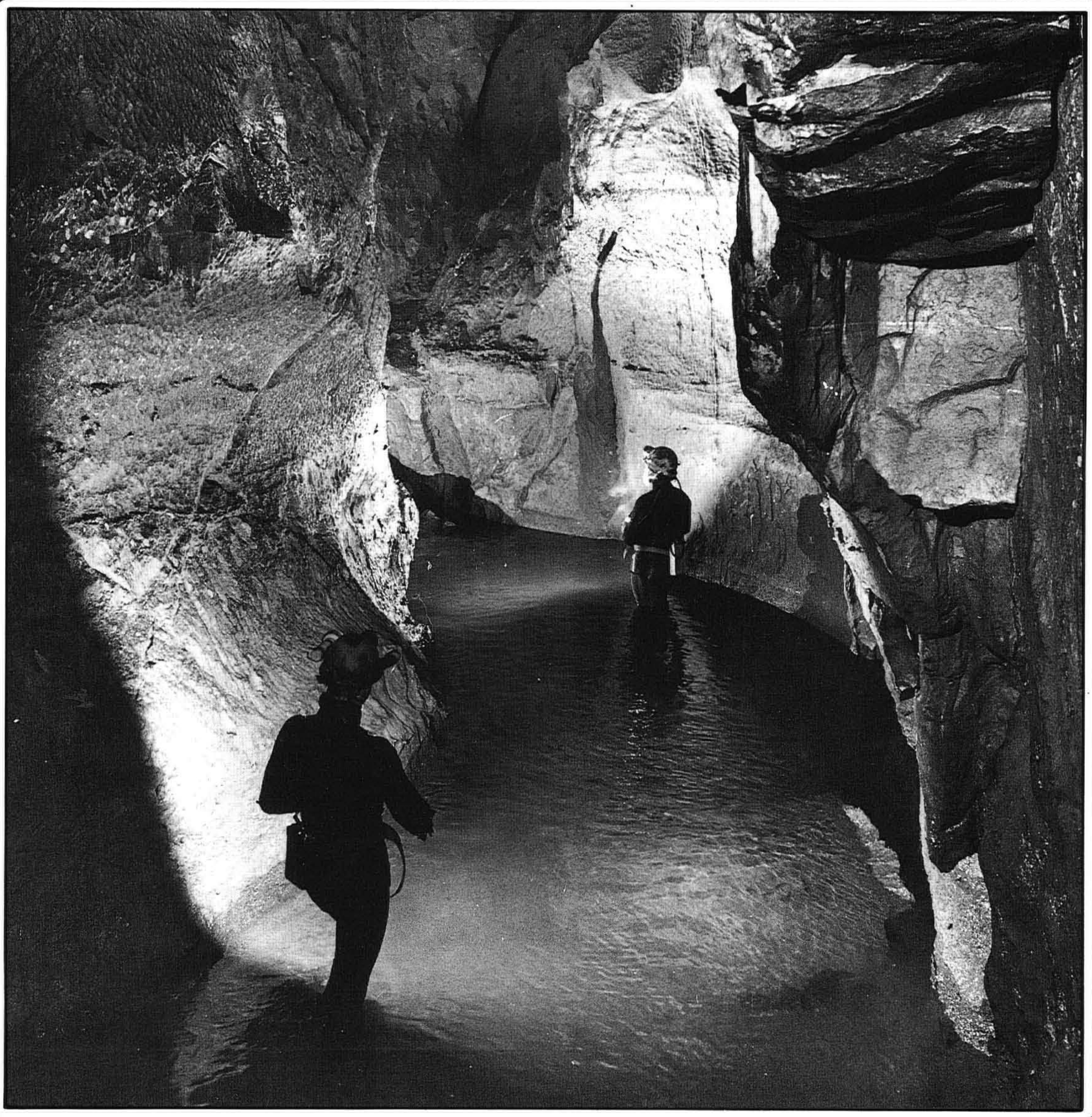
Cave Science

The Transactions of the British Cave Research Association

BCRA

Volume 20 Number 1 July 1993



Wombeyan Caves, NSW

Radon in Clwyd

Phytoliths in Fermanagh

Bristol Speleological Research Society

Gypsum Caves in Cumbria

Mondmilch

Speedwell sediments

Cave Science

The Transactions of the British Cave Research Association covers all aspects of speleological science, including geology, geomorphology, hydrology, chemistry, physics, archaeology and biology in their application to caves. It also publishes articles on technical matters such as exploration, equipment, diving, surveying, photography and documentation, as well as expedition reports and historical or biographical studies. Papers may be read at meetings held in various parts of Britain, but they may be submitted for publication without being read. Manuscripts should be sent to the Editor, Dr. T. D. Ford, at 21 Elizabeth Drive, Oadby, Leicester LE2 4RD. Intending authors are welcome to contact either the Editor or the Production Editor who will be pleased to advise in any cases of doubt concerning the preparation of manuscripts.

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Cave Science

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Transactions of the British Cave Research Association

The History of Karstification at Wombeyan Caves, New South Wales, Australia, as revealed by Palaeokarst Deposits

by R.A.L. OSBORNE

Abstract: Palaeokarst deposits exposed in cave walls and at the surface at Wombeyan Caves, New South Wales, Australia indicate that the Silurian Wombeyan Limestone, a coarsely crystalline marble, has undergone three, possibly four periods of karstification beginning in the Devonian.

Volcaniclastic palaeokarst deposits form dyke-like deposits with restricted strike lengths and fill cave-like cavities in the marble. They are lithologically similar to units of the Lower Middle Devonian Bindook Porphyry Complex which unconformably overlies the Limestone and are interpreted as effusive volcanic deposits, filling karst fissures and caves that developed during the Devonian.

Limestone breccias with a coarse crystalline matrix, some with the form of crackle breccias, are exposed at the surface and in the walls of a number of caves. Coarse crystals, similar to those of the breccia matrix, line open vughs intersected by modern caves and in one instance a whole cave. The breccia and crystals postdate the Late Devonian metamorphism of the Limestone and Early Carboniferous folding and predate development of the present caves and surface karst landforms.

Quartz sandstone deposits with circular outcrop patterns, representing filled dolines, lie within the marble. These are lithologically similar to sandstones which unconformably overlie topographically higher levels of the marble. Lithic sandstone, forming a palaeokarst deposit, is intersected by Creek Cave. The sandstones postdate metamorphism and folding and predate the present phase of karstification which began in the Early Tertiary. They could be either Permo-Triassic or Latest Cretaceous to Early Tertiary in age.

INTRODUCTION

Wombeyan Caves is one of the five most cavernous karsts and the second most visited show cave locality in New South Wales (Fig. 1). It is located 45 km west of Mittagong and 25 km north of Taralga in rugged country just east of the drainage divide between the easterly flowing Wollondilly River, into which the caves drain, and the westerly flowing Abercrombie River. Osborne and Branagan (1988) listed Wombeyan as one of the karst areas associated with the eastern escarpment of the highlands plateau in New South Wales. These karsts are characterised by the development of gorges, large through-caves and dynamic phreatic caves with significant vadose development containing coarse gravel fill.

The Wombeyan Limestone, in which the caves are developed, is intensely metamorphosed, forming a coarsely crystalline marble which is quarried for building stone and for use in the glass and chemical industries.

Osborne (1984) presented preliminary evidence that the Wombeyan Limestone and a number of the other limestones in the Lachlan Fold Belt had been subjected to multiple periods of karstification over geologically significant periods of time.

Subsequently palaeokarst deposits have been described from Billys Creek (Osborne and Branagan, 1985), Timor Caves (Osborne, 1986) and Jenolan Caves (Osborne, 1991). Osborne and Branagan (1988) indicated that karst processes had operated on a number of separate occasions in New South Wales during Palaeozoic times.

Research in progress suggests that there are a number of palaeokarst deposits of differing ages in the Wombeyan Limestone. This paper describes the three main types of palaeokarst deposit at Wombeyan and discusses their likely origins and age.

Specimen numbers refer to material held in the Petrology Collection of the Department of Geology and Geophysics, University of Sydney.

GEOLOGY

Geological Setting

Wombeyan Caves lie towards the eastern margin of the Lachlan Fold Belt (Fig. 1B), a zone of highly deformed lower Palaeozoic rocks in which limestones of Late Ordovician to Early Devonian ages are found in distinct north-south trending zones associated with silicic/intermediate volcanics and shallow water marine facies.

The Wombeyan Limestone (Brunker and Offenberg, 1970) was considered by Carne and Jones (1919), Naylor (1938), Scheibner (1973) and Pickett (1982) to be of Silurian age, although no determinable fossils have been found as it is extensively recrystallised in places to saccharoidal marble.

The Limestone is surrounded and overlain by silicic volcaniclastics of the Lower-Middle Devonian Bindook Porphyry Complex (Fig. 2). It is intruded by the Late Devonian Columba Granite and by small basic intrusions, both of which were probably responsible for its metamorphism. The volcanics are unconformably overlain to the south and west of Wombeyan Caves by sandstones of the Upper Devonian Lambie Group .

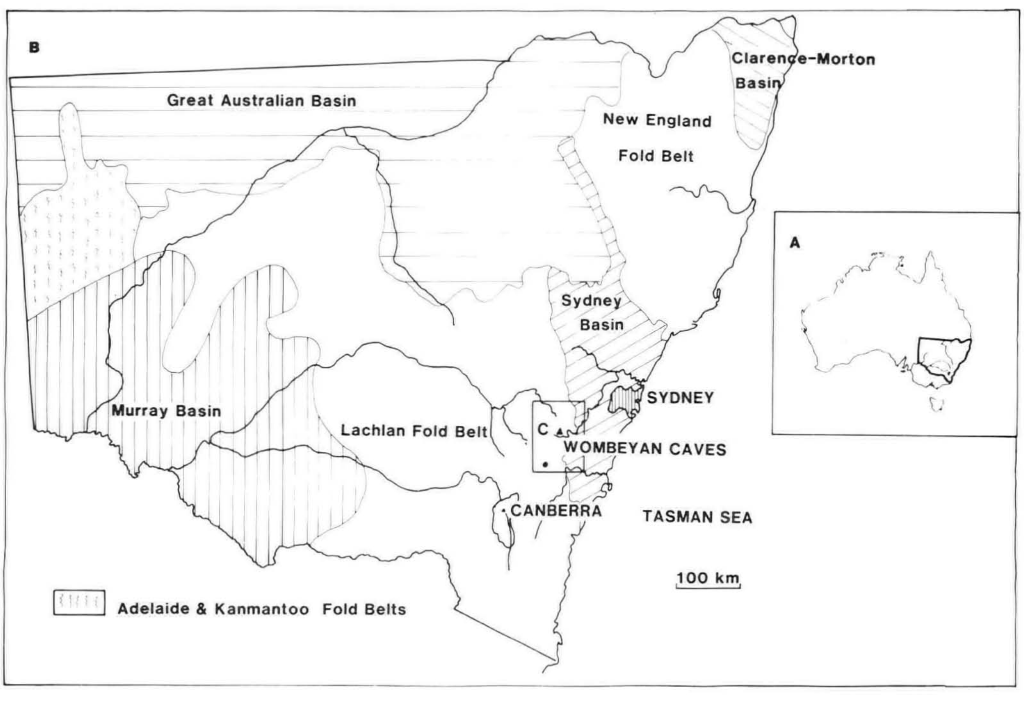


Figure 1
A Australia showing New South Wales
B Tectonic Zones of New South Wales and location of Wombeyan Caves.
C Outline of Figure 2.

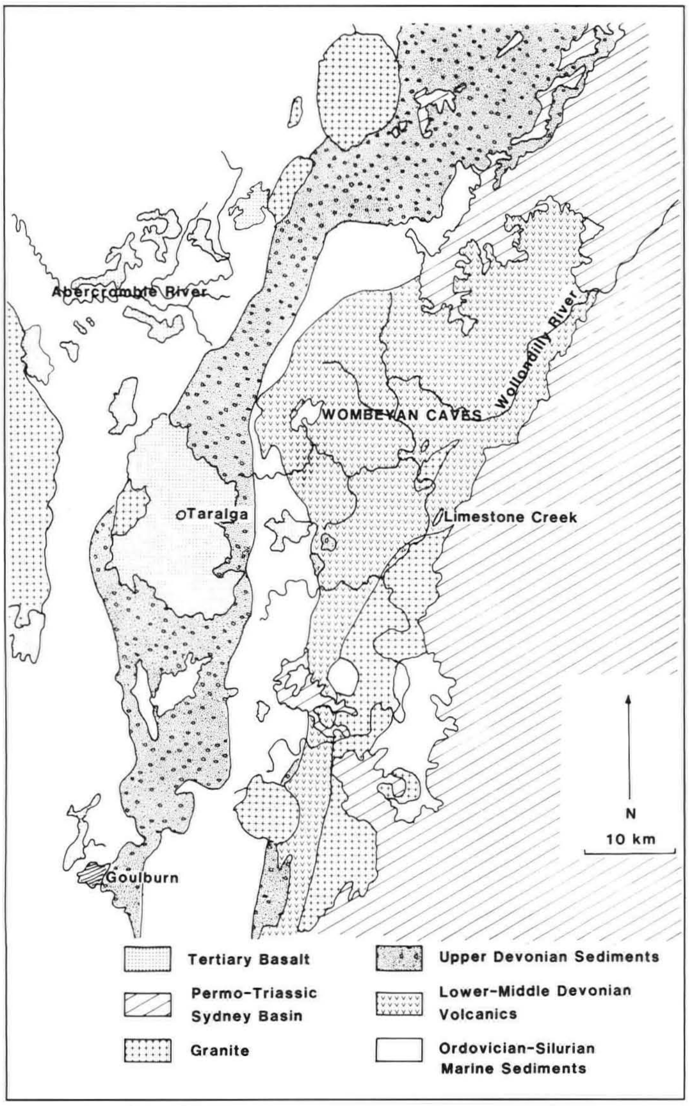


Figure 2. Geological Setting.

Permian conglomerates and sandstones, outliers of the relatively undeformed Permo-Triassic Sydney Basin, unconformably overlie the Lower Palaeozoic sequence to the south and the east of Wombeyan Caves.

Basalt of presumed Tertiary age caps Mt. Guineacor 2 km south-west of the marble (Fig. 3). Extensive basalt flows in the Taralga area, south and west of Wombeyan Caves (Fig. 2) were dated as Miocene by Wellman and McDougall (1974).

Quartz sandstones and ferricretes occur as remnants overlying topographically higher parts of the marble (Fig. 3).

Structure

There have been a number of structural interpretations proposed to explain the outcrop pattern of the Wombeyan Limestone and its relationship with the surrounding volcanics .

Phipps (1950) and Jennings *et al.* (1982) considered that the volcanics had intruded the Limestone and interpreted two small bodies of dacite tuff within the boundaries of the marble (Fig. 3) as intrusions.

Scheibner (1973) recognised that the Bindook Complex and related volcanics had an effusive volcanic origin. This was confirmed by later workers (e.g. Powell and Fergusson, 1979; Fergusson, 1980; and Cas *et al.*, 1981). Scheibner (1973) indicated that the marble had a faulted boundary with the surrounding volcanics and an intrusive boundary with the Columba Granite. Scheibner's interpretation that the whole of the marble boundary was faulted implied that the marble was a roof pendant that had subsided due to cauldron collapse.

Hansen (1979) found that the western boundary between the Limestone and the volcanics was a disconformity or low angle unconformity, with bedding in the marble dipping, and younging to the west, conformable to the westerly dipping bedding in the overlying volcanics, and that the eastern and northern margins of the Limestone were faulted. Hansen further proposed that the Wombeyan Caves area was the exposed core of a dome, produced by the interference of Mid-Devonian and Latest Devonian fold axes.

Field observations, however, suggest that the northern boundary between the marble and the volcanics is not faulted, but that along this margin volcanics overlie the marble with a sub-horizontal boundary. The eastern margin of the marble in the north is faulted in places, as suggested by Hansen (1979), and dips to the west, while in the south it dips to the east, suggesting that the southern boundary, like the western boundary, is unconformable. Angular fragments of volcaniclastics are found in many places on the surface of the marble, often on the tops of hills some distance from the boundary, consistent with the volcanics overlying the marble.

The relationships between the Wombeyan Limestone and the volcanics confirm that the Wombeyan Limestone is overlain and not intruded by the volcanics. The two bodies of volcanics within the marble, regarded by Phipps (1950) and Jennings *et al.* (1982) as intrusions, are remnants of the former pyroclastic cover and may fill depressions in the pre-volcanic limestone surface.

GEOMORPHOLOGY AND CAVES

The Wombeyan Limestone outcrops in a topographic basin surrounded by steep hills of volcanics (Fig. 3). The basin is drained by Mares Forest Creek, a tributary of the Wollondilly River, which has an incised course, forming a gorge up to 50 m deep through the floor of the basin. Wombeyan Creek, which joins Mares Forest Creek, runs underground through the Fig Tree Cave system. Upstream from its capture Wombeyan Creek forms a blind valley with a flat alluvial floor, while downstream it has a narrow, incised course. Jennings *et al.* (1982) considered the area to be a fluviokarst, with surface stream flow being the dominant agent of landscape development.

The hills forming the rim of the basin extend up to 920 m A.S.L. while the bed of Mares Forest Creek where it leaves the marble has an elevation of approximately 540 m A.S.L. (Fig. 3). The highest outcrops of marble have an elevation of approximately 680 m A.S.L. In the south and east the edge of the basin is marked by the 700 m contour while in the north and west the 780 and 800 m contours form the lip.

A number of distinct terrace levels, cut both on volcanics and marble, can be recognised within the basin. The highest terrace has an elevation of between 660 and 670 m. This terrace is well developed on volcanics in the ridge south of Sigma Cave and below the road level at the northern edge of the marble where sandstone rests on the terrace. The doline entrance of the highest level cave at Wombeyan Caves, Durrins Tower Cave ("a" in Fig. 3), has an elevation of 660 m. Surfaces at 660 m are a prominent feature of the marble landscape south of Wombeyan Quarry .

Caves

Ellis *et al.* (1982) recorded 232 cave entrances at Wombeyan Caves and described the major features of the caves. While many of the caves are simple vadose shafts, major cave development at Wombeyan has resulted from the underground capture of tributaries to Mares Forest Creek, principally Wombeyan Creek (Fig. 4).

The Fig Tree Cave System (Figs 4 & 7), consisting of Victoria Arch, Fig Tree Cave, Creek Cave, Olympian Cave and Junction Cave, completely captures Wombeyan Creek underground. Base level flow drains via Olympian Cave and Junction Cave to resurge at Junction Cave Spring while higher level flow drains via Victoria Arch and Creek Cave. Victoria Arch, Fig Tree Cave and Junction Cave are developed as show caves.

The Bouverie-Bullio Cave System (Fig. 4) appears to act as an internal drainage system for the marble (James *et al.* 1982). Bouverie Cave consists of extensive low level passages and chambers connected to the surface by a dyke-controlled breakdown zone. Bullio Cave (Fig. 5) contains both active streamway and high level abandoned phreatic passages.

Basin Cave (Fig 4) is an isolated cave with a largely joint-controlled phreatic morphology. It contains significant deposits of lacustrine and cold-climate talus deposits and is used as an over-wintering cave by Bent-Winged Bats.

Sigma Cave (Fig. 6) was discovered in 1975 and contains many pristine speleothems. The cave consists of a high level largely phreatic northern section leading into an active vadose-incised streamway which opens into large caverns at its southern (upstream) end.

VOLCANICLASTIC PALAEOKARST DEPOSITS

Dyke-like Bodies

A number of dyke-like bodies with little lateral continuity, and small outcrops of coarse volcaniclastics surrounded by marble, are found in surface exposures at Wombeyan Caves.

One dyke-like body of vesuvianite-diopside rock (U.S.G.D. 65753)

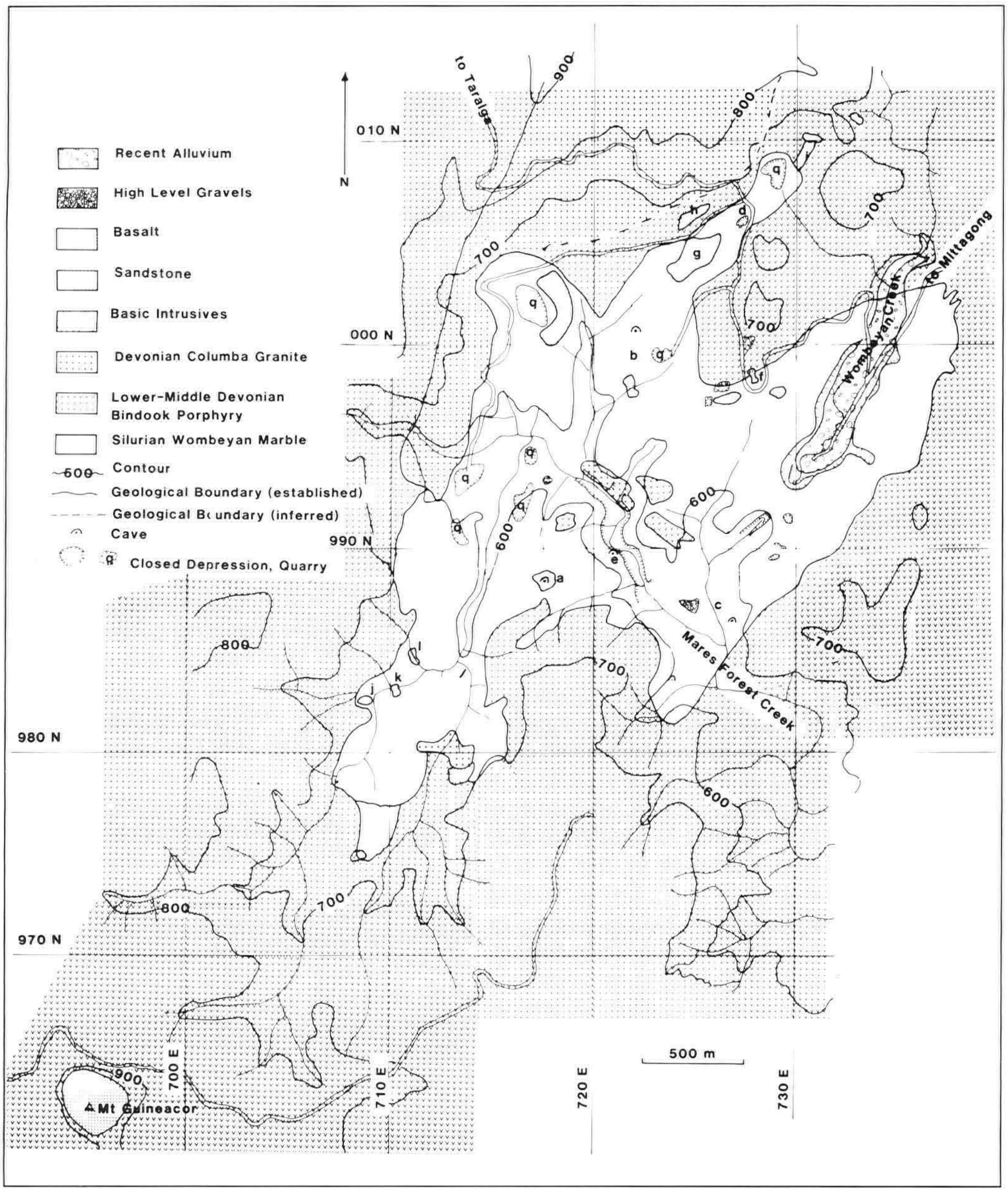
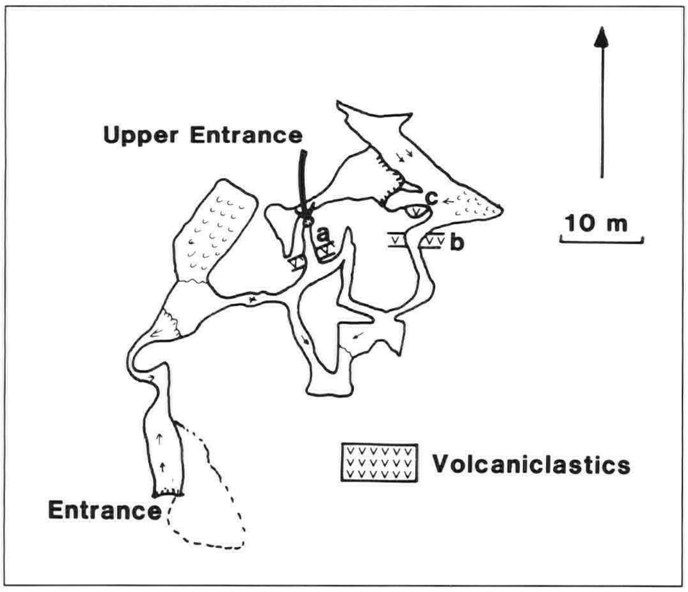


Figure 3. Geology Contours and grid after Richlands 8829-II-N 1:25,000 Topographic Map.

- *a* — *Durrins Tower Cave*
- *b* — *Location of vesuvianite-diopside rock, U.S.G.D. 65754*
- *c* — *Location of sulfide rich dyke in Wombeyan Creek*
- *d* — *Location of dyke-like bodies*
- *e* — *New Glass Cave*
- *f* — *Ironstone and conglomerate remnant on highest marble outcrop*
- *g* — *Large ironstone deposit*
- *h* — *Location of ironstone overlying granite*
- *i* — *Location of conglomerate pillar*
- *j* — *Circular sandstone deposit*
- *k* — *Circular sandstone deposit*
- *l* — *Circular sandstone deposit*

Figure 4.
Bullio Cave. Upper Plan G.R.G. Grade 5 after D. Rolls & J. James, March 1967. Reproduced by courtesy of the Sydney Speleological Society.



("b" in Fig. 3) is 0.5 m wide and has a strike length of 8 m, abruptly terminating at each end (Plate 1). Another dyke-like body exposed in the bed of Wombeyan Creek (location "c" in Fig. 3) is 0.6 m wide and discontinuous along strike. It consists of coarse volcaniclastic rock containing angular quartz, feldspar, lithic fragments up to 5 mm across and sulfides (U.S.G.D. 65754).

Three dyke-like bodies of volcanics (at "d" in Fig. 3) are resistant to weathering and rise above the level of the surrounding marble (Plate 2). They consist of angular quartz fragments (up to 3 mm) in a matrix from which clinopyroxene, garnet, and an albitized feldspar cement have developed (U.S.G.D. 65755). One body has an antiformal structure with a marble core and appears to be the result of the resistant rock body draping over the marble and bifurcating downwards. The boundaries between all the bodies and the marble are sutured, anastomosing and indicate that the bodies narrow downwards. In a number of places small outcrops fit into depressions within the marble.

Dyke-like bodies of volcanics are intersected by Sigma Cave (Fig.6) and Bouverie Cave (Fig. 4) and have been important controls over cave development.

Bullio Cave

Bullio Cave (Fig. 5) intersects a number of irregular bodies of volcaniclastic rock, which are often dyke-like in outcrop pattern.

An irregular body of volcanic rock outcrops in the Upper Entrance of Bullio Cave ("a" in Fig. 5) (Plate 3). This body strikes east-west and dips to the south at 45°. Its boundary interdigitates with the surrounding marble and its bedding, which in places is slumped, is developed parallel to its boundaries. The rock from this body (U.S.G.D. 65751) consists of layers of sub-angular to rounded volcanic quartz and lithic sand clasts (1 mm diameter), interbedded with layers of vitric fines with a few volcanic quartz sand grains.

Another irregularly-shaped body of similar rock has restricted cave development in the section of Bullio Cave just before the iron ladders ("b" in Fig. 5). This body has sub-horizontal bedding which is parallel to its boundary with the surrounding marble. This rock (U.S.G.D. 65752) is much finer-grained than U.S.G.D. 65751, consisting largely of devitrified fines.

Near the top of the iron ladders ("c" in Fig. 5), outcrops of these

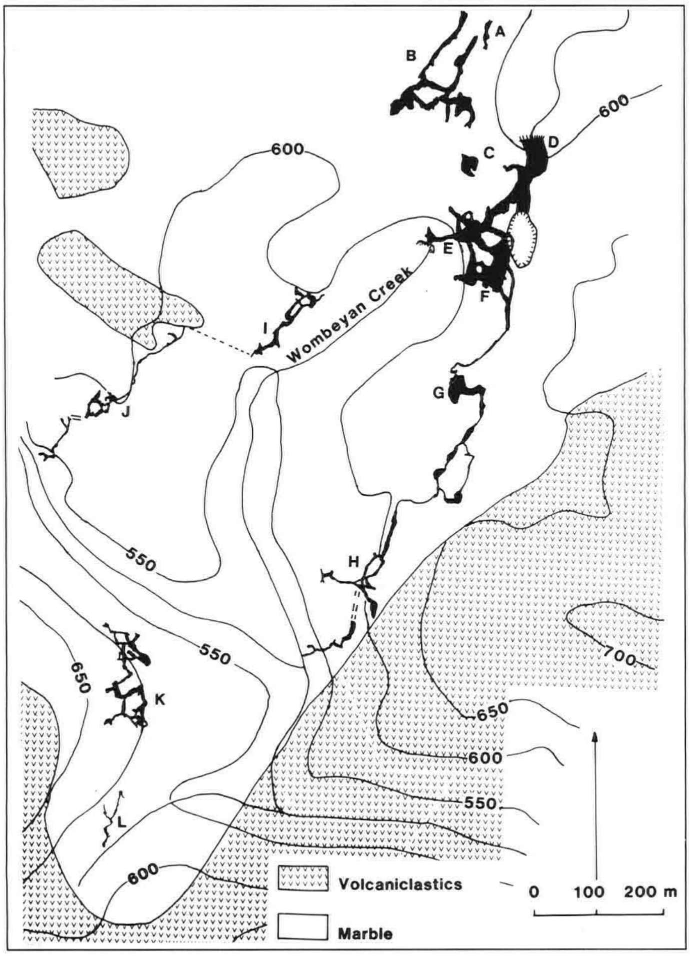


Figure 5. Major caves of the Wombeyan karst. Cave silhouettes largely after James et al. *1982.*

A	*Guineacor Cave*
B	*Wollondilly Cave*
C	*Kooringa Cave*
D	*Victoria Arch*
E	*Creek Cave*
F	*Fig Tree Cave*
G	*Olympian Cave*
H	*Junction Cave*
I	*Bouverie Cave*
J	*Bullio Cave*
K	*Basin Cave*
L	*Sigma Cave*

volcanic rocks are unconformably overlain by gravel and sand. In one wall niche gravel has a vertical boundary with the volcanics (Plate 4). The boundary between this outcrop of volcanics (which are horizontally bedded) and the marble is sutured and resembles a keyhole-shaped cave passage. Other outcrops of the volcanic rock in this part of the cave show it to be cleaved and displaced by minor faulting.

Origin of the Volcaniclastic Palaeokarst Deposits

The volcanics exposed both on the surface and underground are unlikely to have been emplaced as intrusions owing to their grain size, fragmental grain shape, and composition. The presence of cleavage, the displacement of the volcanic rock bodies by minor faulting, and the alteration of the matrix suggest that they are quite old, predating metamorphism of the marble. The nature of their boundaries and the dominance of coarse quartz clasts indicate that they are an eruptive facies of the Bindook Porphyry Complex and not metamorphosed non-carbonate lenses within the Wombeyan Limestone.

Their discontinuity along strike, anastomosing and sutured boundaries, downward bifurcation and narrowing are all consistent with the dyke-like structures being filled karst fissures. For these features to be preserved, the present landsurface on the marble must be not far below the Early Devonian surface prior to the extrusion of the volcanics. This is in accordance with the concept of Hansen (1979) that the volcanics disconformably overlie the Wombeyan Limestone which is now exposed as the core of a dome.

A karst origin for the non dyke-like bodies of volcanic rock exposed in Bullio Cave is indicated by their irregular and sutured boundaries, and by development of bedding parallel to their boundaries. In petrography these rocks also resemble the volcaniclastics of the Bindook Porphyry Complex and were most likely deposited in water-filled karst cavities in Devonian times, during the early stages of the eruption.

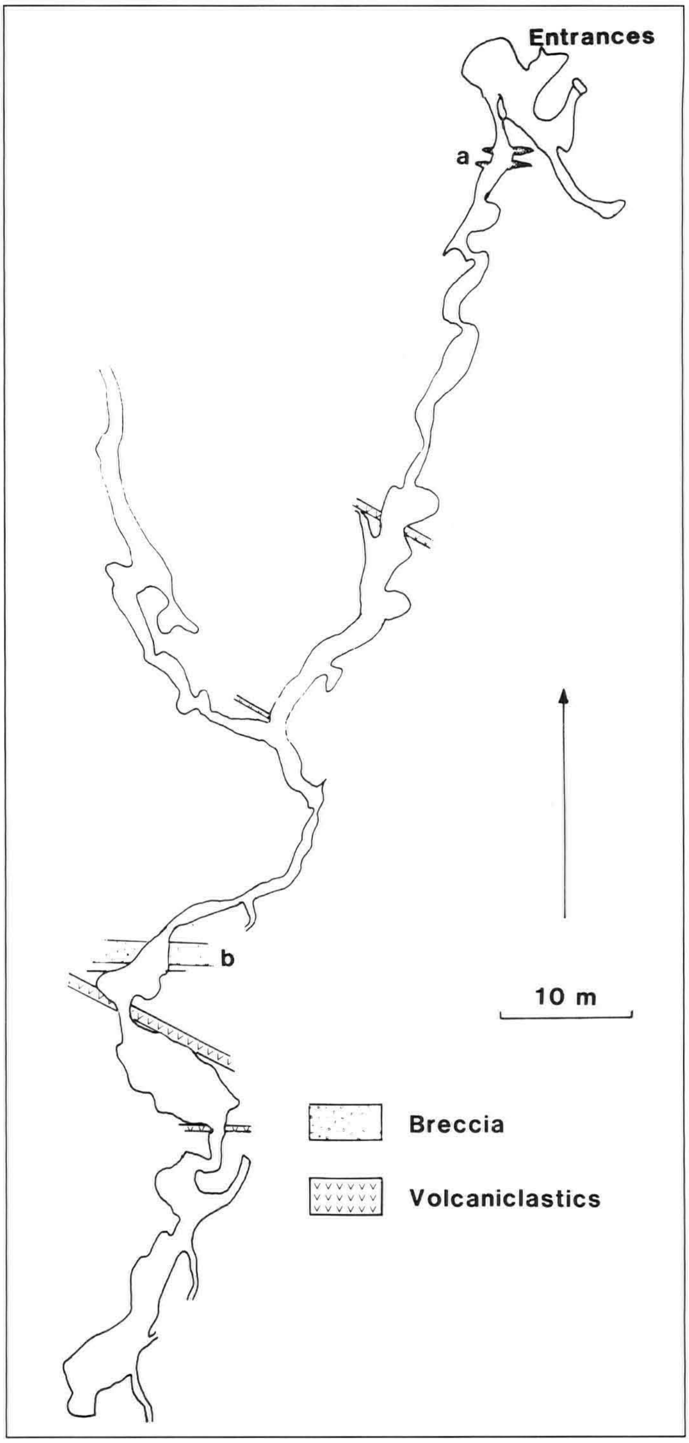


Figure 6. Sigma Cave. Map C.R.G. Grade 5 after N. Hickson, S. McCann, L. Sprowles & P. Ruxton, January 1976. Reproduced by courtesy of the Sydney Speleological Society.

PALAEOKARST BRECCIAS

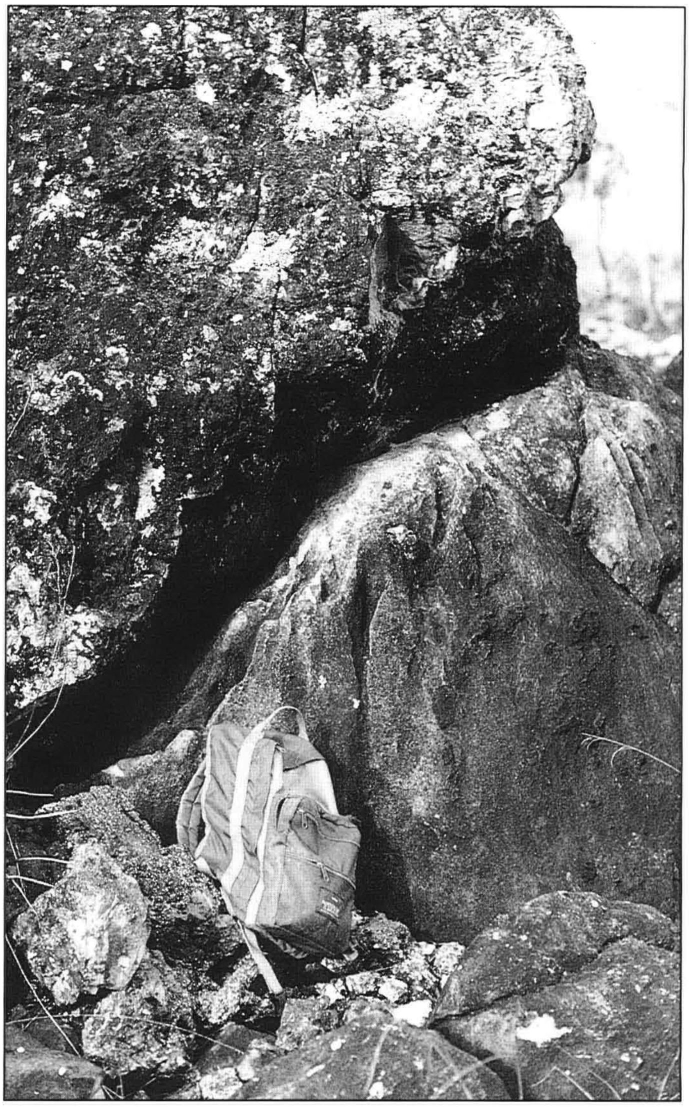
Breccias composed of marble fragments and in places rounded volcanic clasts, with a coarse crystalline carbonate cement are exposed at the surface and in the walls of a number of caves. Crystals, similar to those of the cement, line caves and vughs intersected by modern caves. Osborne (1984) suggested that these breccias are palaeokarst features.

Breccia deposits in Basin, Bouverie, Creek and Sigma Cave and crystal linings in Sigma and New Glass Cave have been examined.

Basin Cave

Basin Cave (Fig. 4) is partly developed in a breccia composed of marble clasts in a sparry calcite matrix. James, Jennings and Dyson (1982) reported that adjacent blocks in the breccia varied in colour

Dyke-like body of volcaniclastics at "b" in Figure 3. Lens cap 55mm.



Contact between volcaniclastics in dyke-like body and marble at "d" in Figure 3. Note curved boundary between volcaniclastics, left and marble, lower right.

and texture, and that the matrix between the marble blocks was composed of 90 % calcite and 10 % iron oxides and clay.

The breccia in Basin Cave is restricted to well-defined zones with complex embayed boundaries within massive marble (Plate 5). The clasts in the breccia are mostly marble, but volcanic clasts are also present. Some of the clasts appear to have been transported, with adjacent marble clasts showing variation in texture while others seem to be bedrock fragments, separated by *in situ* solution. Calcite-lined vughs are developed in the spaces between the clasts.

Bouverie Cave

Breccia composed of red-brown coloured calcite crystals among which are interspersed angular marble fragments is exposed in the Lower River Section of Bouverie Cave. The breccia occurs in well-defined zones and in many places lacks grain support containing far more sparry cement than clasts. In thin section it can be seen that the crystals in this breccia have sharp boundaries with the marble clasts and that the boundary truncates crystals within the marble, indicating that the crystal breccia is post-metamorphic in origin.

Creek Cave

Breccia occurs in the eastern branch of Creek Cave (Fig. 7). Some of the breccia is found in well-defined zones within unbrecciated, massive marble. Other breccia has a penetrative boundary with the marble with adjacent pieces of marble showing little or no displacement. This type of breccia was described as a *crackle breccia* by Norton (1917).

The crackle breccia is composed of thin plates of marble, many of which have a sub-horizontal orientation separated by a sparry carbonate cement containing crystal-lined cavities (Plate 6).

New Glass Cave

New Glass Cave ("e" in Fig. 3) is largely lined with brown calcite crystals similar to those forming the cement of breccias exposed in the other caves. The wall morphology and shape of the cave suggest that this is a karst solution cave that has been lined with crystal after flooding and not an irregular vugh in the marble.

Sigma Cave

Sigma Cave (Fig. 6) intersects bodies of breccia composed of angular marble clasts cemented together by brown sparry carbonate. The breccia occurs in well-defined zones within massive marble.

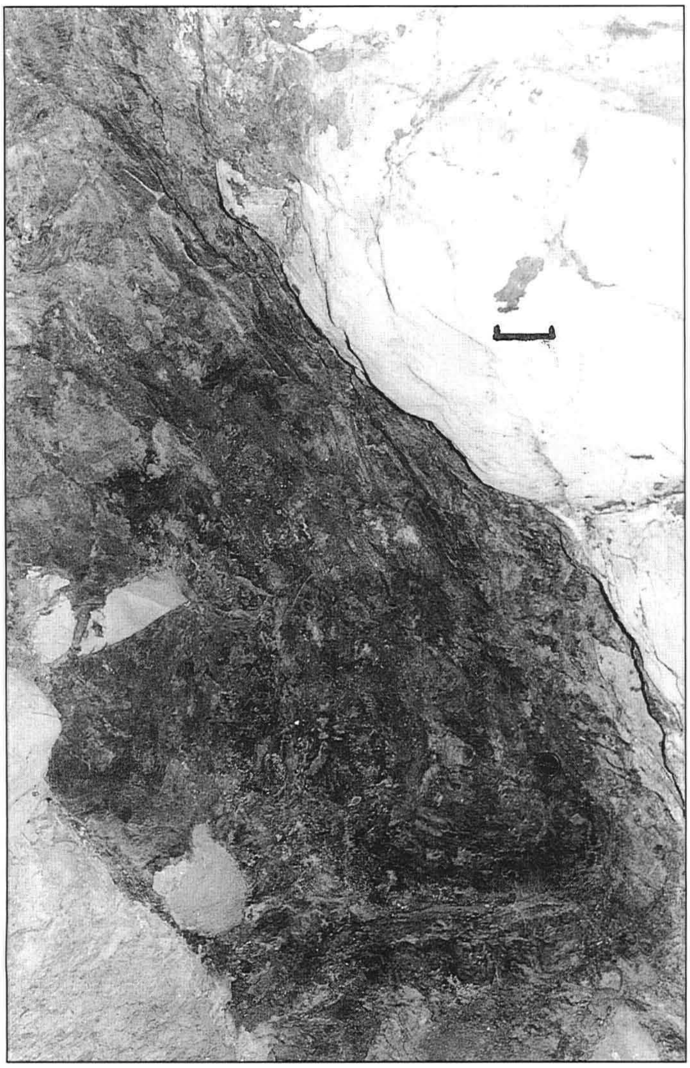
One section of Sigma Cave ("a" in Fig 6) intersects and partly follows cavities lined with crystals of red-brown spar which is in continuity with the cement of the breccia (Plate 7). These cavities have the form of a phreatic cave and are lined with up to 100 mm of spar. Some contain deposits of red laminated clay. The relationship between the crystal-lined cavities and the cave indicates that the cavities are palaeokarst features that have been intersected by, and have partly controlled, the development of Sigma Cave.

Where the cave exposes breccia (e.g. at "b" in Fig. 6) speleothems is abundant, growing prolifically out of the matrix of the breccia. This indicates that the breccia is more permeable than the enclosing massive marble and may well have controlled cave development.

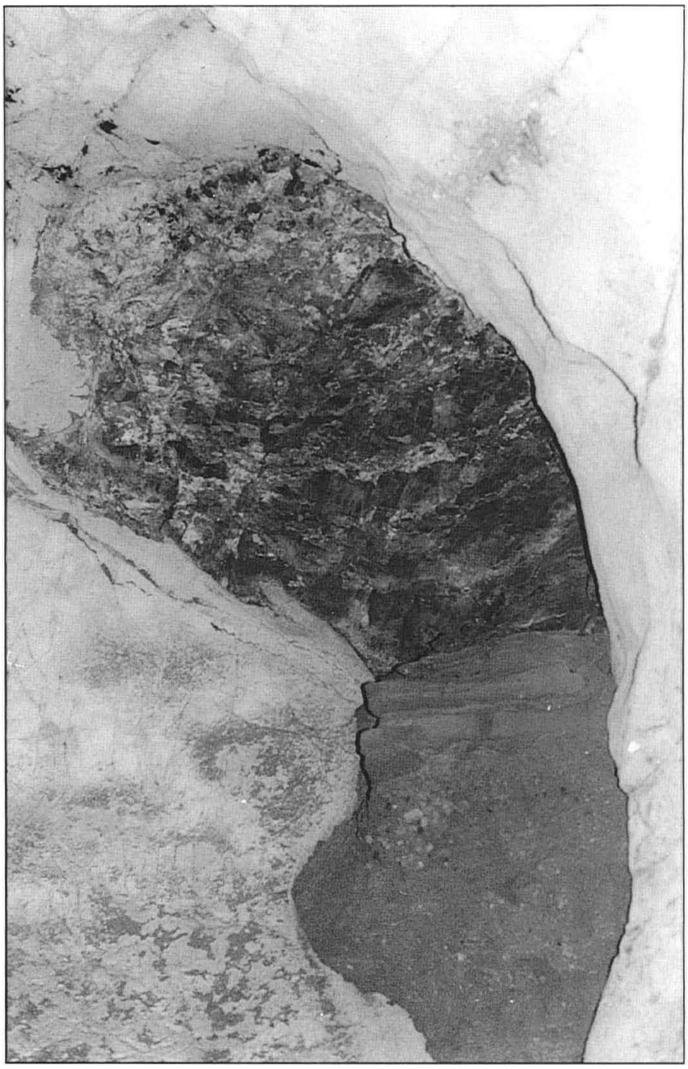
Origin of the Breccias and Crystal Linings

The breccias exposed at the surface and in Basin, Bouverie, Creek and Sigma Caves have a number of characteristics in common. They are composed of marble clasts, contain a few volcanic clasts, and have a porous, often vughy spar cement. Some of the breccias are cement rather than grain supported, while others such as those in Creek Cave have the form of crackle breccias with cement apparently invading and fracturing the host marble. The relationship between the sparry cement and the marble indicates that the spar was deposited after the metamorphism of the Limestone.

Phipps (1950) described garnet-cemented breccias adjacent to the granite in Mares Forest Creek which he related to the emplacement of



Bedded volaniclastics exposed in upper entrance to Bullio Cave ("a" in Fig. 5). Note how bedding follows right hand contact before slumping. Scale bar 100mm.



Body of volaniclastics, upper, covered by gravel remnant, lower. Exposed in Bullio Cave ("c" in Fig. 5). Field of view. Approx. 2m x 1m.

the granite. The breccias described here, however, do not contain any metamorphic phases nor does their distribution appear to be governed by proximity to the granite.

The field relationships of the breccias indicate that they were not formed by tectonism, rather that they fill or have been emplaced in well-defined zones within the marble. The breccias are intersected by and are therefore older than the caves in which they are exposed.

The morphology of New Glass Cave and the relationship between the crystal-lined cavities and the breccia in Sigma Cave suggests that the breccias are palaeokarst deposits of similar origin to the lined caves. This is supported by the presence of volcanic clasts in the breccia in Basin Cave. The texture of the breccia in Creek Cave is not unlike that seen in some modern breakdown piles.

The sub-horizontal orientation of the clasts in the breccia in Creek Cave suggests that there has not been significant post-depositional tectonism implying that the breccia is no older than Early Carboniferous.

SANDSTONE PALAEOKARST DEPOSITS

Young (1880), Phipps (1950) and Jennings *et. al.* (1982) all reported ferruginised quartz sandstone, conglomerate, and ironstone unconformably overlying the Wombeyan Limestone at high levels in the landscape. The distribution of sandstone, conglomerate, and ironstone outcrops suggests that they represent the remnants of a once more extensive deposit that filled the topographic basin at Wombeyan Caves prior to the incision of Mares Forest Creek. The base of the sandstone has a variable elevation indicating a relief of at least 30 m on the depositional surface and extends down to 650 m A.S.L. Sandstone and ironstone remnants occur at quite high topographic levels on the marble. Coarse conglomerate and ironstone occur on the highest marble outcrop (elevation 680 m A.S.L.) forming the knoll of the large bend on the Taralga Road ("f" in Fig. 3). Laminated ironstone fragments are found on the surface next to the doline entrance of Durrins Tower Cave (elevation 660 m A.S.L.)

A large deposit of sandstone and ironstone occurs in the area between the two quarry roads ("g" in Fig. 3). Field relationships in this area indicate that the sandstone and ironstone overlie an irregular marble surface. At G.R. 724 004 (Fig. 3) ironstone drapes over the north east face of a marble hill and extends to the level of the Quarry Road (650 m A.S.L.).

At G.R. 724 006 ("h" in Fig. 3) the ironstone overlies the granite forming a flat terrace with an elevation of 660 m A.S.L. A mine shaft was dug in this terrace. Concretionary ironstone in the north-western part of this deposit is up to 30 m thick and was investigated as a possible economic resource.

Another large body of iron-cemented sandstone occurs at the southern extremity of the limestone (Fig. 3). Sandstone also occurs at Hockey Gully where relationships indicate that it was deposited over an irregular karst surface. Coarse conglomerate is preserved in this area as pillar-like remnants up to 3 m high. ("i" in Fig. 3 and Plate 4).

Previous workers (Mulholland, 1942; Phipps, 1950, Hansen, 1979) considered that these deposits were either false gossans, fault breccias, or of metamorphic origin. However the concretionary ironstones grade into ferruginised sandstone indicating that both are a product of varying degrees of ferruginous cementation.

The sandstones and conglomerates are quartz-rich consisting of subangular quartz and silicic volcanic fragments up to 5 mm with a ferruginous cement (U.S.G.D. 65747). Cross-bedding is visible in some outcrops. The grains in these sandstones have suffered minimal transport and alteration prior to deposition, indicating that they have been derived locally from the surrounding volcanics. The iron oxides, forming the cement and concretionary deposits, were probably derived from **in situ** weathering of iron-rich phases eroded from the granite and the volcanics.

Circular Sandstone Deposits

Roughly circular bodies of sandstone up to 80 m in diameter and entirely surrounded by marble are exposed to south of the main quarry ("j" , "k" & "l" in Fig. 3). These sandstones are similar in composition

Crystalline breccia exposed in the wall of Basin Cave. Lens cap 55mm.

Crystal-lined cavity in Sigma Cave ("a" in Fig. 6). Lens cap 55mm.

to those described above and represent dolines filled when the limestone surface was buried under the sandstone.

Creek Cave

Osborne (1984) described iron-cemented sandstone exposed in Creek Cave ("a" in Fig. 7). The sandstone forms the centre of a crystal-lined vugh and has been exposed by downcutting of the present course of Wombeyan Creek through the cave. The boundaries of the palaeokarst deposit intersect a breccia zone in the marble, indicating that the sandstone post-dates the breccia. The sandstone body is made of iron-cemented quartz-lithic wacke containing clasts of quartz, feldspar and silicic volcaniclastics (U.S.G.D. 65756), indicating that it, like the sandstones found on the surface, was derived from the surrounding volcanics.

Crackle breccia exposed in the wall of Creek Cave. Lens cap 55mm.

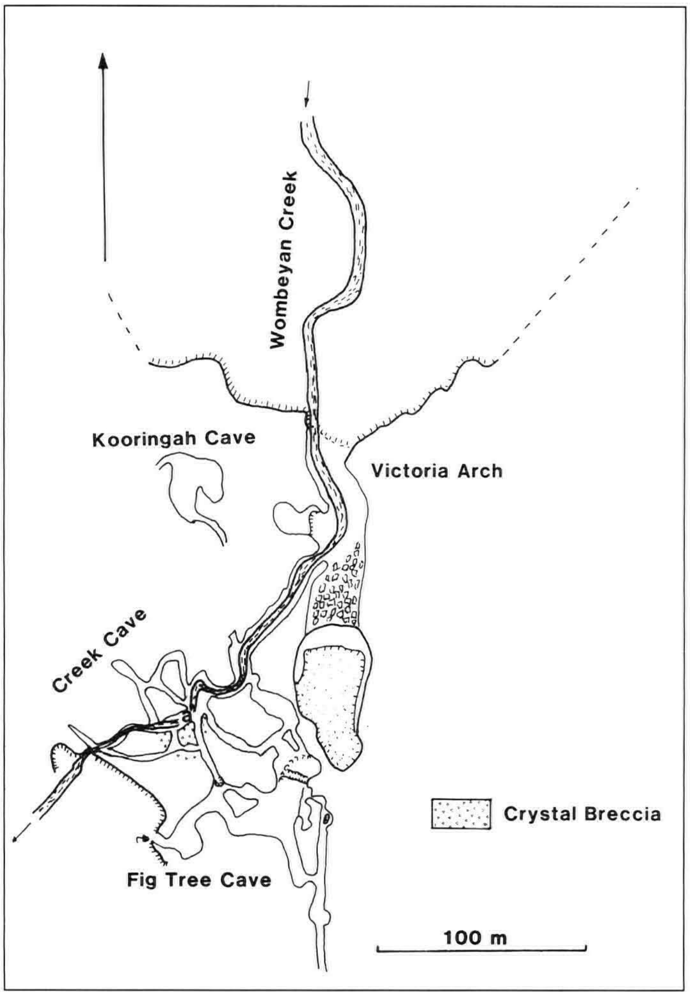


Figure 7. The Fig Tree Cave System after Trickett (1900).

Age of the Sandstone Deposits

The sandstone deposits and associated conglomerates resemble both the sandstone and gravel facies found around the western margin of the Permo-Triassic Sydney Basin, 10 km south east of Wombeyan Caves and the Latest Cretaceous to Early Tertiary sands and gravels found at Bungonia Caves, 60km south of Wombeyan Caves (Osborne, in press).

No fossils of any type have, as yet, been found in the sandstones and so their age at this stage must considered undetermined. It does, however, seem most likely that they are either Permo-Triassic or Latest Cretaceous to Early Tertiary in age.

DISCUSSION

Osborne (1984) suggested that more than one period of karstification has affected the Wombeyan Limestone and indicated that the Wombeyan Limestone may have been exposed to subaerial conditions in Middle Devonian and Permo-Carboniferous to Recent times.

Exposure and karstification was possible in Early Devonian times since the volcanics disconformably overlie the Limestone and, as proposed by Hansen (1979), there is a "hiatus of uncertain duration" between deposition of the Wombeyan Limestone and the first stage of volcanism. Middle Devonian surface exposure, proposed by Osborne (1984) is unlikely as at that time the Wombeyan Limestone would have been covered by the volcanics.

By the Early Carboniferous folding responsible for the dome structure at Wombeyan was complete. Removal of the volcanics from the marble may have begun by Permo-Carboniferous times.

It is difficult to reconstruct the palaeogeography of the Wombeyan Caves area during Permo-Carboniferous times. At Limestone Creek, 10 km south east of Wombeyan Caves, the eroded western edge of the Sydney Basin is exposed. Here Permo-Triassic strata fill valleys in a surface with an elevation of approximately 700 m A.S.L., very close to the 680 m A.S.L. maximum elevation of the Wombeyan Limestone. It seems likely that the Wombeyan Limestone was either exposed or within 100 m of the surface during Permo-Carboniferous times.

Given the lack of any substantial Permo-Triassic cover in the area, and the proximity of the Limestone to the base level of the the Sydney Basin it seems likely that the Limestone was exposed during Mesozoic times. Whatever the Mesozoic situation, the incision of the eastern highlands in the Early Tertiary or Late Cretaceous would have quickly exposed the Wombeyan Limestone making karstification possible during most, if not all, of the Cainozoic.

CONCLUSIONS

The Wombeyan Limestone has been subjected to three, possibly four, distinct phases of karstification during which caves developed. The first stage of karstification ended when the area was covered by effusive volcaniclastics of the Early Middle Devonian Bindook Porphyry Complex. This phase of karstification is now preserved as dyke-like and other irregular bodies of volcaniclastics within the limestone.

A second phase of karstification produced the crystalline breccia and crystal lined cavities. This phase postdates metamorphism and folding of the limestone and could be as old as Permo-Carboniferous. The relationship between this phase and that now represented by the sandstone palaeokarst remains uncertain, however it is possible that these events are temporally related.

A third and continuing phase, beginning in the Early Tertiary is responsible for the formation of the present caves and karst landscapes which truncate and expose the palaeokarst deposits and crystal-lined cavities produced by the earlier phases.

ACKNOWLEDGEMENTS

Palaeokarst research at Wombeyan Caves was supported in 1991 and 1992 by University of Sydney Research Grants. The Jenolan Caves Reserve Trust permitted access to the caves. E.M. Chalker, Superintendent Wombeyan Caves and his staff assisted in many ways. Special thanks are due to E.M. and A. Chalker for providing accommodation. S. Reilly made his extensive local knowledge available and assisted with work in the field. Unpublished cave maps are reproduced by courtesy of the Sydney Speleological Society. P.J. Osborne assisted with preparation of the text.

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A preliminary study of Radon in the mines and caves of East Clwyd, North Wales

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Abstract: Radon daughter levels in two caves and three local mines were monitored during November and December 1992 using carbon absorbers. The locations chosen for the study are all used by local cavers, albeit some to a greater degree than others, and represent a fairly good cross section of the available caves and mines in East Clwyd in terms of extent, depth and other physical attributes. Other parameters such as external and internal site temperatures and air movements were recorded during each placement and collection trip while air pressures at each entrance was calculated from the records of a local weather station. Correlation graphs were then produced using these additional readings in an attempt to identify their possible effect on radon daughter concentration.

Scientific research of any kind carries its own intrinsic fascination, but it must above all, provide us with greater information with which to make a more informed assessment of our environment. Underground radon data in Clwyd is scant; with this in mind, together with the desire to understand more fully the local caving and mining environment, this study was instigated.

The research is based on five locations, all in the upper division of the North Wales Carboniferous Limestone; a faulted limestone where wide but varying deposits of sulphide ores are found, mainly lead (galena) and zinc (blende). These are mixed with gangue minerals such as calcite and quartz, all of which were deposited from hydrothermal solutions which formed mineralised veins. Due to the highly mineralised nature of the area one can therefore appreciate that the locations used for the study were either abandoned mines or natural caves containing some signs of past mining activities.

THE SAMPLE MINES AND CAVES

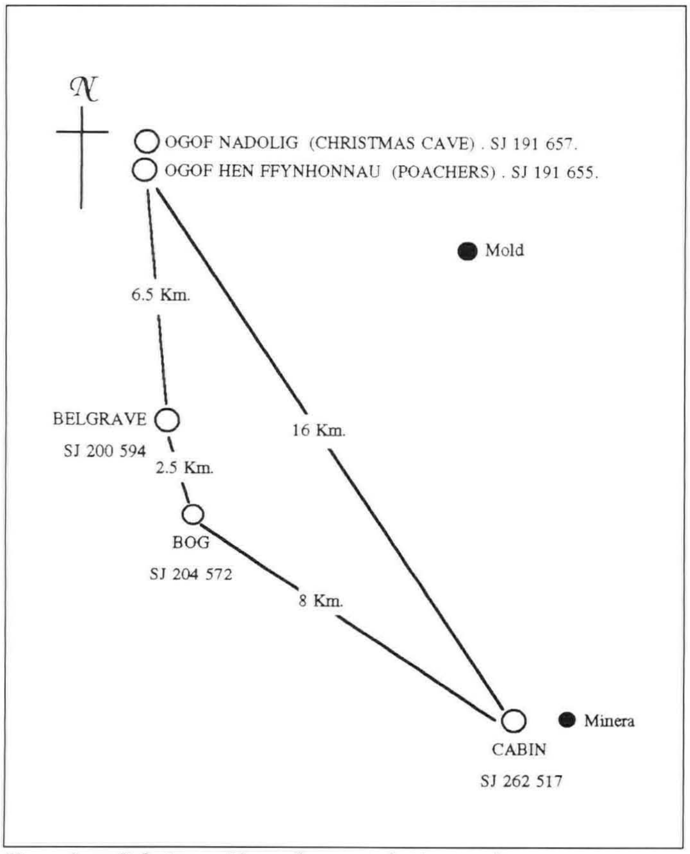


Figure 1 — Relative positions of caves and mines used.

Cabin Mine (Fig. 2)

Like several other local mines, Cabin, in the Minera area of Clwyd, is believed to date back to Roman times. It has since been extensively mined by successive operations to form a complex network of workings which saw the extraction of mainly lead ore from the Red Vein, Main Vein, Busy Bee Vein and many others. These were vigorously worked until about 1897 after which the area experienced a rapid fall in output leading to a very low level by 1912. Today, the workings can be reached via the 38 foot Cabin shaft.

Bog Mine (Fig. 3)

This is a deep mine which yielded galena in calcite together with some fluorspar and blende. It is connected to its sister Westminster mine by the Nant Adda Adit, which was driven around 1850 to drain both mines. Mining probably started here before 1800 and continued until 1868 when all operations ceased. Bog Mine was re-opened by the Grosvenor Caving Club in 1990.

Belgrave Mine (Fig. 4)

This mine worked a mineralised fault in an almost straight line south east from the River Alyn. It eventually incorporated the Brynyrorsedd Mine and three other levels on the north west side of Bryn Alyn — the final complex incorporated thirteen runs which were worked from eight shafts. The mine last worked on a large scale in 1855 and finally closed in 1882. Since closure several major falls have occurred so that today all workings beyond the Big Run are inaccessible. The main ore mined here was galena.

Ogof Nadolig (Fig. 5)

This is primarily a natural system some 220m. in length. Its entrance is about fifteen metres about the Alyn valley floor through which the middle natural series is reached by a 5m pitch. Mining activity was limited to the lower series, of which now only 14m of a 145m mined level is accessible from the cave.

Ogof Hen FFyhonnau (O.H.F.) (Fig. 6) Also known as Poachers.

A natural resurgence cave of 800 m in length with some evidence of mining at the base of the 3.5m entry pitch (3m in). It contains an active streamway in its furthest reaches which sinks to the lower tighter series; it is also prone to flooding without warning. Compacted muddy deposits are extensively found in many parts of the cave.

METHODOLOGY

Each of the locations was sampled for radon at three predetermined sampling sites (see Figs. 2 to 6) using carbon absorbers supplied by the Radiological Protection Service at the University of Manchester. The absorbers were left at the sites for precisely 48 hours, at the end of which time they were sealed, collected and returned to Manchester for analysis.

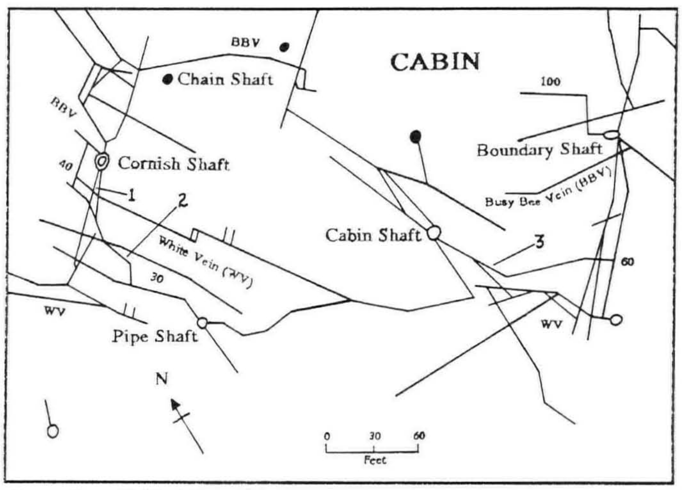


Figure 2 — Cabin Mine (Plan)

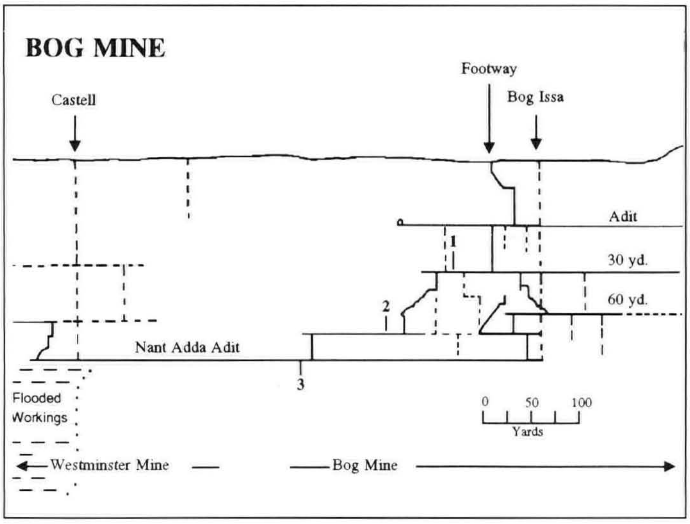


Figure 3 — Bog Mine (Elevation)

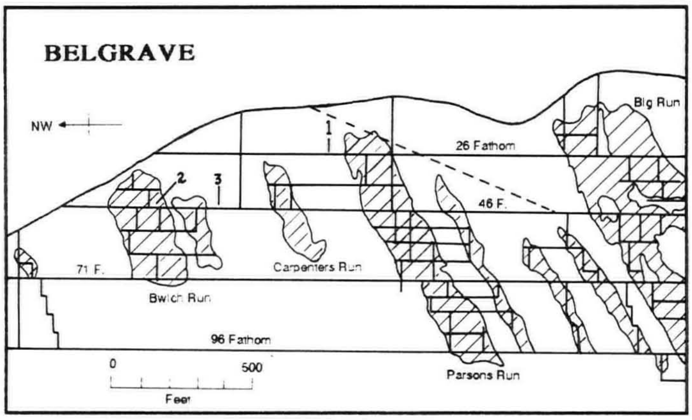


Figure 4 — Belgrave Mine (Elevation)

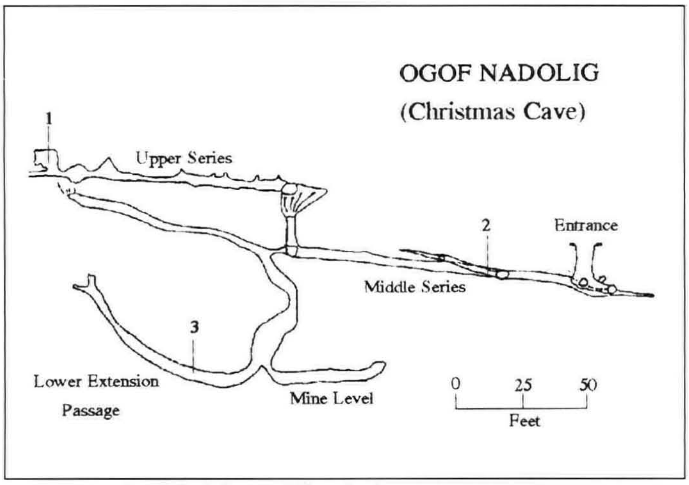


Figure 5 — Ogof Nadolig — (Elevation)

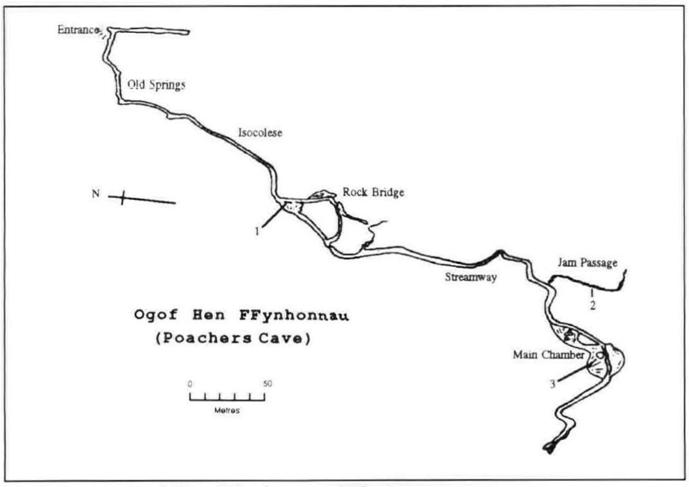
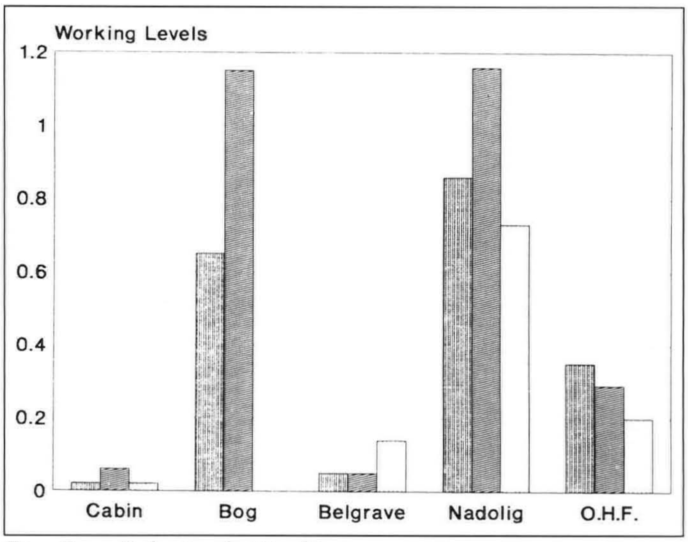


Figure 6 — Ogof Hen FFynhonnau (Plan)

The measurements obtained indicated the levels of radon decay products (radon daughters) in the air recorded in Working Levels rather than the radon gas concentration in Bequerels per cubic metre. The results are shown below:



Figue 7a — Radon Levels (Graph)

Results Table (WL)

	Sampling Dates	Site 1.	Site 2.	Site 3.
Cabin	09/11/92 - 11/11/92	0.02	0.06	0.02
Bog	16/11/92 - 18/11/92	0.65	1.15	----
Belgrave	23/11/92 - 25/11/92	0.05	0.05	0.14
Nadolig	30/11/92 - 02/12/92	0.86	1.16	0.73
O.H.F.	14/12/92 - 16/12/92	0.36	0.29	0.20

Figure 7b — Results Table

It must be appreciated that the above results are in effect "snap shot" measurements and as such give an accurate picture of the radon daughter level at each sampling site for the specified time and date only. Radon levels can vary considerably at different locations within the cave/mine, as well as from system to system and at different times of the year as a consequence of geological and other environmental factors. Interpretation of the data obtained must take such variables into consideration.

THE INFLUENCE OF ENVIRONMENTAL FACTORS

During the placement and collection trips, external air temperature, site temperature and airflow readings were taken, while external air pressures for the exposure times were obtained from a local weather station based at an altitude of 263m on Halkyn mountain 3.5km north of the survey area. A digitial thermometer was used for the temperature readings for ease of use, while the airflow measurements were taken from the deflection of a candle flame set against a simplified protractor scale.

The results obtained were then superimposed on the radon daughter levels obtained at each site, the results of which are shown on the graphs below. In one location, Bog Mine, the data is incomplete as the deepest placed absorber was lost due to flooding, the water level throughout the Westminster and Bog Mines having risen by 2.5m in the 48 hour sampling period.

THE EFFECT OF AIR PRESSURE ON RADON LEVELS

The air pressure shown was the average external air pressure prevailing during each 48 hour exposure at the cave/mine entrance altitude. Although statistically the data to hand is insufficiently large to draw any hard and fast conclusions at this time, there does seem to be some correlation between low pressure and high radon concentrations and vice versa. Pressure trends could also be a significant contributory factor, as radon gas emission from the parent rock, like that of methane, may be influenced by whether the pressure was falling or rising at the time. Frequent spot measurements would however be required to verify this.

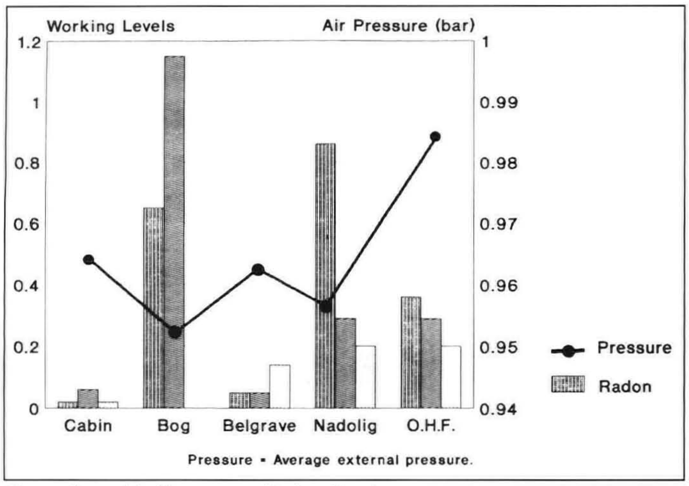


Figure 8 — Air Pressure vs Radon Levels

THE EFFECT OF AIRFLOW ON RADON LEVELS

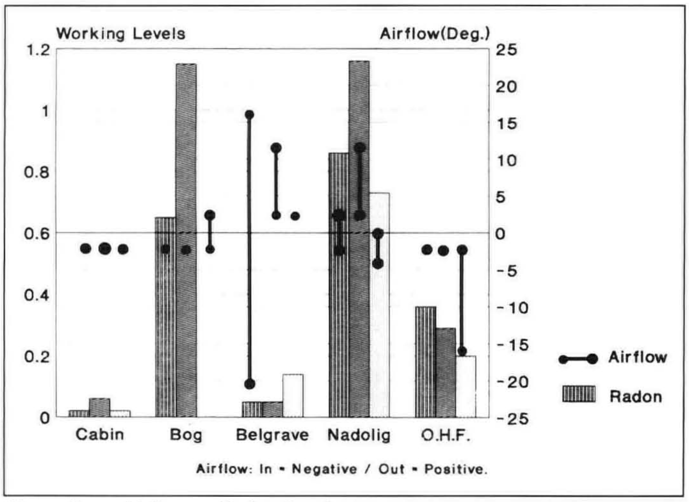


Figure 9 — Airflow vs Radon Levels

Airflow has always been considered a major influencing factor governing radon levels, as any draught would disperse the gas and lower the concentration at a given site. It was with this in mind that a prediction that Bog Mine (which has a sealed entrance and had not been entered for the last six months) would consequently have high levels of radon due to poor air circulation. This, as can be seen from the results, proved to be a correct assumption. However, other locations bucked the trend, notably Cabin, which had nil ventilation at the sampling sites used and Nadolig which is fairly well ventilated but showed surprisingly high radon daughter levels.

THE EFFECT OF TEMPERATURE ON RADON LEVELS

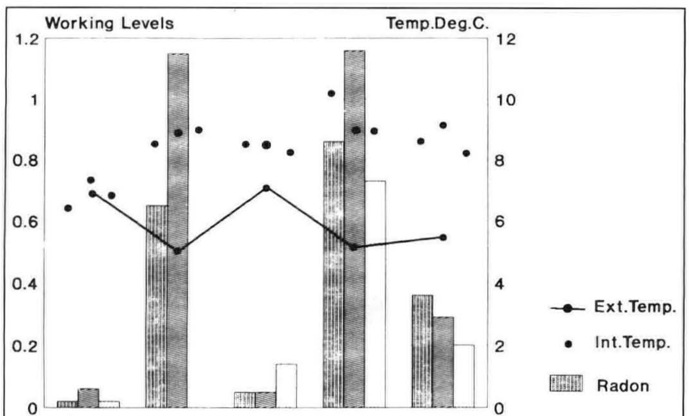


Figure 10 — Temperature vs Radon Levels

All the temperatures reading shown on the graph above are the averages between the temperatures recorded during placements and those recorded during the collection of the carbon absorbers. Internal temperatures were as expected quite stable throughout each of the cave/mine system used and as the differences between sampling sites were minimal, further study would be required to determine if any correlation exists between temperature and radon daughter levels. External temperatures could also have varied considerably during each 48 hours sampling period and as such, the averages obtained may not be such a valid representation of the parameter in this study.

CONCLUSION

From the practical caving point of view, it must be remembered that any inherent danger due to radon daughters is a factor of an individual's exposure time as well as the levels of radon decay products in the air. Therefore although the present maximum house safety limit is 0.05 WL., this figure takes into account the premise that a person spends a great proportion of his/her time in the house and will automatically incur extremely long annual times. In Britain caving trips are normally in the order of hours, thus keeping the exposure time to a minimum.

The author would be the first to admit that meaningful conclusions could not be drawn based on this limited survey. It is planned therefore that a further study, using some of the present locations, be carried out over the next twelve months using TASTRAK film as a detector. It is hoped that this longer project will provide more comprehensive information of the effect of seasonal changes on the levels of radon in underground systems in Clwyd.

ACKNOWLEDGEMENTS

This study could not have taken place without the help obtained from Dr. David Prime and Fred Ashworth of the Radiological Protection Service at the University of Manchester and that given by members of the Grosvenor Caving Club especially Pete Robertson who gave up his time to accompany me on all the trips made during the sampling periods. I am also grateful to the North Wales Caving Club who kindly gave permission to use O.H.F. for the study and to Mr. L. J. Walls who runs the Halkyn weather station for providing me with comprehensive pressure information.

The maps included in this report have been published by the kind permission of the following individuals or bodies: Belgrave — Director, British Geological Survey: Crown Copyright Reserved; Bog Mine — Ebbs, C. Grosvenor Caving Club. Newsletter No. 44; Cabin — Original mine plan of 1799; Nadolig — Hunter, P., North Wales Caving Club; O.H.F. — Northern Pennine Club. 1979 Journal.

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The Palaeoenvironments of Coolarken Pollnagollum (Pollnagollum of the Boats) Cave, County Fermanagh, Northern Ireland: Evidence from Phytolith Analysis

P. THOMPSON and B.K. MALONEY

Abstract: Phytolith analysis is developing rapidly in the U.S. but is a very new technique for Britain. Phytoliths will preserve where pollen will not and this paper presents the first results from a cave environment in the British Isles. It is based only on the grasses but a large number of other plants also produce phytoliths.

INTRODUCTION

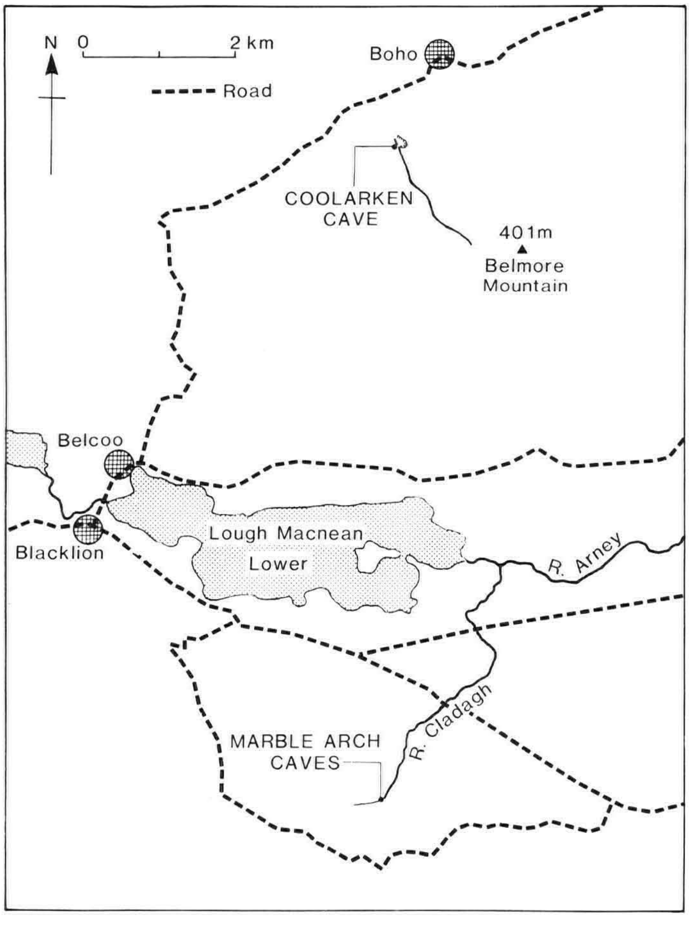
Coolarken Pollnagollum Cave is situated near Boho in County Fermanagh, N. Ireland (Fig. 1). This is not to be confused with the Pollnagollum of Co. Clare. The only palaeoecological research carried out in the general area (on pollen) is on samples from the Skreen Hill region some distance from the site and in a different cave system (Jones and McKeever, 1987). Unfortunately like the data presented here they are undated but assumed to be of Holocene age. Human skulls were recovered during an Ulster Museum archaeological excavation at Pollnagollum in 1972 and have been radiocarbon dated at c. 4500 B.P. but this does not help in placing the palaeoecological record in a time perspective.

The main feature of Pollnagollum of the Boats (Fig. 2) is a massive boulder choke (a wall of boulders which has fallen from the roof and which completely fills the end wall of the cave). This lies directly under a large sub-surface depression : an apparent solution doline. Normally the river sinks near the cave entrance and the lower sections of the cave remain dry. However during floods water fills the floor of the cave and disappears through two holes in the choke. The cave was flooded at least six times from May to September 1989 when fieldwork took place.

PHYTOLITHS

All the pollen spectra from the Skreen Hills contained grass pollen but as is common this could not be identified below the family level. Thus it was decided here to investigate the grasses further using a very different technique, that of phytolith analysis, to see if palaeoenvironmental data could be derived employing them.

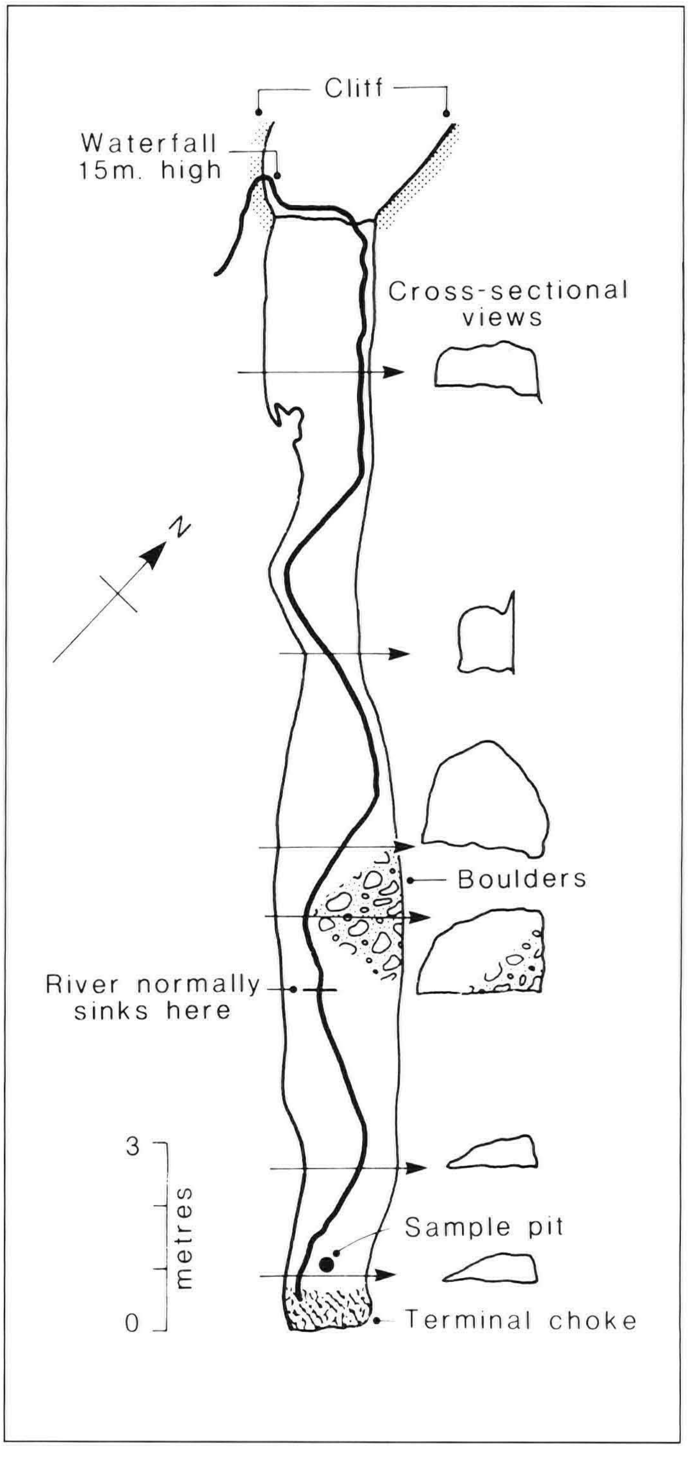
Figure 1. Location of the site.



Phytoliths consist of microscopic particles of opaline silica or calcium oxalate which adopt the morphology of the plant cells in which they accumulate. They are produced by a wide range of flowering plants and by some pteridophytes (Piperno, 1988). Modern calcium oxalate phytoliths have been less well studied than those consisting of opaline silica so this pioneer research has been confined to the latter.

It is possible that the type which we choose to call Chloridoid could derives from *Phragmites australis* (Ollendorf *et al.* 1988) or a sedge but only a few studies of modern sedge phytoliths have been made so

Figure 2. Coolarken Pollnagollum Cave in section.



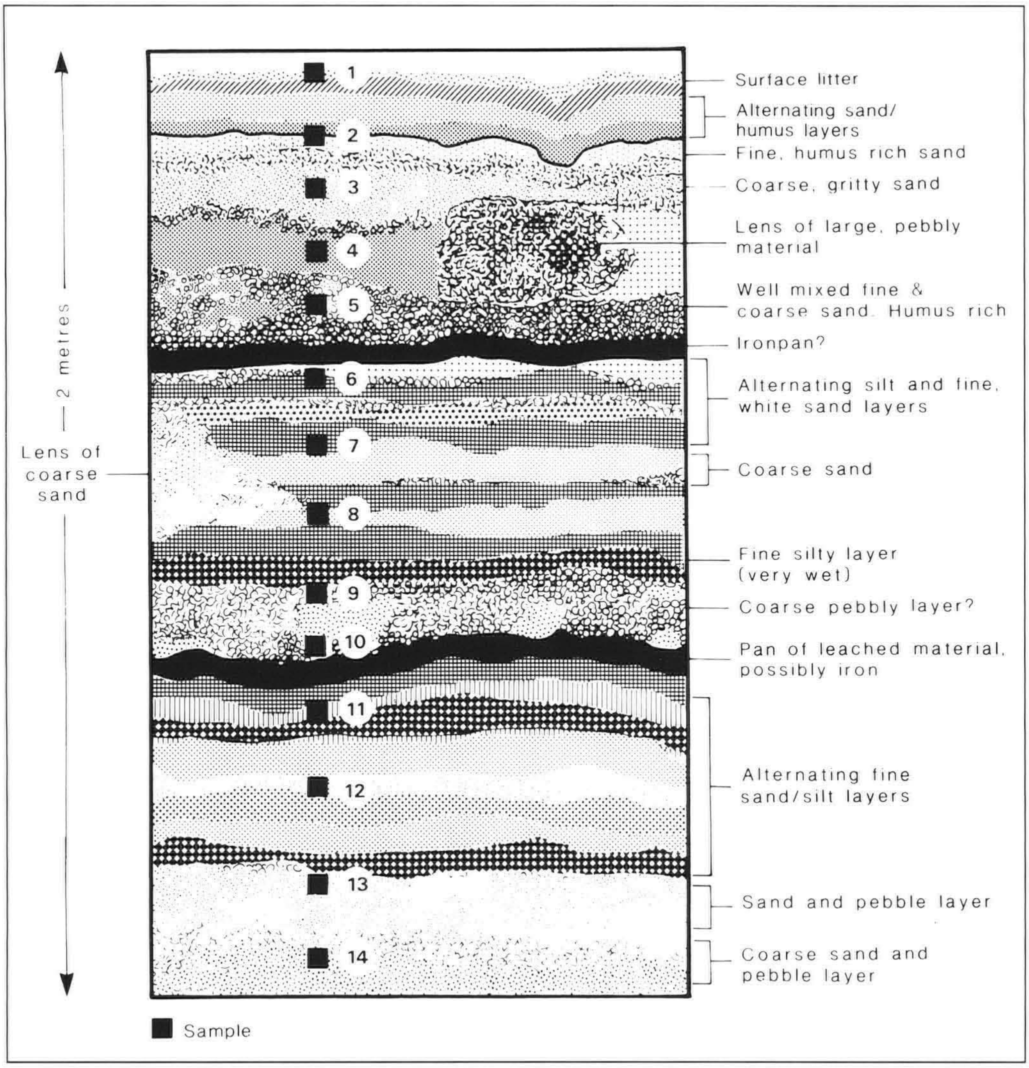


Figure 3. Plan of the cave sampled for phytolith analysis showing route taken in exploration (heavy black line).

far. Data from these is summarised in Ollendorf (1992). The only grass in the Chloridoid sub-family present in the British Isles is *Spartina townsendii*, a recent introduction, and the phytoliths are extremely unlikely to be from this.

There are very few published phytolith analyses from the British Isles yet (Maloney, 1985 ; Powers, 1988) and the one presented here seems to be the first from an area of calcareous rock and from a cave system. It is generally accepted that pollen preservation is not good under calcareous conditions and dissolution of phytoliths must also be considered as a possibility. Samples from caves other than Coolarken Pollnagollum had indistinctive corroded phytoliths or none at all.

COLLECTION, PREPARATION AND COUNTING OF SAMPLES

The samples were collected from a 2 m. deep pit dug into the floor of the cave. Testing using a metal probe indicated that this was where the sediment accumulation was greatest. An impenetrable bed of coarse sand and gravel (Fig. 3) cemented together by calcite formed the base of the section. Fourteen samples were taken for phytolith analysis from a vertical cleaned face of the pit. In each case c. 4 g. of sediment was chemically pre-treated by dissolution of the calcium carbonate in HCl, deflocculation of the clays using Calgon and destruction of the organic matter using a 20 % solution of hydrogen peroxide. The samples were centrifuged at 3000 r.p.m. and washed several times in deionised water to neutralise the acids in between preparation stages. The supernatant liquids were decanted away. Only material smaller than 63 microns was considered for analysis and silicone fluid was used as the mounting medium. Two hundred phytoliths per slide were counted and identified using the categories adopted by Twiss *et al.* (1969). The number of traverses used ranged from 2-5. No attempt has been made to establish the concentration of phytoliths in the samples. The percentages (Fig. 4) are based on the total number of microfossils counted. Twenty four phytolith types were distinguished.

RESULTS AND DISCUSSION

It is likely that the phytoliths were transported to the depositional site by water and that the main source of the phytoliths was either grasses growing in the doline or on Belmore Mountain to its south. Approximately 90 % of Irish grasses are in the Festucoid sub-family (Farragher, 1973) and the identification of phytoliths from these even to the genus lies a long way off. So the dominance of the samples by Festucoid phytoliths is neither surprising nor informative. What is interesting is the consistently high percentage of phytoliths from Panicoid grasses. The most likely sources of these are *Phragmites australis*, which grows in doline areas, and the three common moorland grasses : *Molinia caerulea, Nardus stricta* and *Sieglingia decumbens*. If the phytoliths are largely from Phragmites and the moorland grasses they are of relatively local origin. Regardless of the actual source, the phytolith record bids us beware of conclusions inferred from the grass pollen curve at Marble Arch. Grasses and sedges are a natural element of the flora of limestone areas and percentage expansion in the pollen record may be due to changes in the transport of microfossils to the depositional site, an artifact of the percentage method or due to forest clearance by man. They are not necessarily due to forest clearance as Jones and McKeever (1987) suggest.

It is notable that where the Panicoid phytolith percentages decrease those of the Festucoids generally increase. This could suggest that minor variations were occurring in the environment outside the caves but this also might simply be an artifact of the percentage method. If the environment did alter it may have been towards slightly drier conditions but not all the Irish Festucoid grasses are found under drier conditions than the Panicoid ones.

The elongate type is uninformative as it can be produced by any of the grass sub-families.

Stratigraphically adjacent samples were compared using Chi-squared to test the null hypothesis that there was no significant difference between them other than those resulting from random sampling variations, i.e. that they came from the same statistical population. The degree of significance used was the 95% confidence level. The null hypothesis was rejected for all except samples 1-2, 5-6, 7-8 and 12-13. The alternative hypothesis that there was a significant difference between the two adjacent samples and that they came from two different populations was therefore a possibility but could not be proven using Chi-squared which is simply a method of hypothesis testing.

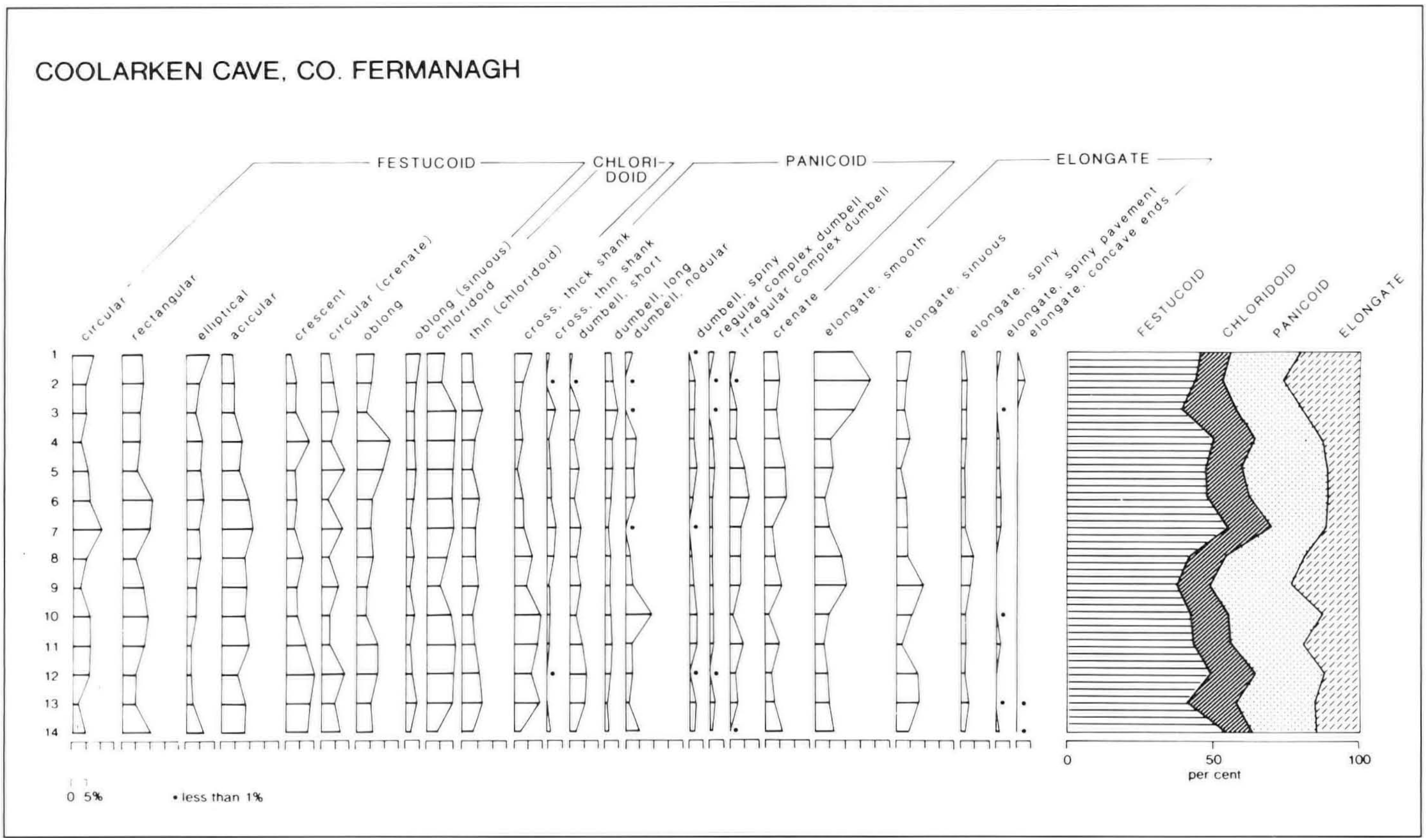


Figure 4. Percentage frequencies of phytoliths. The units sampled are numbered 1-14.

Interpretation of these changes is by no means easy, partly because nothing is known about variations in the sedimentation rate within the cave over time or if gaps in deposition occur. However, an associated study of the quartz grains using scanning electron microscopy indicated that no radical changes in the hydrology took place since the collapse of the cave roof. Unfortunately chemical activity inside the cave has modified the quartz grains overwriting the mechanical imprints resulting from fluvial processes.

CONCLUSION

This study draws attention to a technique which, in the general absence of pollen preservation, may with S.E.M. analysis of quartz grains give information on the palaeoenvironments of cave systems and could be of use in provenancing sediments. Unfortunately in this instance the samples are from undated contexts but it is difficult to conceive that they could be of pre-Holocene age and the tentative conclusion that very little environmental change has occurred over the time period of deposition is partly substantiated by the S.E.M. analysis of the quartz. Phytolith analysis is in its infancy in western Europe but has the advantage over many other forms of microfossil analysis that the forms which occur are few in number and, unlike with pollen, automated counting using image analysis techniques is a future possibility (Rovner and Russ, 1992). Providing that sedimentation is rapid enough there is no reason why phytoliths should not survive in cave sediments especially where other non-calcareous inclusions occur. Indeed they are much more likely to survive than pollen but very often they may be corroded as with the rectangular phytolith shown on Fig. 5. This is actually from Black Bog in the Mournes and shows corrosion resulting from acidic rather than alkaline conditions.

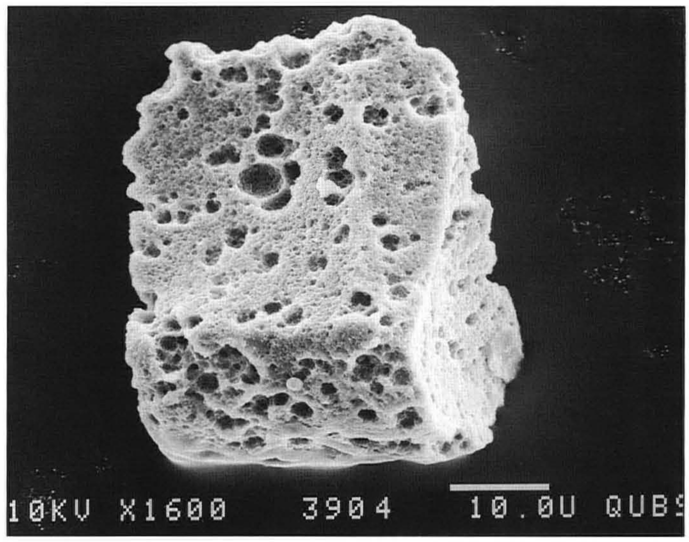


Figure 5. S.E.M. of a rectangular phytolith showing corrosive pitting.

ACKNOWLEDGEMENTS

We wish to thank Prof. W.B. Whalley for assistance with the S.E.M. work, the staff of the S.E.M. unit and the Biogeography Laboratory at Queen's, Richard Watson, the warden of the Marble Arch caves, for his valuable advice and supply of equipment and Joanne McVicker of the Palaeoecology Centre at Queen's for the use of Fig. 5.

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The Bristol Speleological Research Society 1912-1914

Trevor R. SHAW

Abstract: The BSRS contained 12 or more members, some of them students at the University, with the geology professor, S. H. Reynolds, as President. In their short life they re-opened Lamb Leer, started evaporation tests there and in Eastwater, cleared out Plumley's Hole to a depth of about 12 m, and started the important Palaeolithic excavations in Aveline's Hole. The problem of retrieving the Aveline's specimens after the war is described.

INTRODUCTION

The Bristol Speleological Research Society (BSRS), whose short life was curtailed by the First World War, was the second British group to devote itself exclusively to cave study. The Yorkshire Ramblers' Club, founded in 1892, was mainly concerned with climbing, and caving was not among its original objectives although members made and published many original explorations. The Yorkshire Speleological Association (1906-1914) did concentrate on cave exploration and had surveyed 8 km before its demise. The Mendip Nature Research Committee (MNRC), formed in 1906 as the Mendip Nature Research Club, of the Wells Archaeological and Natural History Society, was interested in caves among many other subjects.

The BSRS did not publish a journal and, if they kept records, these have not survived. The sources of this paper, therefore, are a few letters in the Wills family archive at Langford Court, the published comments of contemporaries, and the later reminiscences of the BSRS Secretary and of people who knew its members after 1918.

As its name suggests, the Society was interested mainly in research (archaeological and otherwise) but it was also responsible for reopening the entrance of Lamb Leer and for digging to about 12 m in Plumley's Hole. The war interrupted its activities in 1914 and when its members came together again afterwards they formed the University of Bristol Speleological Society (UBSS, spelled thus in its early years). The importance of the first society lies not only it its relatively early date but in the influence it had on the subsequent UBSS and, especially, the important excavation of Palaeolithic human remains it started in Aveline's Hole.

Bristol Speleological Research Society

HON. PRESIDENT: Prof. S. H. REYNOLDS, M.A., F.G.S.

OFFICIAL ADDRESS: *12 Cannon Street, Bedminster,*

Fig. 1. The letterhead of the BSRS, printed in green. By courtesy of Sir John Wills.

It will be seen from Figs. 1 and 5 that the word Speleological in the Society's title is spelled without the æ diphthong usually quoted. It probably followed the Yorkshire Speleological Association in this, or adopted the equivalent of the French usage. Palmer (1958a) used 'Spelaeological' in his reminiscences of the BSRS written some 45 years later, and that spelling was followed in the fiftieth anniversary history of the UBSS (Shaw, 1969) and elsewhere. Palmer may well have been influenced by the present UBSS usage which he would have absorbed for most of those years. In fact the UBSS itself did not adopt the diphthong until 1921 when it first appeared in print in the Guild of Undergraduates' magazine *The Nonesuch* for March (Grigg 1921). The revised spelling was perhaps intended a few months earlier, for it had appeared as the Spaeleological Society in the previous issue (Griggs, 1920).

FORMATION OF THE SOCIETY

The four schoolboys who were later to form the BSRS did their first caving together in 1908 when they explored the disused mines at Dundry (Palmer, 1958a). These four were Lionel S. Palmer ('Leo'), then aged about 17, Edward K. Perdue, aged 15, Reginald F. Read and Reginald E. Essery. It was not until four years later that circumstances brought them together again. They, with several others, formed the BSRS in the early spring of 1912. The President was Prof. Sidney Hugh Reynolds, then professor of geology; the first Secretary was Leo Palmer, then an undergraduate. Palmer became one of the first vice-presidents of the BSRS but it is not known who the others were. The names of all the members who have been identified (thirteen including the President) are listed later. Although several of them were at the University it was not a University society.

It is not known whether the objectives of the new Society were ever formally agreed. In any case, they have not survived. Their scope, however, is made clear in Palmer's (1958a) reminiscences:

> The Society started work with four somewhat ambitious projects. One was to make a wooden-rung rope ladder with which to explore Lamb Lair Cavern. The second objective was to measure the rate of evaporation of the water in this cavern and also in Eastwater Swallet; the third to commence excavating "The Cave" now known as Aveline's Hole, and the fourth was to open up Plumley's Den, later known as Plumley's Hole — a vertical shaft situated in the north-east corner of the quarry at the bottom of Burrington Combe.

Balch (1914a) refers thus to the Society's creation in the MNRC Report for 1913:

> In Bristol a Society has been formed to work along our lines, and it is probable that the northern part of Mendip will receive much more attention from them than we are able to give to it. They will specially devote attention to Burrington Combe, where there is much to be done. They will work upon the problems of evaporation and precipitation, which offer a profitable field for enquiry, as well as the larger matters of exploration.

THE AVELINE'S HOLE EXCAVATION

Aveline's Hole (NGR 47615867) was first opened in 1797 and several human skeletons were seen there then (Anon., 1797). In the 19th century excavations were made by Buckland, Beard, Williams and Boyd Dawkins.

The BSRS excavations were started, under University guidance, with the intention of making a more thorough investigation. Indeed the work started by them and interrupted by the war continued until 1931, with great success. The importance of the excavation and its results have been covered thoroughly in the archaeological literature and are not re-examined here. The intention in this paper is to describe the part that was played by the BSRS, and the unexpected difficulties experienced in recovering the specimens in 1919.

Work may possibly have started as early as 1912, as remembered by Palmer (1958a), but probably not until 1914 when the specimens were found (Palmer, 1919b; Davies, 1922). The 1914 date is further supported by the fact that the Secretary's report written in 1914 (see Appendix II) refers to excavation 'in accordance with the permit recently issued to Mr Palmer'. Several human skulls were obtained, together with other human bones, flint tools and animal bones. The skulls were described by Fawcett (1919), and Davies (1922) included a short account of the 1914 excavations in his report on the post-war continuation.

The work done by the BSRS included the removal of stalagmite and earth from the floor of the Inner Chamber and in the lower part of the Outer Chamber. The results were never published in detail and the position of some of the finds have been lost. However Palmer (1919b) copied part the unpublished records, subsequently lost, and these notes include the positions in which the skulls were found, 23 m from the mouth of the cave embedded in a calcite floor 9 cm below the surface. A rough sketch map in Palmer's 1919 notes, reproduced here as Fig. 2, shows the area of the excavation immediately on the entrance side of the squeeze between the Outer and Inner Chambers. As Palmer's notes have never been published, they are printed here as Appendix I. Another list of remains, with less detail, was compiled in the late summer or autumn of 1914 and included in a report sent to Mr G. A. Wills (afterwards Sir George Wills, the 1st Baronet). This too is unpublished and so is printed as Appendix II.

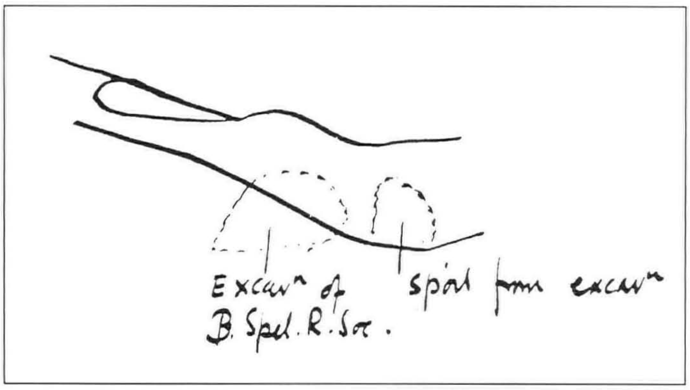

Fig. 2. Site of the 1914 BSRS excavations at the back of the Outer Chamber, Aveline's Hole, drawn by L. S. Palmer in 1919. Used in conjunction with the published plans of the Outer Chamber, this shows clearly where the digging took place.

The report containing this second list goes on to record the beginning of the strange custody story of the remains during the 1914-1918 war. One of the first actions of the new Society in 1919 was to retrieve the 1914 specimens from the BSRS temporary secretary. He was apparently unwilling to relinquish them. Tratman (pers. comm. 20 May 1970) wrote 'I have an idea that Barker was the bloke they had all the trouble with over the Aveline's skulls'. This is borne out by correspondence with the Wills family, now held in their archives at Langford Court.

George Edgar Barker is listed in *Wright's Bristol Directory* from 1906 to 1919 as a cycle dealer at four successive addresses in Bedminster. He was never a member of the University and it appears from what follows that relations became strained between him and most of the other BSRS members.

The 1914 report to Mr Wills already mentioned is signed 'A.G. Edwards. Hon. Sec. and R.E. Essery. B.Sc. . . . For Mr. Palmer B.Sc. and the working members of the Society'. It is undated but written in the later part of 1914, after excavation was finished and Essery had been awarded his BSc, and before about the middle of November. Before reading the extract below it should be remembered that in 1914 the word 'socialist' was still to some as emotive as 'communist' or 'marxist' became to many later. London's 'anarchists' had featured in Conrad's *The Secret Agent,* published only seven years before.

> Professor Fawcett of Bristol University took the first skull to Dr. [Arthur] Keith, of the Royal College of Surgeons. He pronounced it to be Palaeolithic, and requested Professor Fawcett to read a paper on it before the Anthropological Institute. At the same time Dr Andrews of South Kensington [British Museum (Natural History)] pronounced the animal remains as those of an entirely new species.
>
> As a result Professor Fawcett requested to become a member. A member who has obtained a prominent position in the Society, announced his intention of opposing his membership, and threatened to whip up non-working members to support him. This member, who unfortunately has possession of all the remains, is a Socialist of the most pronounced type, and in our judgement, opposed Dr. Fawcett purely on Class Prejudice. Every working member has intimated to me, the Secretary, his intention of resigning from the Society, and I of course, shall do the same. When this happens the remains will thus remain in the possession of this member, and will therefore be lost to Science, as Dr Fawcett will thus be unable to read his paper.

We therefore urge the Lord of the Manor to exercise his right to remove these remains from the member referred to.

Mr. H. W. Seccombe Wills (a cousin of George Wills) must have written to Barker, for on 25 November he wrote to him again referring to 'my recent conversation with you and Mr Rennolds' and asking 'how the relationships of your Society now stand'. Barker's reply, signed as 'Sec.pro.tem.' the following day, says that he has been unsuccessful in getting a reply from 'Mr Edwards [the elected Secretary who] is away with the troops . . . re jaw bone'. He goes on, 'In the mean time we are making every effort to repair the damage in society & will immediately let you know any results'. He also invites Mr Wills to join in a visit to 'Lambs Lair'.

Nearly two years later Seccombe Wills was writing to Moses Rennolds on 19 September 1916:

> Will you kindly let me know if anything is being done now in the matter of the "Finds" at Burrington Coombe, and also where the relics are being stored, and if anything has been done in regard to removing the same to the Museum?

Next in the file, though undated, is the following formal statement by Barker and Rennolds:

> We the undersigned hereby acknowledge the possession of a quantity of remains, human & otherwise, discovered by members of Bristol Speleological Research Society at the cave known as Avelines Hole, Burrington Combe now in the possession of Geo E Barker of 12 Cannon St Bedminster & agree to maintain its safe custody.
>
> Geo E. Barker
> 12 Cannon St
>
> Moses H Rennolds
> 123 East St

Barker and Rennolds were perhaps the natural people to keep the specimens safe, as they were not called up for military service like the others. The real trouble began when the new UBSS, taking the place of its predecessor, sought to regain them. Palmer (1958a) recalls that, after consultation with Prof. S. H. Reynolds (who had been President of the BSRS) and Prof. Edward Fawcett (soon to become the first President of the UBSS), it was decided as a first step to recover all the remains that had been excavated previously. After several vain attempts to get these removed to the University, appeal again had to be made to the legal owner, Mr George Wills. Prof. Fawcett, Mr Seccombe Wills and L. S. Palmer called on the custodian who then brought up the bones from a well in his back garden where they had been hidden. The garden, and the well, have since been built over. Herbert Taylor, an early UBSS member, writes (pers. comm. 16.5.1968) 'I gather that he was unwilling to hand them over and some compulsion was used!' The skulls were available in time to be exhibited at one of the very first meetings of the UBSS, on either 11 or 19 March 1919.

PLUMLEY'S HOLE

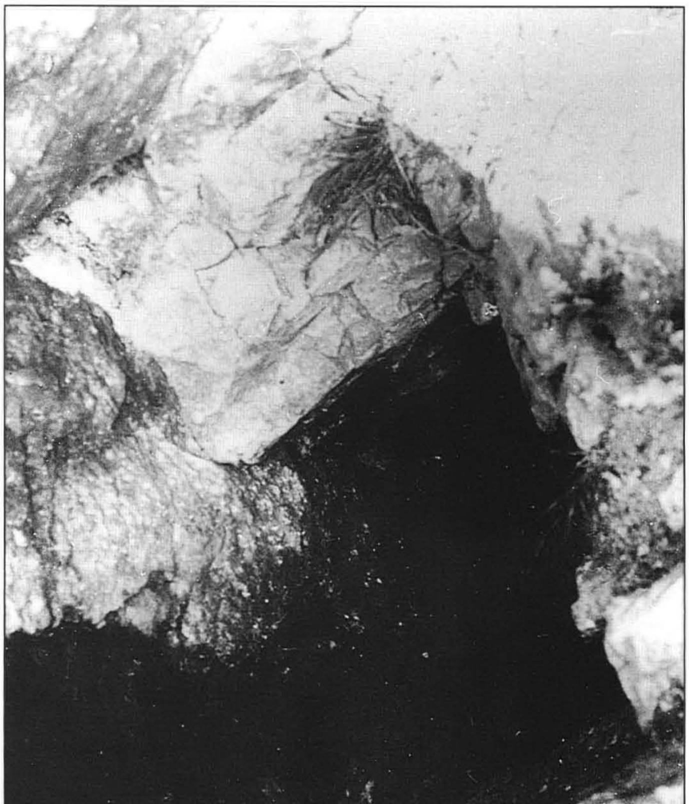

Fig. 3. Looking down the then open entrance of Plumley's Hole the year before the BSRS started work; a photograph taken by J. H. Savory on 6 June 1911. Diameter about one metre. By courtesy of the Trustees and Managers of Wells Museum.

Plumley's Hole (NGR 47665875) had been opened in the course of quarrying and Joe Plumley had died in attempting to explore it on 5 January 1875 (Anon.,1875), not 1874 as commonly stated.

Fig. 4. Coral Cave, showing Jack Brownsey above and George Barker below. Photographed by J. H. Savory, probably in 1914. Courtesy of Dr. John Savory.

After that it was a convenient place for dumping rubbish and became less and less deep. The view looking down on Whit Tuesday 1911 (Fig. 3) gives no indication of the depth then and it is not known to what depth it had become filled.

The BSRS attempt to unblock Plumley's Hole was continued from 1912 to 1914 (Palmer, 1958a,b). A bucket cable-way was erected and many tonnes of stones were removed together with a large tree trunk and some recent horse bones, in spite of considerable danger from stones falling from the bucket on to the heads of the two workers below. By the time the war stopped work the depth reached was about 12 m. At 9 m or so the steeply sloping face ended in a small ledge (Tratman, 1954), perhaps the one under which Plumley had become trapped in 1875. Apart from a little clearing in 1919 and 1920, the UBSS did not continue the work. In 1924 the top was covered by a manhole cover and a thin coating of cement.

The cave was temporarily reopened in 1946 by R. A. Bendall and R. D. Stride; their entry in the UBSS Log for 18th August reads:

> . . . put charge in Plumleys & opened up cave. Perfect. Went down 32 ft [10m drop]. Slope of 50° at bottom, big choke of rubble. Put charge in hole after digging 4 ft. No visible effect — Concreted up & left.

LAMB LEER

The descent of Lamb Leer (NGR 54325505) necessitated the making of a rope ladder (Palmer, 1958a,b) and it was perhaps for this reason that it did not take place until August 1913. Although rope ladders had been used on the continent for many years and also in Yorkshire, this appears to have been the first instance of their use in Mendip; Balch's work had previously been done on single ropes. The exploration was by no means an easy one, for the timbering of the 1880 entrance shaft had collapsed and its clearance was effected in conjunction with the MNRC (Balch, 1914b).

Opportunity was taken in August to install the new BSRS apparatus for measuring the rate of evaporation in the cave. Two calibrated glass jars were placed in a zinc tray at the north side of the Main Chamber, with a cover above to shelter them from drip (Savory 1989, p.98). The cover was dated 16 August 1913 (Palmer, 1958a). By 1934 no evaporation loss had taken place (Balch, 1935), indicating a relative humidity of 100%, consistent with Trombe's (1952, pp.259-260) statement that cave humidity is usually between 95% and 100%.

One of the covers, almost destroyed by trampling, was recognized for what it was and removed from the cave in the spring of 1958 by P. A. E. Stewart. It was presented to Professor Palmer (H. W. W. Ashworth, pers.comm. 5 June 1968) but it is not known whether it has survived.

EASTWATER

Similar evaporation tanks or jars were installed in Eastwater (NGR 53875062) on 26 December 1913 by a combined BSRS/ MNRC party (Balch, 1914b; Palmer, 1958a,b). One was in the First Rift Chamber, beyond the Canyon, and the other at the bottom of the Boulder Chamber. The original calibrations for the Eastwater tanks were in Palmer's possession in 1958, together with a letter from him to Balch dated 8 January 1914 giving instructions how to read the tank gauges (Palmer, 1958a,b); their present whereabouts is unknown.

The lower parts of the cave were visited on the same day, for the first time for five years. Ladders 'were used for the first time [for this cave], and one is bound to say that they introduce a degree of comfort in the descent and return, quite absent from the strenuous rope work of other days. Yet the fatigue of transport is great'. Fortunately 'a monstrous Christmas pudding [had been] smuggled down by one of the Bristol men' (Balch, 1914b). It was on this occasion that Jack Brownsey of the BSRS forced a squeeze at the bottom of the cave and entered the passage which now bears his name in the vicinity of the Mud Escalator.

The evaporation tanks were examined again in 1922 and, unlike those in Lamb Leer, 'even in that saturated atmosphere evaporation is proceeding' (Balch, 1921).

The apparatus remained in place, though damaged, until 1954, when Frost (1954) explained the significance of the 'jam jars' found there by Wessex Cave Club members. On 21 February Lloyd (1954) reported that 'the crumpled remains . . . were removed, as they were no longer in a condition to be useful.' They were thrown way in the depression nearest to the cowyard at Eastwater Farm (Lloyd, pers.comm. 14 June 1968).

Somewhat similar experiments, using self-recording hygrometers, were started by the British Speleological Association in Lancaster Hole (Easegill Caverns) in 1948 (Simpson 1948, p.204) but did not continue for long.

CORAL CAVE

BSRS members Barker, Brownsey and Perdue visited Coral Cave (NGR 40705524) near Compton Bishop, probably in 1914. There is no written record of this, but they appear in three photographs taken by Harry Savory (1989), one of them reproduced here as Fig. 4.

GOUGH'S CAVE

Seven BSRS members went to Gough's Cave on 28 February 1914. The value of this visit is that their signatures appear in the visitors' book (Fig. 5). It is noticeable here that George Barker was a leading, or assertive, figure for it was he who wrote the 'thank you' comment in the book and signed first.

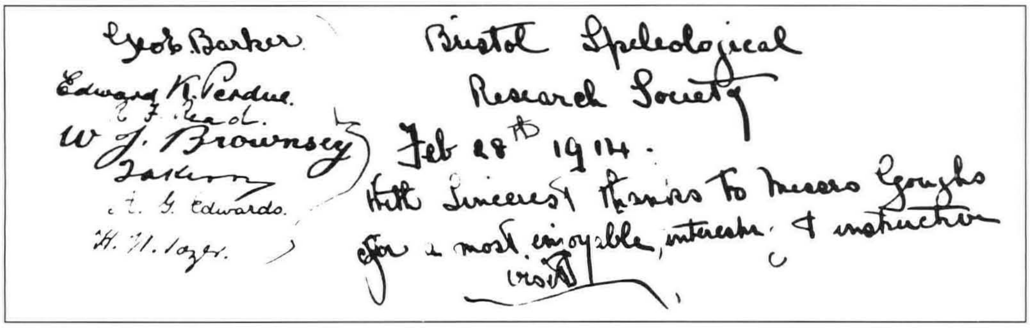

Figure 5. The entry in Gough's Cave visitors' book, showing the BSRS party on 28 February 1914. By courtesy of the late Douglas Gough.

BSRS INFLUENCE ON THE UBSS

When the former members of the BSRS returned from war service they planned to continue with the Aveline's Hole excavations. In view of the obvious importance of their previous finds, George Wills as owner of the cave decided that further work should be continued only by a society formed under the auspices of the University. Only one of the BSRS members (L. S. Palmer, who was working for his PhD by then) was at the University at this time and he took the necessary steps to form such a society.

Before the new Society was formally founded, a preliminary meeting of staff and students of the University was held on Tuesday 11 March. Prof. Fawcett presided and 'A brief but interesting account of former explorations of these caves was given by Mr. Palmer, a member of the old Society, who also outlined a scheme for future operations' (Anon., 1919). A further meeting, to elect officers and formally to inaugurate the Society as the University of Bristol Speleological Society, was arranged to take place the following week, on March 19. Prof. Fawcett was elected President and L. S. Palmer, Secretary; George Wills was made Honorary President (Palmer, 1919a). It was agreed that former members of the BSRS would be eligible for membership, whether or not they were at the University. Among those who took advantage of this were J. Brownsey, G. Crandon, H. Peet, E. K. Perdue and R. F. Read. Read became a founder member of the committee and, together with Palmer, was the driving force behind the creation of the UBSS.

At the March 19 meeting Palmer outlined the initial work that he thought should be undertaken. Naturally, with the Aveline's pre-war material on exhibition, further excavation at that cave became the foremost objective of the new Society (Palmer, 1958b).

Thus, the earlier Society must have had a profound influence on its successor, largely as a result of continuity, both of objective and membership. It also inherited Balch's allocation of the Burrington area as its supposed sphere of influence.

MEMBERSHIP OF THE SOCIETY

Known members of the BSRS are listed here, with the authority for their inclusion:

Barker, G. E.: Wills correspondence; Fig. 5; Balch, 1914b; Balch, 1915; Savory, 1989.
Brownsey, W. J.: Fig. 5; Balch, 1914b; Palmer, 1958a.
Crownsey, G.: Palmer, 1958a.
Edwards, A. G.: Wills correspondence; Fig. 5; Tratman (pers.comm. 24 Oct. 1968).
Essery, R. E.: Wills correpondence; Palmer, 1958a.
Kerry, J. A. [?]: Fig. 5.
Palmer, L. S.: Wills correspondence; Davies, 1922; Palmer 1958a,b.
Peet, H.: Palmer, 1958a; Tratman (pers.comm. 20 May 1970).
Perdue, E. K.: Fig. 5; Palmer, 1958a; Tratman (pers.comm. 20 May 1970).
Read, R. F.: Fig. 5; Palmer, 1958a; Taylor (pers.comm. 16 May 1968); Tratman (pers.comm. 20 May 1970).
Rennolds, M. H.: Wills correspondence.
Reynolds, S. H.: Palmer, 1958b.
Tozer, H. W.: Fig. 5.

Possible members are:

Coysh, R. H.: Taylor (pers.comm. 16 May 1968); disputed by Tratman (pers.comm. 20 May 1970).
Grigg, H. C.: Taylor (pers.comm. 16 May 1968); disputed by Tratman (pers.comm. 20 May 1970).

Brief biographical information follows, where it is known, together with note of any continuing interest in caves after 1918:

Barker, George Edgar. Cycle dealer of Bedminster 1906-1919. Lived at 78 South St. in 1912, at 16 Cannon St. in 1913 and 1914, and at 12 Cannon St. from 1915 on. BSRS 'Sec. pro.tem.' from late 1914. See also the section on Aveline's Hole above.
Brownsey, W. J. ('Jack') forced the squeeze into Brownsey's Passage, Eastwater, in 1913. Balch (1937, p.65) described him as 'a very small man'. He afterwards became a UBSS member.
Edwards, A. G. BSRS Secretary in 1914; became a UBSS member.
Essery, Reginald Ernest. BSc 1914; UBSS committee 1919-1920.
Palmer, Lionel Stanley ('Leo'). b.1891; d. 17 March 1962. BSc 1913, PhD 1921, DSc 1933. First Secretary of BSRS and of UBSS; subsequently vice-president of each.
Peet, Harry. Became a UBSS member in the early 1920s. Said to have inspired the UBSS unofficial motto 'Go straight on', when his bicycle took him into a manure heap on the way home from Burrington.
Perdue, Edward Keedwell. b.27 Jan. 1893; d. 27 Feb. 1973. BSc 1922. Became a UBSS member, then a schoolteacher. At the time of his death he believed he was the oldest BSRS member.
Read, Reginald F. d. 7 Jan. 1967. An engineering student, though never at the University. He was a UBSS committee member from 1919 to 1926. His name is commemorated in Read's Cavern and Read's Grotto. He emigrated to USA where he died.
Rennolds, Moses Henry. Ironmonger of Bedminster 1896-1939. Lived at 123 East St., Bedminster, from 1896 until the 1920s or later.
Reynolds, Sidney Hugh. b. 1867; d. 20 Aug. 1949. MA, ScD., Professor of Geology, University of Bristol 1910-1933. Vice President of UBSS 1921-1937.

Fig. 6. R. F. Read at Symonds Yat in 1929 or 1932. Photograph by H. Taylor.

The following portraits are known:

Barker: Fig. 4; Baker 1932, opp.p.24; MNRC 1965, opp.p.10; Savory 1989, pp.25,95,97; Witcombe 1992, p.67.
Brownsey, Fig. 4; Savory 1989, pp.25,28,112.
Palmer. Fig.7.
Perdue: Savory 1989, pp.25,28.
Read, Fig. 6; Baker 1932, opp.p.24; MNRC 1965, opp.p.10; Savory 1989, pp.95,97; Witcombe 1992, p.67.

Brownsey, Edwards, Peet and Read are said to be present in the photograph published in Davies (1975,p.18) and Savory (1989, p.115) but the identifications are conflicting and uncertain.

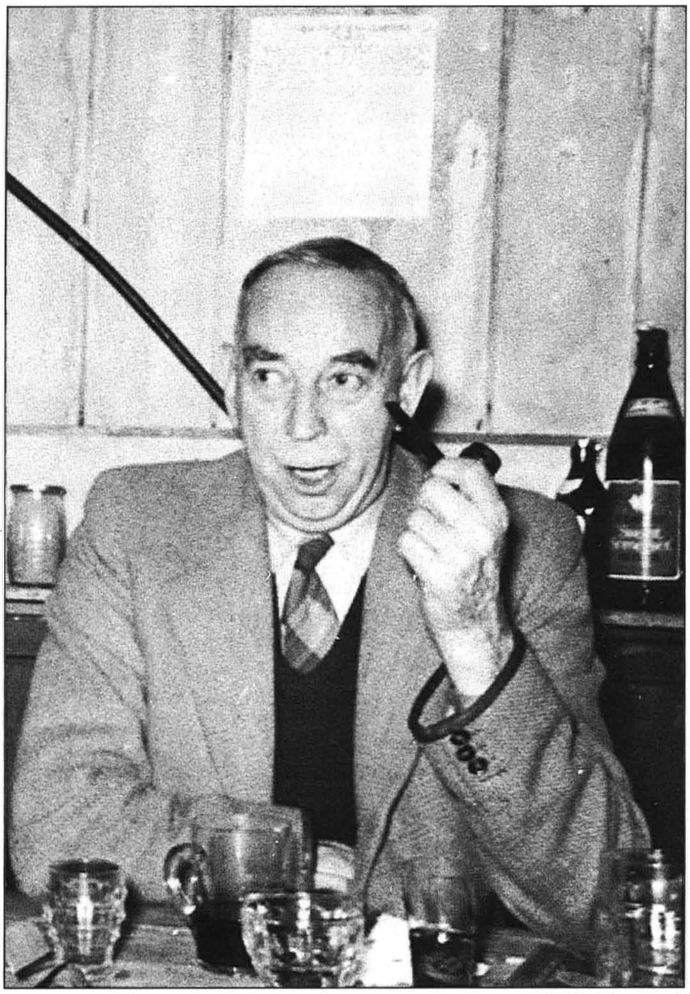

Fig. 7. 'Leo' Palmer at the UBSS New Year party at Burrington, 1956/57. Photograph by G. D. Witts.

Members recorded as visiting individual caves were:
Aveline's Hole: Barker, Palmer
Coral Cave: Barker, Brownsey, Perdue.
Eastwater: Browsey.
Gough's Cave: Barker, Brownsey, Edwards, Kerry[?], Perdue, Read.
Lamb Leer: Barker, Read.

ACKNOWLEDGEMENTS

I am grateful to Sir John Wills for permission to search through and quote from the BSRS correspondence in the family archives. Many early members of the UBSS who knew former BSRS members in the 1920s replied to my enquiries when preparing the UBSS anniversary history in 1968. Dr. Tratman also provided a copy of Palmer's 1919 manuscript report and the print from which Fig. 6 has been prepared. Alan Dougherty drew my attention to the evidence for the true date of Plumley's death. The Gough's Cave visitor's book entry was shown to me by the late Douglas Gough, with permission to reproduce it. Wells Museum has allowed me to use the Savory photograph in Fig.3, and Dr. John Savory provided the copy prints for Figs. 3 and 4. All other photographs have been prepared for publication by Chris Howes, FRPS.

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APPENDIX I

Notes on skull found in Aveline's by the Bristol Spelaeological Research Society. Copied by LSP.

Found 75' from mouth of cave imbedded in tufa floor, 3½" below surface and 4½" below base of skull.
'Cave Earth' mixed up w[ith the] calcite surrounding skull.
POSITION back of skull resting against a stalagmite boss, the orbits facing, roof.
Humerus 4' 10" vertically below & 12" nearer datum
Second skull 12" to of o skull on centres. Skull facing cave mouth.
The tufa was softer below skull possibly by atmospheric action on the upper, the tufa having formed since skull placed against stalag. boss.
Skull originally found complete but damaged by removal.
Beneath the skulls, besides the humerus were a no: of rounded stones resting against the face of the rock.
The skull was ¼-⅓ capacity filled w[ith] calcite & cave earth.

Animal Remains
A tooth of Giant Deer embedded in cave earth 12" below calcite floor & 5' to right of skull on looking down cave. A jaw of Giant Deer* with a flint lying underneath it the edge resting on the scar on the jaw.
The fracture not done during excavation. The retouched edge lay against jaw.
Animal remains found in 1914 (no record kept)
1) **Wild-cat** Upper jaw encrusted in stalag. (Accord[ng] to D[rs] Andrew and S. Woodward, an exceedingly large individual, larger than existing wild cat and most Pleistocene specimens.
F. cattus
2) ? **Bos longifrons** horn core embedded in stalag.
3) ? Wapiti frontal bones, antlers tines, occipital bones vertebrae, various limb bones & jaw fragments. Covered with red earth.
*1/ D[r] Andrews (Brit. Mus.) "not the Red Deer or Irish Elk as the remains are larger."
2/ These originally described as "Bos" remains.

APPENDIX II
EXTRACT FROM UNPUBLISHED REPORT WRITTEN IN 1914 BY A.G. EDWARDS & R. E. ESSERY

The Bristol Speleological Research Society have been recently excavating Aveline's Hole in accordance with the permit recently issued to Mr Palmer. We have discovered

1. Human Palaeolithic Skull.
2. Portions of eight skulls very similar to the Neanderthal Spy Race.
3. Human bones not yet identified.
4. Humerus of Cave Woman.
5. Set of upper teeth — Human.
6. Skull of carnivorous animal.
7. Jaw of animal which Dr Andrews states to be of an entirely new species of Irish Elk.
8. Neck and back vertebrae of animal.
9. Pair of Antlers.
10. Ribs of animal.
11. Bird bones.
12. Flints.

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A Cave system in Permian gypsum at Houtsay Quarry, Newbiggin, Cumbria, England

Peter RYDER and Anthony COOPER

Abstract: A newly discovered phreatic cave system is described from Permian gypsum at Houtsay Quarry in the Vale of Eden, Cumbria. This is believed to be the first time gypsum caves have been described from England; the system has now been removed by quarrying. The cave system developed along joint and bedding intersections and chambers up to 6m across were present. Some of the more important gypsum deposits in England are described and evidence is given to suggest that gypsum caves and buried gypsum karst occur elsewhere in the country. They occur within soft, readily eroded sequences of strata and their presence is largely confined to low drift-covered areas.

INTRODUCTION

Gypsum cave systems have been recorded in various parts of the world (Middleton and Waltham, 1986; Cooper, 1986 and references therein; Klimchouk, 1992), but until recently were not recorded in Britain (Figure 1). From the distribution of active subsidence over gypsum deposits, Cooper *(op.cit.)* suggested the existence of a phreatic gypsum cave system beneath Ripon, North Yorkshire, but no direct observations of such caves could be made. Site investigation boreholes, however, did prove the presence of cavities and sedimentary cave deposits including washed-in peat and laminated clay.This current record and survey of gypsum caves at Houtsay Quarry in Cumbria (NY624276) is believed to be the first description of such a system in England.

The cave system at Houtsay, that is described here, was intersected by an active gypsum quarry owned by British Gypsum Limited and excavated by Coal Contractors Limited. The survey was undertaken not only to record the caves, but to show their distribution as an aid to the quarrying and extraction of the gypsum by the contractors.The cave system has now been quarried away and this description stands as the only record of its former presence. In April 1988 three separate sections of cave passage were explored and surveyed; presumably these had all been part of the same system until it was intersected and partly destroyed by quarrying.

GEOLOGICAL SETTING

The gypsum at Houtsay Quarry is the "B" Bed within the Eden Shales of Permian age; this gypsum is the most widespread evaporite in the Eden Shales of the Vale of Eden and varies from 4.9 to 6.6 metres in thickness (Arthurton & Wadge, 1981).The gypsum in the area has been extracted for a many years and as long ago as 1897 was excavated from a quarry about 500 metres to the west-north-west (NY618278) near Acorn Bank (Dakyns *et al.* 1897). Here Dakyns *et al. (op cit)* recorded that the gypsum occurred in massive beds with an uneven top and was between 15 and 20 feet thick.

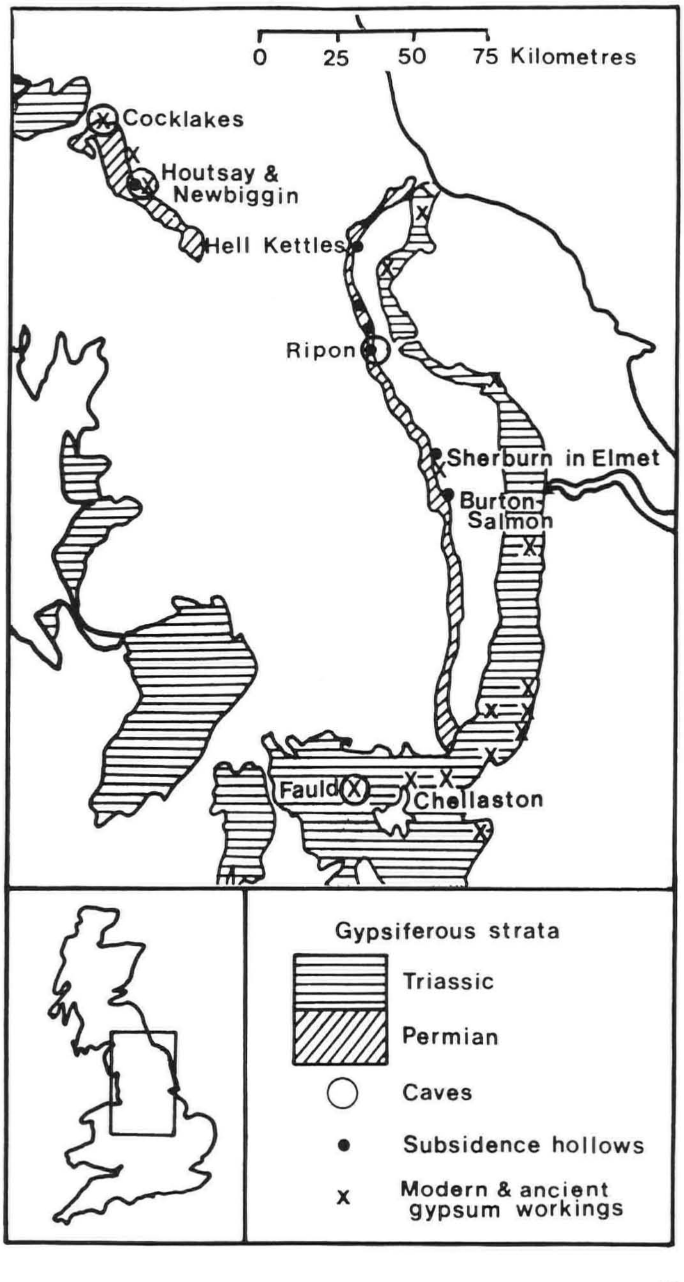
The gypsum ($CaSO_4.2H_2O$) at Houtsay Quarry is secondary (Murray, 1964; Mossop & Shearman, 1973) in origin after anhydrite ($CaSO_4$), though primary sedimentary structures are preserved; these include lamination of a possible algal mat origin and slightly nodular fabrics indicative of displacive growth. Most of the gypsum is now alabastrine though it commonly includes gypsum porphyrotropes.The gypsum sequence dips gently eastwards passing down dip into anhydrite which is mined nearby in an adjacent fault block at Newbiggin Mine (Arthurton and Wadge, 1981).

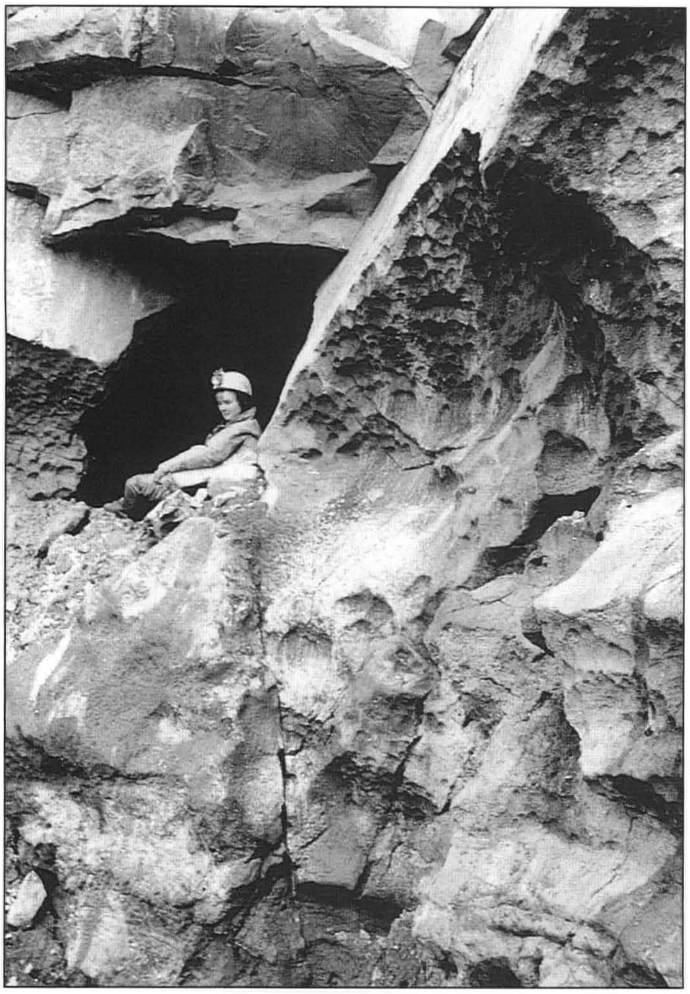
On contact with groundwater that is not saturated with gypsum, gypsum dissolves to produce dissolution features very similar to those produced in limestone karst. Gypsum is, however, much more soluble than limestone and in equivalent conditions dissolves about one hundred times more quickly than limestone (James, *et al.*, 1981).Caves in gypsum are potentially more unstable than those in limestone because they can enlarge at a much greater rate and because gypsum has less strength than limestone.The gypsum occurs in a near surface zone, its distribution dependant on the past local hydrological regime.This was controlled by the proximity of aquifers and faults along with hydrological pathways such as joints by which the water could circulate into the anhydrite.The distribution of the gypsum caves is similarly controlled by the availability of groundwater, its hydrostatic head and its ability to move through the sequence.

Downdip from the outcrop of a gypsum bed there is typically a transition from complete dissolution, through buried gypsum karst with gypsum pinnacles down into gypsum karst with caves, then into massive gypsum and, in turn, massive anhydrite. At Houtsay Quarry the gypsum is sandwiched between mudstones of fairly low permeability.The down-dip extent of the gypsum from the dissolution margin to the anhydrite is locally around 200-400m. It is within this belt that the cave system has developed.

The Permian succession at Houtsay Quarry is overlain by a variable sequence of glacial and later deposits up to 8 metres thick; these comprise till, sand and gravel, and peat. These deposits completely conceal and partly fill in the buried gypsum karst suggesting that some of the features date from pre or en-glacial times.The caves may have partly formed as a sub-glacial phenomenon with increased hydrostatic head. A small amount of active subsidence has occurred in the vicinity, as attested by the collapse cave described below, but this may have been triggered by blasting and the vibration from heavy machinery. Because no major water flows were encountered in the Houtsay caves it is thought that the cave system was not actively expanding like those in the Ripon area of North Yorkshire (Cooper, 1986; 1988; 1989).However, the dryness of the system may have related to de-watering of the sequence for mining of the adjacent area.

Figure 1. The distribution of gypsum-bearing sequences in England showing the location of past and present mines (crosses) caves (open circles) and subsidence hollows (solid dots).





The main entrance to the North Cave, also showing the scalloped surfaces of a cave that has been quarried away.

DESCRIPTION OF THE HOUTSAY CAVE SYSTEM

The North Cave

The caves lay to the east side of the working quarry (Figure 2). The most extensive, the North Cave, had a large entrance 2.7 metres above the quarry floor level (about 83 metres above OD) and opened into a tube-like passage 2 metres in diameter. This lowered into a crawl leading into a chamber 6 metres across with a 4 metre high roof pocket or aven on the right. At the left end of the chamber a low crawl led on northwards into a series of winding passages varying between crawling and stooping height; these ended in an elongate chamber developed on the sloping bedding with faint daylight entering from a choked hole (easily cleared to provide a second entrance) communicating with the quarry face. The chamber ended in a rift completely choked by loose fill. The total length of the passage in the North Cave was around 100 metres.

The cave consisted of a single main passage following an overall south-east to north-west line, although frequent changes of size and direction following the joint pattern in the rock gave an appearance of greater complexity. There were several small and complex side passages, none of which were penetrated for more than a few metres. Two of these passages, one opening off the chamber near the entrance, and one beyond the low crawl, both ascended steeply to the north-east (ie against the dip). They showed slight vadose dissolution and gravel influx both suggestive of formation by small streams during wet weather.Two more complex side passages descended with the dip from immediately inside the main entrance, and from the final chamber, but both became very constricted and muddy.

All the exposed rock faces in the cave were covered by small-scale scalloping. In several places there were circular roof pockets; the aven in the first chamber was of more elongate plan and had a tiny tube entering at the top, below which water flow had cut a deep and slightly sinuous groove in the near vertical wall. This was a well-developed vadose feature in the cave, the remainder of which appeared to have had a mainly phreatic development as a sub-water table conduit flowing from south to north. Some of the collapse modification of the final chamber was probably of recent (post quarry) date. The survey showed the final choke to be about 3 metres behind the quarry face, very close to an exposed dissolutional rift infilled

The large chamber in the North Cave; the chamber was about 6 metres across with well developed scalloping on all the surfaces. The floor of the chamber is covered with thick mud that has developed polygonal mud cracks.

(prior to the quarrying) by shales which collapsed from above the gypsum.

There were no speleothems in the cave, except for a powdery efflorescence from the gypsum walls. The cave floor was covered with an interesting deposit of clay and peat. Its top surface was a thin layer of soft ochre-coloured clay about 0.05 metre thick. Beneath this was a thicker brown granular substrate of thickly laminated stiff clay about 0.1 metre thick. These deposits had dried out and broken up into polygonal plates 0.3-0.5 metre across. A sample pit cut in the floor deposits (in the small side passage on the east and just inside of the main entrance) revealed a thin black peaty layer about 0.02 metre thick, 0.15 metre down. Where water had flowed into the cave from the small ascending passages the mud was overlain by a dry rubbly deposit.

On the quarry face to the south of the North Cave, areas of scalloped cave wall were exposed. These suggested that prior to quarrying a cave passage had followed a course from the North Cave, parallel and close to the present quarry face, southwards to the South Cave situated 90 metres away.

The South Cave

The South Cave was situated where the quarry face turned south-west (Figure 2). It was a single tubular phreatic conduit, averaging 2 metres in width and 1.8 metres high with an elevation of about +82 metres above OD. It ran in a fairly straight line southwards to terminate in a complete choke (evidently run in from the quarry bench above). Sixteen metres from the entrance a dissolutional aven approximately 1.2 metres in diameter reached the quarry floor 4.2 metres above. The floor deposits in the cave were layered mud similar to that in the North Cave, but here the mud was 0.5-0.7 metre deep and became thickly glutinous when disturbed.

The South-west Cave

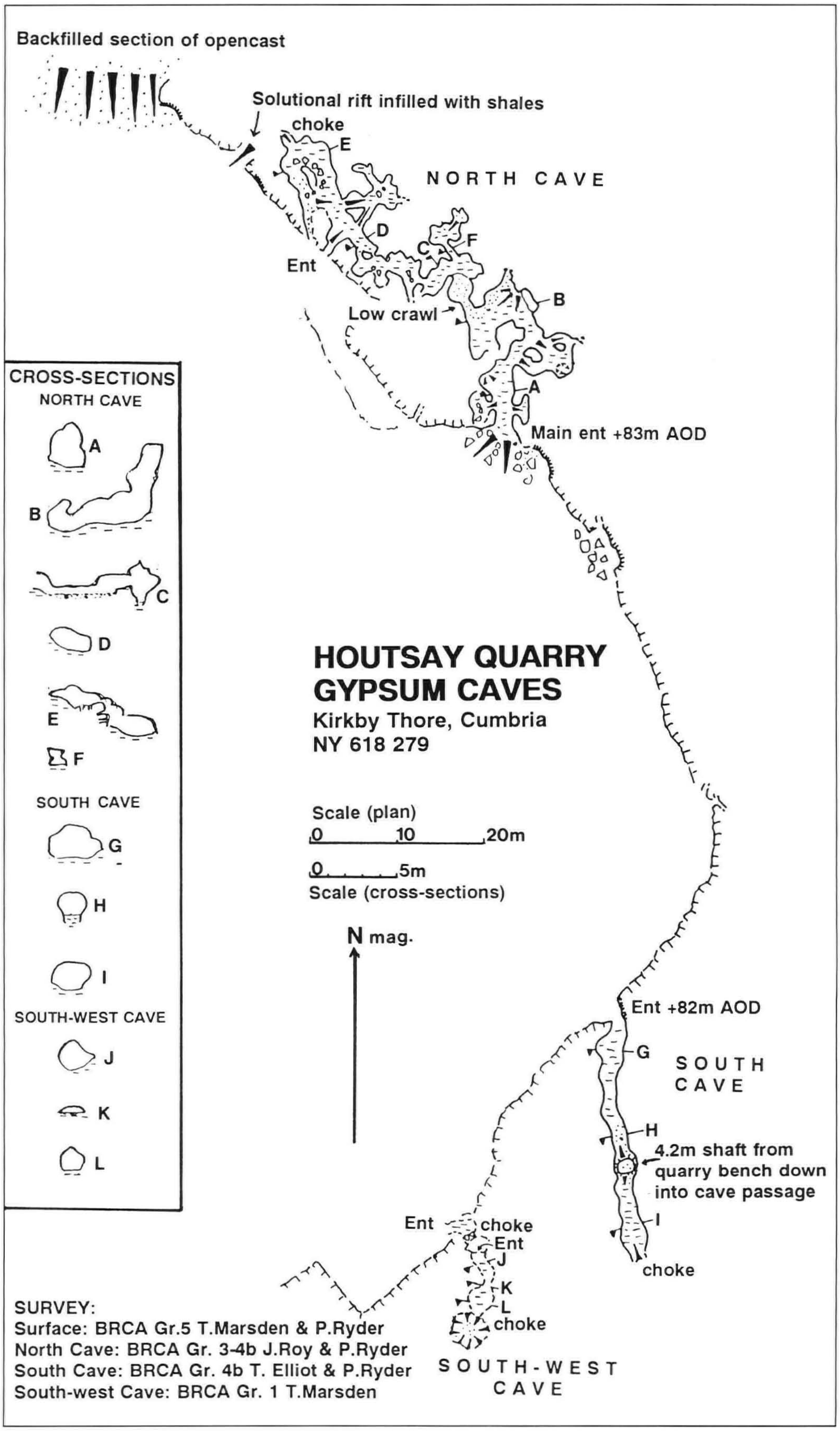
This cave was (Figure 2) situated about 30 metres farther to the south-west along the quarry face and consisted of a small tube-like passage, 1-1.5 metres in diameter, entered through a recent collapse and ending in a recent choke after 10 metres.

In addition to the main caves that could be explored numerous small phreatic pipes penetrated the quarry faces, especially in the south of the quarry. Some of these although circular or oval in cross-section, also had small vadose notches cut in their floors. This indicated that some modification of the phreatic system by infiltrating surface water had occurred. The nature of the two southern caves suggested that they originally converged towards the ramified phreatic water course seen in the North Cave, but that the intervening section had been quarried away. Unfortunately, recent run-ins beneath the track at the rear edge of the quarry bench prevented their exploration beyond the area of the working quarry.

Other caves and gypsum karst features in the quarry

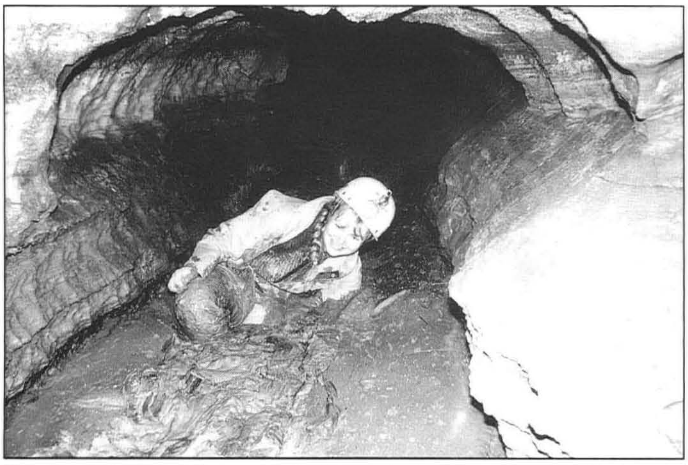
In the south of the quarry, to the west of the South-west Cave, and also at the north end of the quarry the gypsum passed up dip into a zone of pinnacled gypsum karst. This included subvertical fissures and openings with scalloped surfaces suggesting that caves had also existed in this area. Many of the cave surfaces here were also heavily striated with grooves produced by vadose water flow at the base of the glacial drift which largely filled in the gypsum surface.

Figure 2. Plan and cross-sections of the Houtsay Quarry gypsum caves.

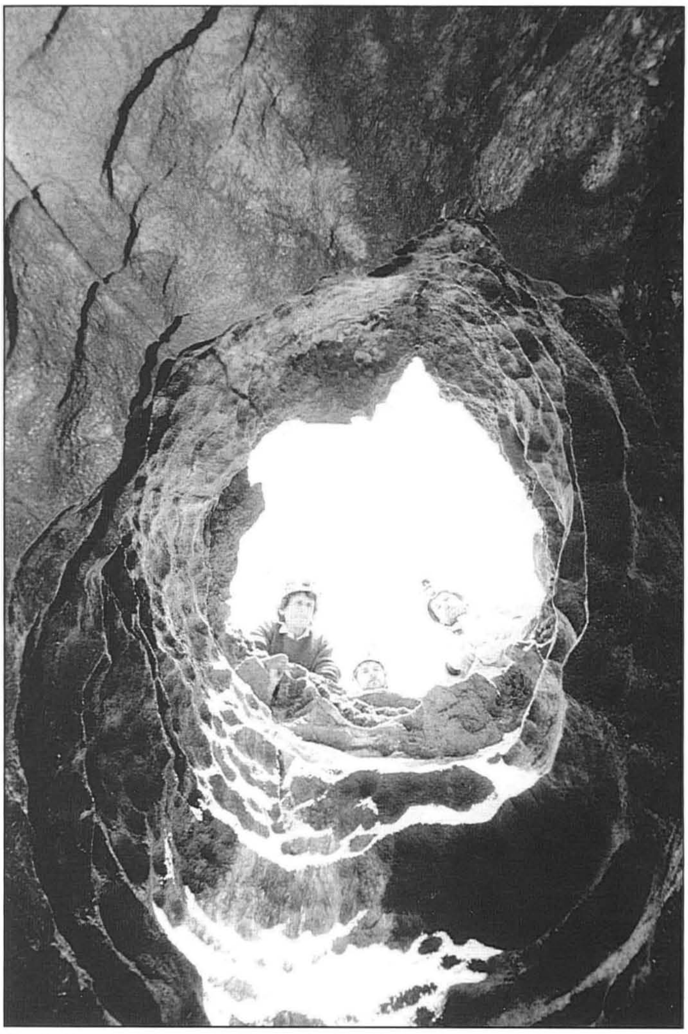


In addition to the obvious phreatically formed caves one small collapse cave was observed in the overlying Eden Shales. This was situated at the south-east corner of the excavation just above the exhumed bench of the "B" bed gypsum.The opening was roughly rectangular in plan, about 3 metres high and up to 3 metres wide. The roof of the cavity was formed by a prominent fibrous gypsum vein and a step in the roof was also supported by another vein. The bottom metre or so of the collapse was filled with debris that had fallen from the opening and formed an open-textured breccia of mudstone and fibrous gypsum clasts. This collapse feature presumably joined up with a collapse in the cave system in the underlying gypsum. The fallen debris had not increased in bulk by a significant amount as its generally soft nature had caused the fragments to mould around each other. This observation reinforces other observations made by Cooper (1988) that Permian and Triassic mudstone have only a small increase in bulk when they collapse into caves. In addition some of the fibrous gypsum veins within the Eden Shales may also dissolve, further reducing the volume of material in the breccia pipe. Furthermore, collapsed fine-grained material may also be eroded away to be re-deposited as clay cave deposits. The result of these processes is that cavities that collapse propagate upwards as breccia pipes through considerable amounts of overburden (Cooper, 1986).

The South Cave looking northwards towards the entrance. The single phreatic tube shows scalloping and bands of water staining.



The South Cave looking towards the south, the phreatic tube shows some preferential dissolution among some of the gypsum beds. Some of the horizontal banding is within the gypsum, some is water staining. The floor of the conduit is covered with thnick glutinous mud to a depth of about 0.5 metres.



South Cave looking vertically up the dissolutional aven which was 4.2 metres high. The overlying rock has been removed and the figures are standing on the top surface of the gypsum.

Factors controlling the development of the caves

The most striking observation about the caves is that they formed under phreatic conditions. The morphology of the passages explored at Houtsay were very much akin to phreatic caves developed in limestones. The plan and passage form of the North Cave was very similar to phreatic caves in the Cadeby Formation (formerly Lower Magnesian Limestone). It has similarities to the Herne Hill system at Maltby in South Yorkshire (SK533922), though the controlling geological factors there are different being related to a combination of folding and jointing (Dr. D. J. Lowe, pers comm. 1992).The fact that the Houtsay cave system was dry when explored may have been the result of dewatering of the area by mining of adjacent portions of the 'B' bed gypsum. This was formerly undertaken in the Acorn Bank gypsum mine (NY619279) immediately to the north (Sherlock and Hollingworth, 1938) and continues in the Newbiggin anhydrite mine immediately to the east. Alternatively the lowering of the water table may have been a post-glacial phenomenon. The presence of a few small vadose notches in some of the smaller passages showed that rainwater had drained into the system, but the high solubility of gypsum and its rapid dissolution rate (James *et al.*, 1981) mean that these features could be very recent.

Measurements of the cave orientations as shown on the plan (Figure 2) and of the joint orientations in the gypsum show that the joints are one of the main factors in the development of the caves. The main joints measured in the quarry were orientated in north-south (350-360 degrees) and east-west (090 degrees) directions and had steep dips; minor joints also occurred with an orientation of 030-045 degrees.The large phreatic tubes followed the main joints and commonly ran sub-horizontally along the bedding sometimes opening out along the bedding. The joints were narrow and it is unclear how an apparently tight joint can guide a cave. The lithological variation in the 'B' bed was not very great, but some bedding surfaces formed obvious weaknesses which the cave system had exploited. It was also surprising that some of the minor phreatic tubes appeared to spiral through rock with no apparent controlling weakness. In some of the passages prominent avens were present; these were generally developed at the intersections of the north-south and east-west joint sets. Some of these avens were circular in plan with sides covered with large scallops. This suggested that they may have formed conduits with a considerable flow of water through them; though the direction of movement is not certain it was most likely from above.

The other main factor in the development of the caves was the water movement. The present cave system ran downhill slightly to the north and included branching tributaries to the south. Its western extent was determined by the feather edge of the 'B' bed gypsum and its eastern limit presumably by the down-dip passage into anhydrite. The Houtsay caves suggest a hydrological pathway going in a general northerly direction, but the details are unclear.

OTHER GYPSUM CAVE SYSTEMS IN ENGLAND

Gypsum is widespread in the Permian and Triassic sequences of England (Figure 1) (Sherlock and Hollingworth, 1938; Notholt and Highley, 1975; Firman, 1984). It is extensively present in the Vale of Eden and the Midlands areas where it is currently worked; it is also worked locally from the Jurassic of south-east England. Until the mid-1980s gypsum was also worked from the Permian rocks of the Vale of York, but this operation has now ceased. Little modern literature describes the English gypsum sequences and most of the details come from works published prior to about 1940. Because of its soluble nature and the wet British climate it occurs in low ground with extensive drift cover and natural exposures of gypsum are rare. Most of the records are of quarry and mine sections. The historical nature of many of the reports means that the original authors were unaware of the solubility of gypsum or the fact that it produces a karst-like topography with caves, though their descriptions mention all these features.

Cumbria

In the Vale of Eden at Acorn Bank Quarry (NY618278) only 500 metres away from the Houtsay caves, descriptions of the gypsum (Dakyns *et al.*, 1897;) recorded "Gypsum in massive beds, uneven top - 15 to 20 ft". The uneven top surface and the variation in thickness are typical of soluble rocks which have suffered dissolution to produce an uneven karst-like surface. At the mine leading from the same site it was noted that the bulk of water entering the workings issued from fissures in the floor of the mine (Sherlock and Hollingworth, 1938). Also in the Vale of Eden the same authors noted that the gypsum in the quarry at Kirkby Thore revealed many examples of solution phenomena. These included channels, pot holes and cavities, with at some points the dissolution being so intense as to produce pinnacles of gypsum protruding into the overlying marl; these latter features are probably collapsed marl around pinnacles of gypsum.

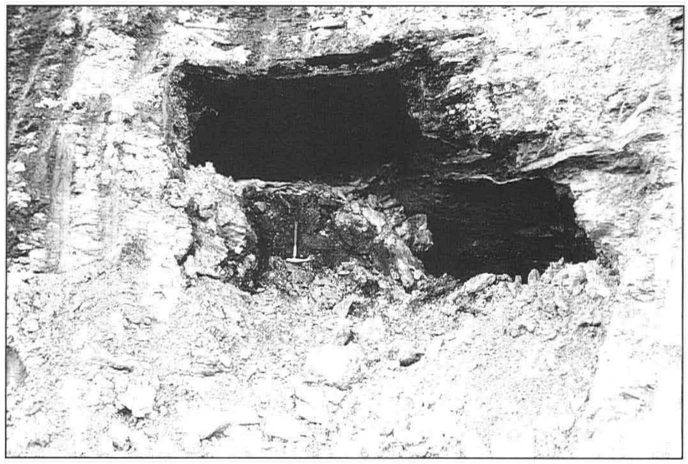
At Cocklakes (and Acrehead) Mine (NY457513), Cumwhinton, near Carlisle (Figure 1), Sherlock and Hollingworth (1938) noted that: "Anhydrite thins out locally - being replaced by gypsum - in areas under considerable cover.This change takes place fairly suddenly and is usually an indication of proximity to a 'trouble', where gypsum becomes soft and mixed with marl or ends against a face of marl. In such situations the gypsum is frequently found to be cavernous with definite indications of solution in the vicinity. Water is liable to be met at these points, and solution, though doubtless in part of great antiquity, appears to be in progress today." These features could be either faults met in the mine or more likely collapsed parts of a cave system similar to that at Houtsay. Sherlock and Hollingworth (1938) also recorded that "Similar troubles occur west of Acrehead, in belts a few yards wide trending more or less along the strike.There is thus a tendency for troubles to be related to the dip and strike - probably also to a joint system with those directions.There are no displacements of the bed in crossing the troubles". From their description the Acrehead (NY457515) "troubles" appear to be similar to the caves and gypsum karst features seen at Houtsay Quarry.

Photographs taken in 1935 and 1936 and descriptions (Sherlock and Hollingworth, 1938) of McGhie's Gypsum Quarry, Thistle Plaster Works, 1 mile N.E. of Kirkby Thore (NY642268) showed karst-like features in the gypsum. The photographs from the BGS photographic archives, numbered A6558-6562 and A6920-6937, illustrate the pinnacled upper surface of the gypsum, scalloping on surfaces and collapse of the overlying strata, probably into caves.The description by Smith and Hollingworth (1938) recorded: "Quarrying has revealed many examples of solution phenomena in gypsum closely analogous to those that are well known in limestone. Thus when the overburden has been removed by the steam navvy and the upper surface of the gypsum washed clean by rain it can be seen that the surface of the Top post has in places a terraced appearance where half, two-thirds, or the whole of the Top post, has been removed over considerable areas, the 'steps' having a characteristic waterworn surface. Channels, pot-holes, and cavities, empty or filled with marl and sand, are characteristic features. At some points deterioration of the gypsum bed by more extensive solution gives a series of residual 'heads' or pinnacles of gypsum in marl. The collapse of these gives irregular masses of gypsum enclosed in marl, such as frequently characterize the margin of the deposit."

These features are very similar to the phenomena described from the Houtsay Quarry site and suggest that gypsum cave systems may be more widespread than is generally assumed in the Vale of Eden and around Carlisle.

North Yorkshire and Cleveland

Where Permian gypsum is exposed at Ripon Parks (SE 307753) James *et al.* (1981) noted a few minor cave-like dissolution features. Recent rockfalls have revealed that the southern end of the section has undergone almost complete dissolution and collapse suggesting the former presence of a cave at the site. The Ripon area is notable for the occurrence of numerous major subsidence hollows forming a belt about 3 kilometres wide and following the line of the gypsum belt (Figure 1).These have been described by Cooper (1986; 1988; 1989; Powell *et al.*, 1992; Cooper and Burgess, in press). The hollows form rectilinear patterns and have been related to the collapse of a phreatic joint-guided cave system in gypsum (Cooper, 1986). This belt of subsidence extends northwards from Ripon to the Darlington area where maps of the British Geological Survey (1973, Darlington1:10,000 and 1987, Stockton 1:50,000) show areas of foundered strata and some historically active subsidence. One such subsidence hollow is called "Hell Kettles" (NZ 281109) (Figure 1) and is reputed to have formed in the twelfth century (British Geological Survey, 1973). Southwards from Ripon, subsidence hollows and collapse features have been recorded (Figure 1) around Sherburn in Elmet (Smith, 1972) and active subsidence reported at Burton Salmon, near Castleford (Edwards *et al.*, 1940).These subsidence features suggest that significant cave systems may exist in the Permian gypsum of Yorkshire and Cleveland. The dimensions of the subsidence hollows are such that caverns up to 30 metres in diameter and 30 metres high must exist in the Ripon area. Around



Collapse cave in the Eden Shales overlying the "B" bed gypsum in Houtsay Quarry. This was situated in the SE corner of the opencast excavation away from the caves explored suggesting that the cave system was more extensive than that recorded.

Ripon the subsidence belt is about 3 kilometres wide and the geometry of the strata suggest the caves extend down to a depth of about 120 metres; the eastern limit of the subsidence belt is marked by the down-dip transition from gypsum to anhydrite. At Ripon artesian water has recently been encountered in boreholes penetrating the gypsum sequences, but the major water outflows into the River Ure rise up through calcareous tufa-cemented river gravels making the likelihood of finding an entrance to the cave system remote (Cooper, 1986).

The Midlands

The most numerous working gypsum mines and former quarries are situated in the Triassic gypsum of the area immediately south and south-east of Nottingham (Figure 1). Many of these deposits have a long history of exploitation, but there is little recent literature about them. Wynne (1906) described the gypsum deposits of the Dove Valley and in his description of the mines around Fauld (Figure 1) illustrates a "circular wash hole" about 19 feet across and 6 feet high. On the basis of Wynne's description this has a form very similar to the phreatic caves described above at Houtsay Quarry.

In the area around Chellaston (Figure 1) Smith (1918) described the sequence as having numerous swallowholes adjacent to pillars of gypsum;he also described the pinnacled upper surface of the gypsum all features typical of gypsum karst. Gypsum breccias are also recorded, but these might be due to the widespread dissolution of ramifying gypsum within the gypsiferous marls of the Midlands; this mechanism of dissolution would result in the formation of flat, depressed, "moors" that occur hereabouts (Dr D. J. Lowe, pers. comm. 1992; Lamplugh & Gibson, 1910, p61). The widespread dissolution of gypsum in the Midlands has been recorded by Elliot (1961). He noted a near surface zone where most of the gypsum had been dissolved, this extended down to a depth of about 60 feet (18m), but reached 100 feet (30.5m) near faults. Elliot *(op cit.)* also recorded the presence of cavities, the brecciated nature of the sequence and water-worn surfaces on the top of the gypsum beds.Firman and Dickson (1969) also recorded the dissolution of the Newark Gypsum at Stanton-in-the-Vale, but they presented evidence for the upward passage of water and dissolution at the bases of the gypsum nodules. Their illustrations also show cylindrical water-worn cavities in the gypsum, but only on a scale of 5-10cm across.The nodular nature of the gypsum in this area make the development of caves hereabouts unlikely.

From the above records and the known distribution of gypsum in England (Sherlock and Hollingworth, 1938; Notholt and Highley, 1975) it is likely that buried gypsum caves and gypsum karst features are much more widespread than was previously recognised.

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Forum

Readers are invited to offer review articles, shorter scientific notes, comments on previously published papers and discussions of general interest for publication in the Forum section of Cave Science.

A COMMENT ON 'TYPE LOCALITY OF MONDMILCH'

Roger G. COOPER

Hans Fischer (Cave Science, Vol. 19, No. 2, 1992, pp.56-90), in defining some nomenclature, states that 'Mondmilch sensu strico . . . [has] . . . a minimum calcite content of 90 weight %'. I am pleased to conclude that the moonmilk in the North Yorkshire windypits, with which I am very familiar, therefore qualifies as Mondmilch sensu stricto. That is, if weight % soluble in dilute (10%) HCl (which is what I measured) is equivalent to Fischer's 'calcite content'. Samples of moonmilk from Ashberry Windypits 1 and 2, and from Noddle End Windypit (see Cooper, Ryder & Solman, 1976) were found to be more than 98% soluble in dilute (10%) HCl (Cooper, 1979).

Like that described by Fischer, the Mondmilch from the windypits has a cauliflower-like appearance (Figure 1). However, Fischer's remark in his paragraph headed 'Genesis of Mondmilch' that Mondmilch is formed by 'one of numerous hypotheses' is rather cryptic. For the record, scanning electron microscope examination (courtesy of technicians at the Department of Geology, University of Keele) has shown the Mondmilch from the windypits to be *lublinite*, 'a variety . . . [of moonmilk] . . . composed of a microcrystalline aggregate of delicate fibrous needles' (Hill, 1976). This is well illustrated in Figure 2 which shows an aggregate of calcite 'rods' of the type identified by Moore & Sullivan (1978, p.80) as characteristic of moonmilk. They describe the rods as having a diagonal grain which is aligned with the crystal structure, and state that 'because the crystal structure of calcite normally runs parallel to the long dimension of calcite crystals, the grains in calcite moonmilk were once erroneously identified and named as a separate new mineral, lublinite' (p.82). Accordingly it now seems perhaps more sensible to speak of "the 'lublinite' form of calcite moonmilk [or Mondmilch]"

Unlike the Carboniferous Limestone caves in the Pennine Yorkshire dales, the North Yorkshire windypits are in Jurassic Corallian limestones and sandstones (the latter are in places sufficiently gritty to be termed gritstones), which considered as limestones are impure at best. However, it is clear from the work of Bertouille (1972) that this 98% pure calcite speleothem can grow from an impure $CaCO_3$ rock substrate. Like Williams (1960), who found *Macromonas* in moonmilk from South Wales, Bertouille found nitrifying bacteria *(Nitrobacter* and *Nitrosomonas)* in moonmilk from the Grotte Bernard at St. Martin de Caralp, Ariège, France. Bertouille was able to show that the growth of the bacteria which he collected, and hence the growth of the resulting moonmilk, was accelerated by the presence of constituents other than calcium, which he termed *'oligo-éléments'*. He suggested that in a warm climate there would be a steep thermal gradient on approaching a cave wall from within a rock body. In such a situation *'thermomigration'* of *'oligo-éléments'* towards the cave wall would be promoted. Thus the presence of moonmilk could be taken as an indication of a period of warm climate, and a succession of moonmilk encrustations would be an indication of climatic fluctuation (Bertouille, 1972). This could add weight to Fischer's (1992) suggestion that Mondmilch could accumulate in layers on older Mondmilch. While the abundance of available *'oligo-éléments'* in the Corallian facies of the Yorkshire Jurassic prevents such interpretation of the Mondmilch encrustations in the windypits (although the Mondmilch is up to 15cm thick in places; Cooper, 1979), Bertouille's theory provides a satisfactory explanation of the growth of Mondmilch on a highly impure limestone (or even gritstone) rock.

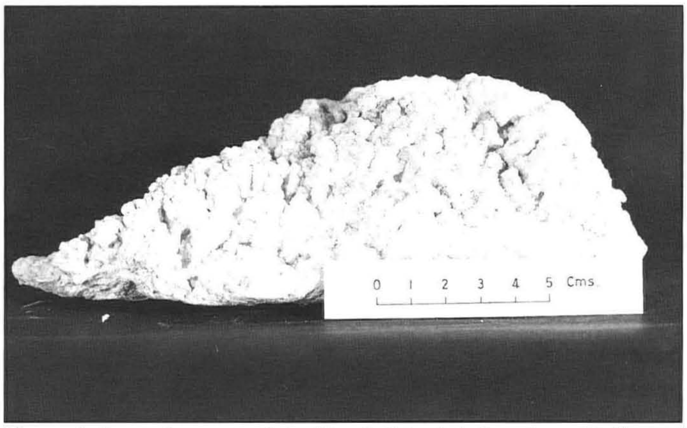
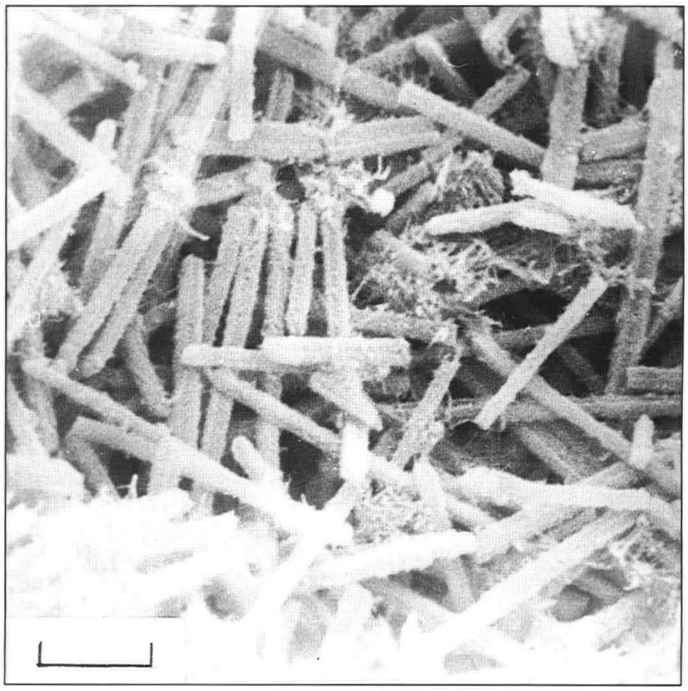


Figure 1. Loose fragment of dry Mondmilch picked up from the floor of Ashberry Windypit 2; it did not grow in this position, and must have fallen from one of the walls of the fissure.

Figure 2. Scanning electron micrograph of a sample of Mondmilch from the fragment shown in Figure 1. The scale bar represents a length of 5 microns.



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TYPE LOCALITY OF MONDMILCH - A REPLY

Carol A. HILL and Paolo FORTI

This is in response to the article by Hans Fischer in Cave Science, v. 19, No. 2, August 1992, entitled "Type Locality of Mondmilch" in which it is stated: "Thus, the term 'mondmilch' should be used for carbonate speleothems only, and not for sulfate, phosphate or even silicate speleothems as proposed by Hill and Forti (1986). "In our book *Cave Minerals of the World* we define "moonmilk" to be a speleothem type, just as stalactites, stalagmites, helictites, etc. are speleothem types. Does the fact that stalactites were first described from a particular location ("type locality") or that these first-described stalactites were composed of calcite restrict this speleothem to a carbonate mineralogy? No. Stalactites are usually composed of calcite, but they can also be composed of gypsum, halite, nitromagnesite, chalcanthite - and many other minerals (Hill and Forti, 1986a, mention over 20 different minerals that are known to form as stalactites).

Fischer further comments that: "With respect to the historical importance and according to mineralogical finds, the term Mondmilch should be reserved exclusively for calcite deposits". Why should the "historical importance" to *man* give moonmilk a special status over other speleothem types? In the caves of the Guadalupe Mountains, New Mexico, USA, moonmilk is composed primarily of hydromagnesite and huntite (Hill, 1987). Do we have to give these powdery, plastic, moonmilk-like deposits a new speleothem name just because they are not composed of calcite? If we do, then other speleothem types (such as stalactites) will have to be renamed if they do not correspond in mineralogy to what was found at the "type locality".

We feel that the classification of speleothems should be based primarily on morphology and origin and should *not* be based on mineralogy (Hill and Forti, 1986b).

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LITHOLOGICAL ANALYSIS OF SEDIMENT SAMPLES FROM THE RUSHUP EDGE — SPEEDWELL CAVERN PEAK CAVERN CAVE SYSTEM CASTLETON, DERBYSHIRE

P. J. MURPHY

Over the winter of 1991/92 five sediment samples were taken from various sites in Peak Cavern, Speedwell Cavern and P8 (Jackpot) by the author and colleagues. Lithological descriptions of the samples and locations of the sampling points are given below in a roughly "down stream" order.

SAMPLE 1. Location: Downstream sump pool (Sump 1) of P8 swallet (Jackpot).
Date Sample Taken: 24/1/1992
Description:
25% *Claystone,* dark grey (N3), non-calcareous, well indurated.
20% *Sandstone,* medium dark grey (N4), fine to medium grain size, subangular to subrounded grain shape, argillaceous cement, micaceous, slightly calcareous, well cemented.
25% *Sandstone,* light brown (5YR 6/4) fine to medium grain size, subangular to subrounded grain shape, argillaceous cement, micaceous, slightly calcareous, moderately well cemented.
30% *Sand,* grains of white (N9), yellowish grey (5Y 7/2) and light brown (5YR 6/4), quartz, fine to medium grain size, subangular to rounded grain shape.

SAMPLE 2. Location: 30 metres into downstream Sump 9 of P8 swallet (Jackpot).
Date Sample Taken: 24/1/1992
Description: Light Olive Grey (5Y 5/2) sludge, with a marked smell of hydrocarbon. Under microscopic examination the sample was seen to consist of silt and clay sized particles, 95% white (N9), 5% black and greyish black (N1-N2). The material reacted vigorously with 10% HC1 solution, leaving an olive grey (5Y 4/1) residue.

SAMPLE 3. Location: Speedwell Cavern streamway, at the junction with the crawl to Cliff Cavern.
Date Sample Taken: 10/5/92
Description:
10% *Claystone,* dark grey (N3), non-calcareous, well indurated.
90% *Sand,* white (N9) to light brown (5 YR 6/4) quartz, fine medium grain size, rounded to well rounded grain shape.

SAMPLE 4. Location: Far Sump Extension, Stemple Highway stream.
Date Sample Taken: 4/4/1992
Description:
›95% *Sand,* moderate yellowish brown (10 YR 5/4), very fine to medium grain size, rounded to angular grain shape, trace mica, in parts calcite cemented to form Sandstone. Plant debris (root fragments) is present in the sample.
‹5% *Claystone,* dark grey (N3), non-calcareous, well indurated.

SAMPLE 5. Location: Peak Cavern Streamway, 5 metres downstream of Far Sump.
Date Sample Taken: 1/3/1992
Description:
90% *Sand,* moderate brown (5YR 4/4), minor dark yellowish brown (10 YR 2/2), very fine to medium grain size, rounded to angular grain shape, trace mica, in parts poorly cemented by calcite to form sandstone.
5% *Claystone,* dark grey (N3), non-calcareous, well indurated.

CONCLUSIONS

1. The sediments sampled from the P8 - Speedwell Cavern system are markedly different from those sampled in the Far Sump Extension-Peak Cavern system in terms of grain size, degree of cementation and percentage claystone, indicative of a different source area for the streams.
2. The presence of plant fragments in sample 4 indicate that the sediment had only relatively recently entered the system.
3. Sample 2 is markedly different from the other samples. Its reactivity with 10% HC1 solution indicates the presence of calcium carbonate. The smell of hydrocarbon and the fine grain size of the material would suggest an industrial source. The nature of this sample appears to indicate that a feeder into the P8 (Jackpot) cave system has been breached by quarrying activity and pollution of the system has resulted.

All colour codes refer to the Geological Society of America rock-colour chart.
The grain size divisions are taken from the Wentworth System.

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B.C.R.A. RESEARCH FUNDS AND GRANTS

THE JEFF JEFFERSON RESEARCH FUND

The British Cave Research Association has established the Jeff Jefferson Research Fund to promote research into all aspects of speleology in Britain and abroad. Initially, a total of £500 per year will be made available. The aims of the scheme are primarily:

a) To assist in the purchase of consumable items such as water-tracing dyes, sample holders or chemical reagents without which it would be impossible to carry out or complete a research project.
b) To provide funds for travel in association with fieldwork or to visit laboratories which could provide essential facilities.
c) To provide financial support for the preparation of scientific reports. This could cover, for example, the costs of photographic processing, cartographic materials or computing time.
d) To stimulate new research which the BCRA Research Committee considers could contribute significantly to emerging areas of speleology.

The award scheme will not support the salaries of the research worker(s) or assistants, attendance at conferences in Britain or abroad, nor the purchase of personal caving clothing, equipment or vehicles. The applicant(s) must be the principal investigator(s), and must be members of the BCRA in order to quality. Grants may be made to individuals or small groups, who need not be employed in universities, polytechnics or research establishments. Information and applications for Research Awards should be made on a form available from Simon Botterill, Dept. of Earth Sciences, University of Leeds.

GHAR PARAU FOUNDATION EXPEDITION AWARDS

An award, or awards, with a minimum of around £1000 available annually, to overseas caving expeditions originating from within the United Kingdom. Grants are normally given to those expeditions with an emphasis on a scientific approach and/or exploration in remote or little known areas. Application forms are available from the GPF Secretary, David Judson, Rowlands House, Summerseat, Bury, Lancs. BL9 5NF. Closing date 1st February.

SPORTS COUNCIL GRANT-AID IN SUPPORT OF CAVING EXPEDITIONS ABROAD

Grants are give annually to all types of caving expeditions going overseas from the U.K. (including cave diving), for the purpose of furthering cave exploration, survey, photography and training. Application forms and advice sheets are obtainable from the GPF Secretary, David Judson, Rowlands House, Summerseat, Bury, Lancs. BL9 5NF and must be returned to him for both GPF and Sports Council Awards not later than 1st February each year for the succeeding period, April to March.

Expedition organisers living in Wales, Scotland or Northern Ireland, or from caving clubs based in these regions should contact their own regional Sports Council directly in the first instance (N.B. the closing date for Sports Council for Wales Awards applications is 31st December).

THE E. K. TRATMAN AWARD

An annual award, currently, £50, made for the most stimulating contribution towards speleological literature published within the United Kingdom during the past 12 months. Suggestions are always welcome to members of the GPF Awards Committee, or its Secretary, David Judson, not later than 1st February each year.

BRITISH CAVE RESEARCH ASSOCIATION PUBLICATIONS

CAVE SCIENCE — published three times annually, a scientific journal comprising original research papers, reviews and discussion forum, on all aspects of speleological investigation, geology and geomorphology related to karst and caves, archaeology, biospeleology, exploration and expedition reports.
Editor: Dr. Trevor D. Ford, 21 Elizabeth Drive, Oadby, Leicester LE2 4RD. (0533-715265).

CAVES & CAVING — quarterly news magazine of current events in caving, with brief reports of latest explorations and expeditions, news of new techniques and equipment, Association personalia etc.
Editor: Mark Dougherty, 7 Edinburgh Terrace, Armley, Leeds LS12 3RH (0532-639288).

CAVE STUDIES SERIES — occasional series of booklets on various speleological or karst subjects.

No. 1 Caves & Karst of the Yorkshire Dales; by Tony Waltham and Martin Davies, 1987. Reprinted 1991.

No. 2 An Introduction to Cave Surveying; by Bryan Ellis, 1988.

No. 3 Caves & Karst of the Peak District; by Trevor Ford and John Gunn, 1990. Second Edition 1992.

CURRENT TITLES IN SPELEOLOGY — annual listings of international publications
Editor: Ray Mansfield, Downhead Cottage, Downhead, Shepton Mallet, Somerset BA4 4LG.

CAVING PRACTICE AND EQUIPMENT, edited by David Judson, 1984. Second edition 1991.

LIMESTONES AND CAVES OF NORTHWEST ENGLAND, edited by A. C. Waltham, 1974. (out of print).

LIMESTONES AND CAVES OF THE MENDIP HILLS, edited by D. I. Smith, 1975. (out of print).

LIMESTONES AND CAVES OF THE PEAK DISTRICT, edited by T. D. Ford, 1977, (out of print).

LIMESTONES AND CAVES OF WALES, edited by T. D. Ford, 1989.

Obtainable from B.C.R.A. Sales
B. M. Ellis, 20 Woodfield Avenue, Westonzoyland, Bridgwater, Somerset TA7 0LQ.