 40 yards, and the passage Eastward about 10 fathom.

Lower in the hole they came to another Cavity wch appear'd to be about 30 feet wide and 30 feet high, and runs in westward for about 30 yards, but towards the further end grows narrower and lower. About 14 fathom lower they came to the edge of the water in the bottom, the whole length of the slope from the surface of the Earth to the surface of the water being as they said exactly 34 fathoms. They plumbed the water with a line, & say it was a full fathom deep, lying on one side of the bottom, they computed the water to be about 30 yards long and 12 yards over, and beyond the water which there was no way to cross, there appeared a roundish hole in the rock about 9 or 10 feet above the surface of the water, of about 7 or 8 foot diameter at the entrance, into which they threw some Stones, they think 20 yards horizontally; the inside of this great Cavern they say represents the appearance of a large glasshouse. They tasted the water, which they said was very clear & sweet.

The descent into this hole about 12 ft below the surface appears to be about 10 yds long and one and a half over and seems for the most part declining to the North East, so that from a small opening about 20ft below the surface where I went I could see them go down and come up the greatest part of the way and see them walk about some parts of the bottom and near the side of the Water; the water they say has been near about 2 fathoms deeper in the hole, which they judge from the mud left there, some of which they brought me up of about the consistency of new made hard sope.

They say that they could not find the least appearance of oar in any part of this Cavern below the place where I was; that there was not the least sign of its having been worked below, nor did they believe it ever had, as the greatest part of the Caverns on top and sides was covered with pointed spare.

This statement, by miners, agrees with the present author's conclusions, given above, that prior to this date at least, the cave had not been worked by miners. It is doubtful that this journal was seen by either Tratman (1963) or Rudder (1779) who had they known of it would have been unlikely to have reached their conclusions about early mining at this site. There is nothing in the written record to show that the cave had been mined before this time, Hunt (1978) mentions Sturmy's descent and Collins' description, but nothing else and as long-time Keeper of Mining Records he is likely to have seen any other extant material.

A few years later came the most well known event to happen at the cave, the death of the Reverend Thomas Newnam, on 17th March 1775. Newnam fell to his death whilst trying to plumb the main shaft, when the branch of a tree to which he was holding broke. As might be expected, this event re-kindled a great deal of interest in the site and led to several further descents being undertaken. Notable amongst this group of explorers were Robert Tucker, whose assistant found the Rev. Newnam's body; William White, a local land surveyor who made several visits and subsequently drew up the second survey of the cave and George Catcott, brother of the aforementioned Alexander Catcott, who made several descents, accompanying White and who subsequently wrote an account of these events, quoting also the descriptions of Sturmy and Collins and including a version of White's survey (Catcott, G.S. 1792).

Rudder (1779) stated that his information on mining within the cave came from a Mr. Harmer. There is in the Bristol Reference Library a manuscript, B10158 which contains handwritten copies of Catcott's and White's descriptions, draft

copies of White's survey and an expanded version of the material in Rudder's book, written in the first person. The hand is neither Catcott's nor White's and is therefore likely to have been written by the said Mr. Harmer and to be the material that Rudder used. It shows that most of the evidence for early mining at this site remains purely hearsay and could easily be applied to other nearby sites, the lead mines on the south side of Coombe hill, for example. The direct quotes about the state of this cave are seen to have come from miners investigating the eastern branch of the cave, unsuccessfully, for ore in about 1769. Their statements do not agree with the evidence to be seen within the cave and as they were attempting to negotiate terms for work at the cave with Mr. Harmer, can be regarded as unreliable. This is the first recorded occasion, however, when miners are known to have searched the cave for ore, albeit unsuccessfully. This account only indicates work in the eastern branch, the present entrance passage. This is confirmed by a passage in White's account, in the same manuscript, which shows that the route through to this part from the main chamber was difficult to locate and to pass. The account of the miners' work also indicates that there is a further eastward running passage from somewhere near the first chamber whose entrance was stopped up by them, and is now lost.

The Nineteenth Century

After the publication of Catcott's book and of Rudder's New History of Gloucestershire (1779) which included a different version of White's survey, no records of explorations can be found until the middle of the next century. Then, in July 1842, Catcott's account was re-published as a descriptive Broadsheet issued for an exhibition of Fine Arts, Natural History etc. held in Bristol (Catcott, G.S. 1842). It may have been the publicity engendered by this exhibition that produced the next activities at the cave for, in 1843, the following notice was published in Felix Farley's Bristol Journal (Anon, 1843):

> Pen Park Hole.- There was a work published about 90 years ago, wherein it was stated that lead was supposed to exist in Pen Park Hole, but it is somewhat remarkable that no effort should have been made to ascertain the fact, until within the last few weeks, when an examination was made by some Cornish miners, under the superintendence of Richard Rowe, Esq. A few days since, Mr. R. accompanied by the men, descended the "hole," which is a natural pit of very considerable depth. they entered it in a slanting direction, much to the peril of their lives, and after descending to the depth of from 20 to 30 fathoms, they came to a large body of water, quite sufficient to float the largest vessel in the port of Bristol. Some very excellent specimens of lead ore were here obtained, yielding as much as 75 per cent., which has lead to some further operations, with a view to the regular working of the hole. For this purpose a large boat has been let down, by means of which the party have been able to explore the recesses. The water is eight fathoms deep, twelve fathoms long, and fifteen fathoms broad. We wish the undertaking may prove successful.

However, as with so many mining ventures, this project did not really get off the ground and "for some reason" was soon abandoned (Latimer 1887), but it is to this period that the evidence for mining to be found within the cave can be most reasonably dated. A careful study of the interior of the cave has shown evidence of mining activity of two sorts. The East (present) entrance shaft, and

the passage below it, have been enlarged by blasting, the remains of numerous shotholes may be found and parts of the Approach Passage have been cleared and drystone walls built. All this seems to have been done to facilitate entry to the cave, but, significantly, the intensity of work falls off the farther one gets from the entrance. This is consistent with work begun in hope, but soon abandoned. This work can fairly well be dated to this time. The use of blasting indicates a date of no earlier than the introduction of gunpowder to the area, in about 1684 (Beaumont, 1685) and there is scant evidence of mining between that date and 1843. Certainly, this work could not have been carried out prior to the first known record of the cave, in 1669. Gunpowder was first used for blasting by Casper Weindle at Schemnitz, in Germany, in 1627 (Hoover and Hoover, 1950); but there is no evidence for its introduction into any English mines before 1670, when it is reputed to have been used in Dutchmans Level at the Ecton copper mines in Staffordshire (Rieuwerts, 1983).

The second type of evidence for the activities of the miners is the presence of numerous places, throughout the cave, where the calcite lining has been punched through either to sample it or to see what lay behind it. The results of this sampling would presumably have led to the abandoning of the work, as the results would have proved disappointing. There is lead ore to be found, but only in small quantities and mainly in the first chamber (Bristow, 1963). There is no evidence for the large scale removal of material from the cave at any time, only for a programme of sampling, as implied by the historical record.

This work may be dated to about 1843, rather than to the above mentioned 1769 trial, as the fact of relatively major works around the entrance carried out during what was to prove a very short term operation are characteristic of the activities of the Cornish miners of the nineteenth century rather than of the local men of a century earlier (c.f. Stanton and Clarke, 1984).

In the late Eighteen-seventies, the land came into the possession of William Smith, Esq., who, to prevent accidents, had the cave securely closed (Nicholls, 1879). For many years after, nothing more could be seen of the site other than a slight dip in the ground and even this vanished after it was filled with builders' debris when Pen Park Road was made in 1922.

The Twentieth Century

The cave was not forgotten and continued to be a topic of local speculation and rumour, until, in the mid-nineteen fifties, it became necessary to accurately locate it in order to allow building works to be safely carried out in the area. A geo-resistivity survey was therefore undertaken by Prof. L.S. Palmer, on behalf of Bristol City Council and the cave was once again found. The Eastern entrance was dug open by members of the Society, the Wessex Cave Club and the Bristol Exploration Club during the winter of 1956/57 and the cave re-entered on 12th January 1957. During the following three years, the Cave Research Group of Great Britain surveyed the cave and carried out geological and biological studies. All this work has been well-documented elsewhere (Tratman, 1963).

In August 1961, the entrance was sealed once more, by a concrete slab. It remained so for the next thirty years.

In 1992, as part of a landscaping scheme for the area around the entrances to the cave, permission was granted by the City Council to re-open the cave and this was done on the 7th February. The method used was to tunnel under one corner of the concrete slab and to position a concrete tube leading vertically down to this. The tube and slab were then covered and surrounded by an artificial hummock of earth and consequently the cave is now about two metres deeper than before. The tube was topped off with a securely lockable lid.

The re-opening of the cave has enabled up to date studies to be undertaken within it, and has allowed further exploration to take place. On the 6th May, the traverse into the Upper East Passage was made for the first time. This passage proved to be only thirteen metres long before closing down and to have the characteristic dog-tooth calcite lining, except where this had fallen off the north wall and was lying on the floor. On the 2nd July and again on 9th July, the lake was dived. A large passage was found to lead off under the eastern wall of Lake Chamber, but after only twelve metres this ended in a blank wall. No penetrable passage was found leading upwards and any continuation downwards is solidly choked with boulders. The only passage not to have been entered by modern explorers is that said to have been stopped up by the miners in about 1769. It is not yet known whether this exists or exactly where it might be found.

GEOLOGY AND GEOMORPHOLOGY

Introduction

Pen Park Hole has been formed in a buried ridge of Carboniferous limestone, the north west side of the Westbury Anticline, surrounded on three sides by a layer of Rhaetic clays (Figure 2). The limestone, Clifton Down limestone (Kellaway and Welch, in litt.) dips at approximately 50° to the north west. The cave has been strongly influenced by a high angle reverse fault which has been formed parallel to the bedding.

The present account draws heavily on the previous work of Bristow (1963), especially in terms of field work, but attempts to give fuller answers to some of the points that he only touched upon.

Sequence of Development

Bristow states that the cave is old, pre-Miocene at the least but possibly as early as pre-Liassic. He bases this on the observations that the cavity pre-dates both the mineralisation found within it, and certain earth movements which have subsequently affected it. He also remarks that, unlike most Permo-Triassic cave systems, it has not been infilled with later, usually liassic, sediment. What he does not do is make any statement about the conditions under which the cave was actually formed, except for a mention of "solutional activity". It is the opinion

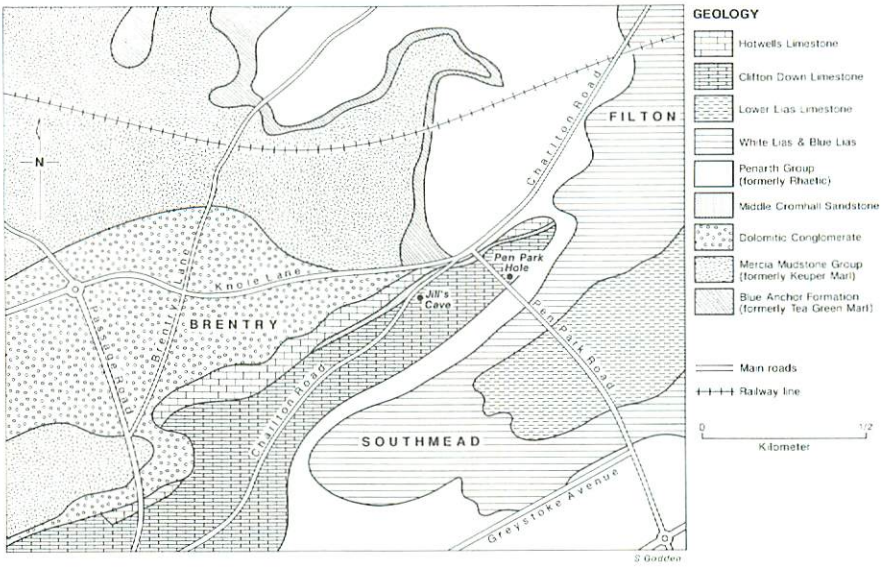

Figure 2. *North Bristol, Location and Geological Map.*

of the present writer that this cave has been formed by hydrothermal processes and that this conclusion explains many of its unusual features.

According to Ford and Williams (1989), certain erosional features are diagnostic of a hydrothermal origin. These include a tree-form of effluent chimneys as the form of the entire cave; deep, rounded solution pockets and highly corroded patches where steam has condensed above hot pools. All these are present here. The tree like layout of the cave can be seen from the survey, particularly on the east-west projection (Figure 6). This form has been largely constrained by the guiding fault zone and gives the appearance of being two-dimensional. It can be seen from the north-south projection (Figure 7) that the cave is confined to a quite narrow span of beds, no more than 20 m in thickness. The detailed form of most of the passage walls has been obscured by the later mineral deposits, but deep rounded pockets divided by smoothly rounded pendants can be particularly well seen in the entrance passage, especially in the second chamber and the approach to the main pitch. Highly corroded patches of rock can be seen at several points in the higher reaches of the cave. A fine example is to be found close to the belay bolts for the main pitch.

Ford and Williams also state that a better indication of such an origin would be given by a cave's mineral deposits, amongst which this cave's all-over covering of walls, floor and ceiling by a crust of dog-tooth spar calcite would undoubtedly be included. Virtually the whole cave is lined with this deposit (Figure 3). It is only not seen low in the Main Chamber, where the walls are obscured by later silt and clay deposits, in the higher parts of the Main Chamber, presumably above the level reached by the thermal waters during that phase of deposition and on

Figure 3. *Hydrothermal Crystalline Calcite. The deposit is approx. 10 cm thick.*

the north wall of the main chamber. In the recently entered Upper East passage the crust has been found to have peeled away from the southern wall and to be lying on the floor. This may also explain its absence at other points, the fallen pieces having been removed by previous visitors.

Taken together, these features indicate a long history of hydrothermal conditions, during which the differing process zones of solution and precipitation have oscillated across the cave several times in response to changing external conditions. There have been at least three different phases: the initial phase was one of solution, during which the cave largely attained its present shape. There then followed several periods of deposition.

According to Bristow, the first phase of mineralisation was the deposition of galena, partly replacing the limestone and partly as a layer on top of it. The galena is mainly found in the First Chamber and dies out to the west and lower down. All the phases of mineralisation can be seen to post date the formation of the cave, as the deposits are all within the cavity and do not pass out of it into the cave walls. The second phase of deposition was of the coarsly crystalline calcite. This takes the form of large, 2-3 cm, scalenohedral crystals in a thick layer covering most of the floor, walls and roof of the cave. The deposit is about 15 cm thick in the eastern parts of the cave, but, as with the lead, thins out, to 8-10 cm, in the western part. The calcite is by no means pure and galena may be found within it along, probably, with other components. A second phase of solutional activity followed after this. It had little effect on the mineral deposits, on which its main result appears to have been a ''softening'' of the outlines of the large calcite crystals; but where this deposit was absent, or had been penetrated, a significant amount of preferential solution of the bedrock took place. The last major phase of activity in the cave, before present day conditions were reached was an episode of limonite deposition, a thin layer of this mineral being present throughout most of the cave, overlying the massive calcite layer.

The final phase in the development of the cave was reached with the onset of present day conditions. This has seen the fairly minor deposition of thin calcite films and small stalactites in the upper part of the cave (Figure 4) and of extensive clay deposition in the lower part of the cave. This latter material appears to have been brought in via the lake at the bottom of the cave as its water level fluctuates.

It is not known what, if any, role is played by the cave in the present hydrology of the area. It is known that the level of the lake is capable of quite large variation. The highest level recorded is approximately 51.5 m AOD, on 29th January 1993. The lowest recorded level is approximately 24 m AOD, on 18th October 1957 and there are, probably apocryphal, tales of the lake drying up completely. Thus there is a known range of 27.5 m and a possible range of over 34.5 m. Tratman (1963) argued that there were likely to be connections of a fair size to adjoining conduits, to explain an apparent rapid and turbulent rise in water level noted in 1959, but direct exploration, by diving, has failed to find them. If they exist they must lie under the debris that completely covers the floor of the main chamber and the lake. The small spring in the main chamber noted by Glennie in 1957 (Tratman, 1963) has not been seen during recent explorations.

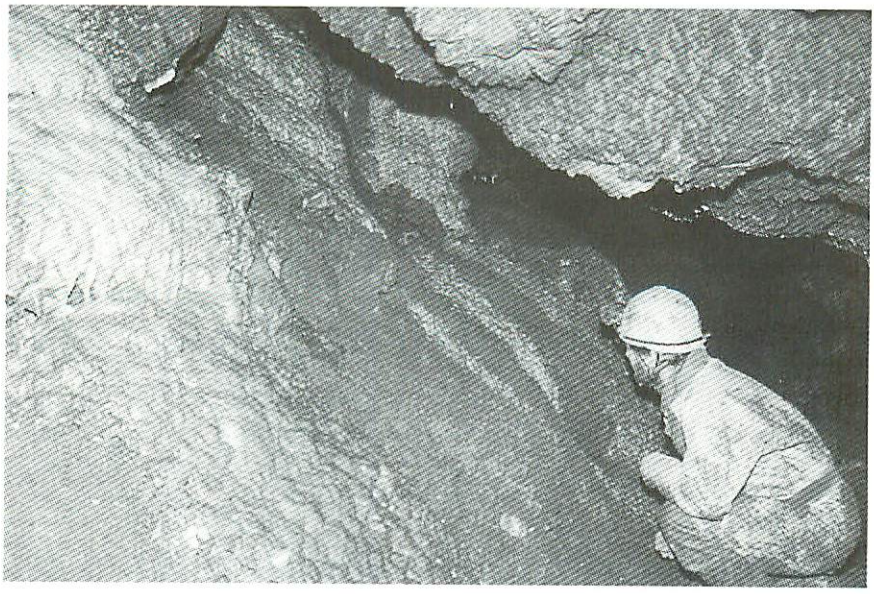

Figure 4. *Recent Calcite deposit overlying ancient mineralisation.*

The Age of the Cave

Bristow argued, using comparative dating techniques, that the cave was very old, probably Permo-Triassic. This conclusion was reached on the basis that the cave pre-dated the mineralisation and also an episode of faulting which affected the mineral deposits. This latter is seen in the First Chamber, although doubt has recently been cast on the significance of this fracture (W.I. Stanton, *pers comm*). Both these events would have to be pre-Liassic, as the faulting affecting the cave did not seem to affect the Rhaetic clays overlying it. Bristow also argued that it was highly unlikely that a solutional cavity would be formed in a limestone deposit completely buried beneath a thick cover of Mesozoic clays and it is certainly true that this area was completely covered by Mesozoic sediment until the early Pleistocene.

Whilst it is true that Permo-triassic caves are known in this area, (Ford, 1989, Halstead and Nicoll, 1971) most of them have been infilled by Triassic deposits. One of the most striking things about Pen Park Hole, if it is this old, is its virtually complete lack of surface derived sediment infill. These other caves would have been formed by meteoric waters at a time when the Carboniferous limestone formed uplands, or an archipelago of islands in a shallow sea (Marshall and Whiteside, 1980). This is not the case for Pen Park Hole, as it is shown to have been formed by geothermal waters rising from below, rather than meteoric waters from above and it is likely that the presently known parts of the cave did not have a direct connection with the Rhaetic sea floor. All the entrances known in historical times are the result of surface denudation and quarrying activities.

The Pleistocene, probably Devensian, faunal collection that was presented to the Natural History Museum in 1884 by Spencer Perceval (R.M. Jacobi, *pers comm*), and is listed as having come from Pen Park cave, or Pen Park fissure (Reynolds, 1931, 1938) has no direct connection with Pen Park Hole. It was discovered in another, separate, cave in a nearby quarry. (Anon, 1883). This may have been Jill's Cave (Rollason, 1963) situated in the bottom of a quarry about 250 m west of Pen Park Hole. This cave, along with the entire quarry, was filled in around 1960 and few records remain.

It is therefore possible to argue that the cave could quite easily have been formed whilst the limestone was buried, which increases considerably the timescale over which this could have occurred. One argument against deep burial, however, is the evidence for a distinct water surface within the cave, above the level of the massive calcite deposition on the one hand and allowing room for steam condensation-corrosion of the roof above hot pools, on the other. If there was no direct connection between the cave, as now known and the surface at that time then the vent for the hot spring may have been further to the east, possibly following the now lost passage (see above) to the edge of the limestone outcrop. Thus Bristow's conclusion of a late Triassic date for the cave remains a valid possibility. A fluid-inclusion study of the calcite might give some information as to the temperature and by implication the depth, at which this deposit was emplaced. It is also possible that the result of a lead isotope determination of the galena deposit would allow it to be compared with samples from the Mendip ore field to estimate whether they had a similar origin. A fuller study of the minerals in this, and other, Bristol caves is to be undertaken by other workers.

Kellaway (1967) describes a concordance between the distribution of galena veins in the Carboniferous Limestone of the Clifton Down plateau, approximately 4 km south of the cave, and the disseminated lead-zinc ores found in the Rhaetic clays and Keuper deposits. Alabaster (1982) interprets this to mean that these latter are "exhalative deposits", formed as a result of the discharge of warm, metalliferous springs onto the Rhaetic and Jurassic sea floor. A similar conclusion was reached by Hamilton (1966) about comparable deposits at Almondsbury, to the north. It would seem that Pen Park Hole is an ideal candidate for such a warm spring. This would also give a late Jurassic, early Triassic age for the cave's major development and functioning. The limonite, however, may have been emplaced much later, the result of the downward movement of iron-rich waters during the Tertiary erosion of overlying Mesozoic strata.

A similar, hot spring origin has recently been suggested for the main fissure at Cromhall Quarry, some 17 km to the north east, by Simms (1990). There the sediment infill has been dated to the Triassic (Halstead and Nicoll, 1971), implying an earlier date for the formation and mineralisation of the cave and a much earlier date for the mineralisation than the mid-Jurassic date proposed for the Mendip lead-zinc mineralisation by Stanton (1981, 1991). This, again, is in line with Bristow's proposed dating for these processes in Pen Park Hole.

It is now impossible to say what the source of the hydrothemal waters feeding this cave was. It is certain that there is no longer any contact with that source. Neither is it possible at present to give an absolute age for the cave. The massive

calcite is unfortunately too old and too contaminated by lead to allow the successful application of Uranium series dating techniques.

The above conclusions about the formation, and especially the dating, of this cave are tentative. A fuller and deeper study of its geology may well lead to their being substantially modified.

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APPENDICES:

1 Brief description of the Cave

The plan survey (Figure 5) gives the general layout of the cave. None of the passages are particularly awkward to traverse. There is a fixed ladder in the artificial entrance tube and also one down the old entrance pitch, mainly to keep visitors out of the mud. There are three rawlbolts at the head of the main pitch, to allow for belaying of ladder and doubled lifeline. Single Rope Techniques are not recommended for this pitch due to the sloping nature of its lower part, and also to the copious quantities of mud which inevitably coat the tackle.

The traverse from the first ledge onto the West Platform has a fixed line, as do the climbs up to West Passage and East Passage. The traverse into Upper East passage is on loose mud and rock and is not recommended.

The climb up to East Passage is very muddy, as is the first part of this passage. For this reason the climb up out of the end of this passage should not be done in order to avoid spreading mud into this much cleaner section of passage

2 The Surveys of Pen Park Hole

This cave has been surveyed three times. The original survey was by Captain Greenville Collins, of the Survey Yacht Merlin and was made by him and his crew on the 18th and 19th September 1682. Collins was at this time involved in carrying out a seven year survey of all the coastal waters around Britain, which was published in 1693 under the title "Great Britain's Coastal Pilot" (J.K.L., 1968) He was persuaded to undertake his exploration and survey of the cave by Sir Robert Southwell, whom he was then visiting and who was later responsible for its publication.

A plan of the chamber and a section of the whole cave were published in January 1683 (Southwell, 1683). This is the earliest recorded published survey of a natural cave (Shaw,

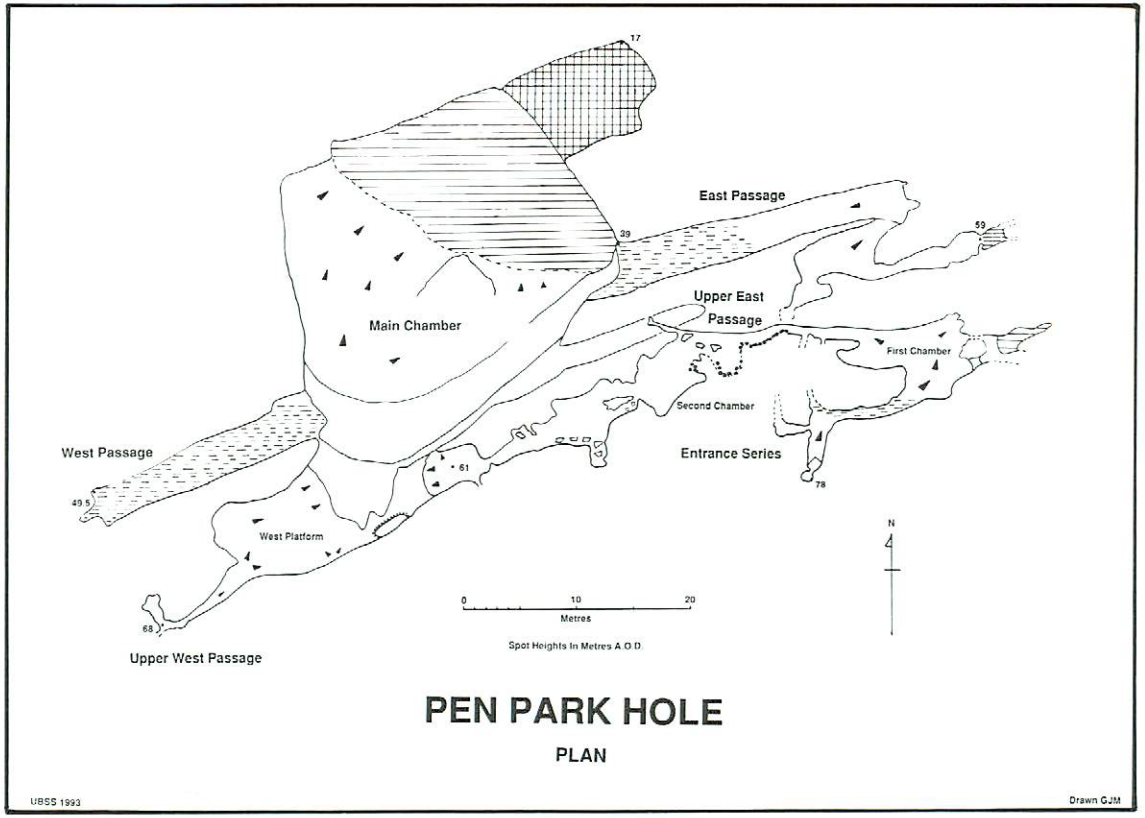

Figure 5. *Plan Survey of Pen Park Hole.*

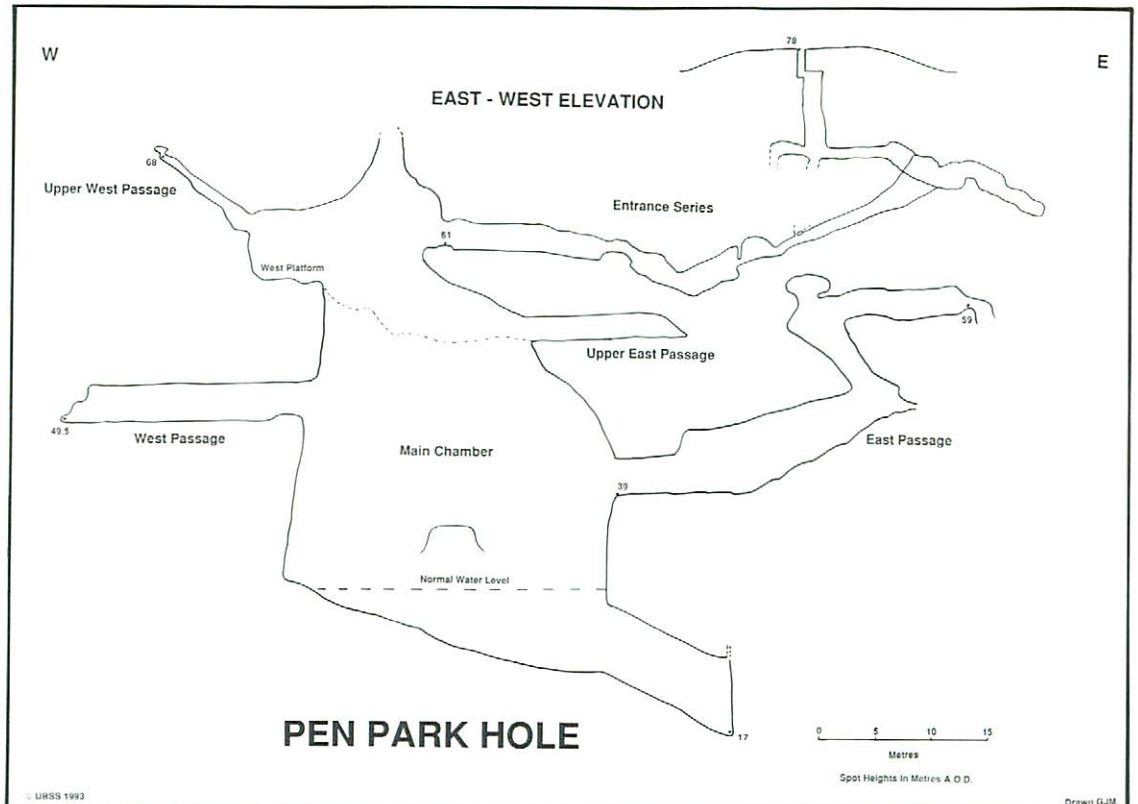

Figure 6. *East-West Elevation of Pen Park Hole.*

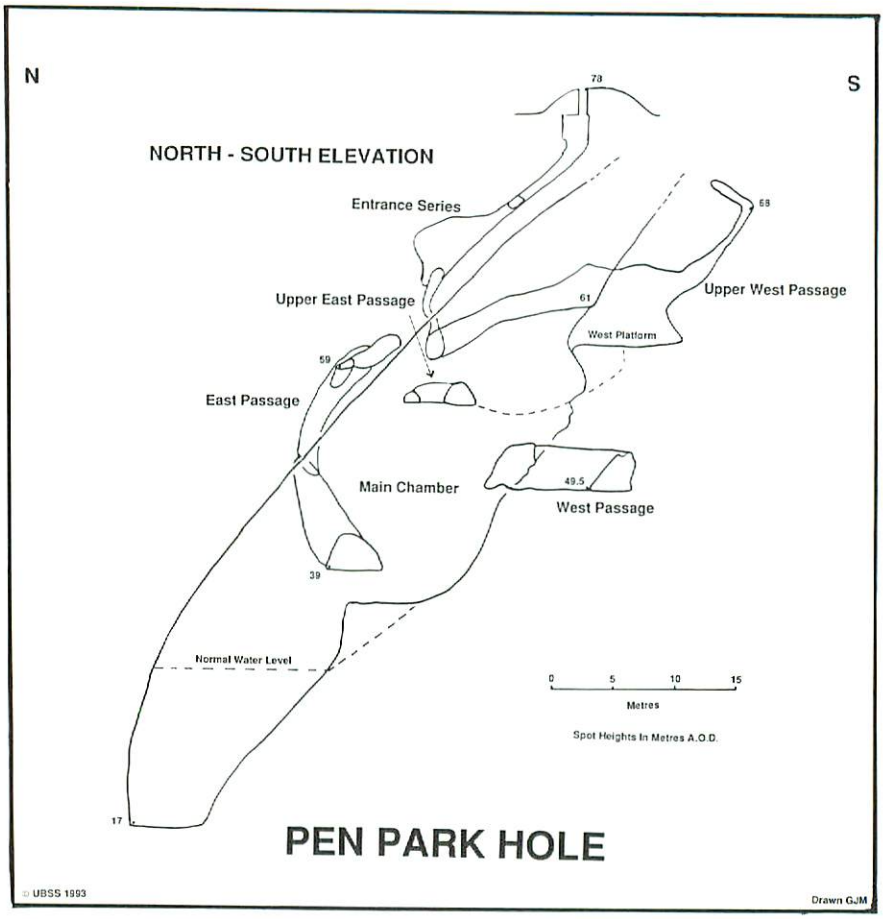

Figure 7. *North-South Elevation of Pen Park Hole.*

1979). Although the section is recognisable as this cave, the whole is inaccurate in detail. The given depth of the cave, to twenty yards above high tide in the Severn, is consistent with modern estimates.

The second survey was made by Mr. William White, who made several descents between March 20th 1775 and the autumn of 1776. He worked sometimes alone and sometimes with the assistance of George Catcott. Manuscript copies of his east-west and north-south sections, as well as his surface plan may be found in Bristol Reference Library (manuscript B10158). These two sections were published in Rudder (1779). The published sections are faithful reproductions in terms of dimensions, but have lost some of the detail recorded on the manuscript and hand-drawn copies, especially the two rock pillars shown as being visible in low water conditions and probably corresponding to the two stones shown in Collins' survey. Later publications based on White's work, especially Catcott 1792 and 1842, appear to be a combination of these two sections and are much less accurately drawn.

The present survey (Figures 5,6 and 7) has been re-drawn from the 1957-59 survey data, in the Society's possession, which was used to produce the plan and sections published in Tratman (1963). It has been amended to correct minor drafting errors and to include information on Upper East Passage and the Lake. It is considered to be to BCRA grade 5C (Ellis, 1988).

3 Access to the Cave.

The cave is on land owned by the City of Bristol. Access is administered on their behalf by a consortium of the University of Bristol Spelaeological Society, the Bristol Exploration Club and the Wessex Cave Club, who have each appointed persons to lead trips to the cave. Those wishing to visit the cave should apply to the secretaries of the above clubs.

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